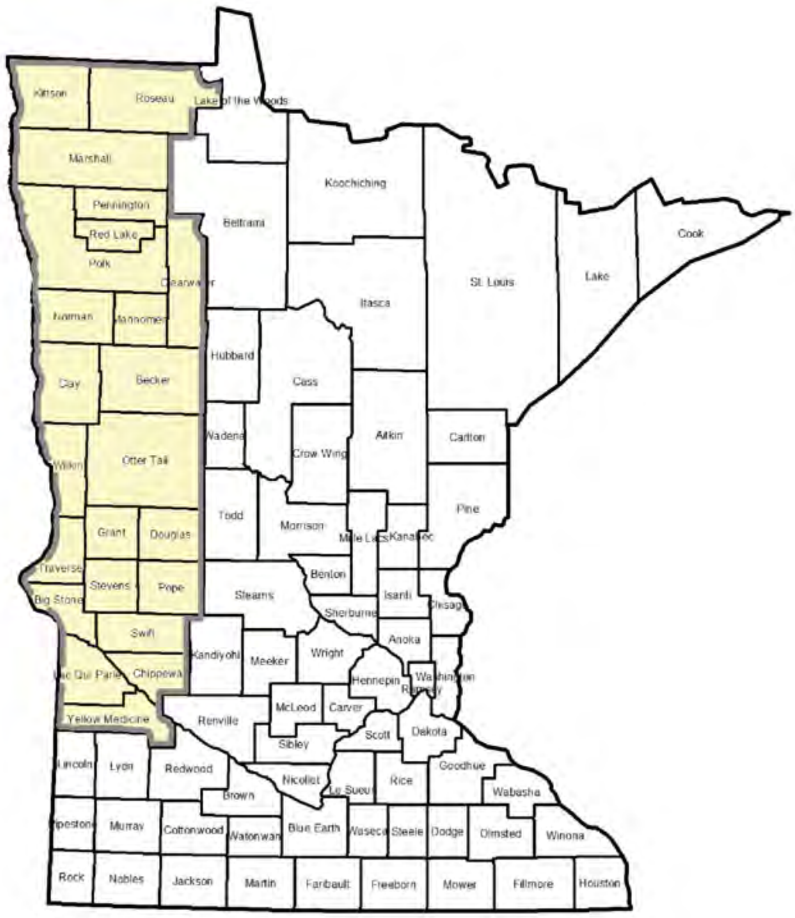
On-Farm Cropping Trials Northwest & West Central Minnesota and 2020 Minnesota Wheat Research Review



MINNESOTA WHEAT RESEARCH & PROMOTION COUNCIL

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2020 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 and Dr. Jared Goplen, Extension Educator, Extension Regional Office, Morris, gople007@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://mnwheat.org/council/wheat-research-reports/

2020 Wheat Research Review

In 2020 the Minnesota Wheat Research and Promotion Council allocated about $740,000 of the total $1,581,000 check-off income to wheat research projects. The 2020 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. Pre-proposals are reviewed 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/council. Click on the Research Committee tab.

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On-Farm Cropping Trials For Northwest & West Central Minnesota

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

Late-Planted Forage Cover Crops — Central MN

Cooperator:	David Emslander; Benton County Soil and Water Conservation District (Gwost)
Nearest Town:	Oak Park, MN
Soil Type:	Brennyville Freer Silt Loam
Tillage:	Conventional
Previous Crop:	Fallow
Experimental Design:	RCB, 2 planting dates, 5 forage crops, 2 replications
Planting Dates:	Early Planting Date July 6th 2020, Late Planting Date August 6th
Forage Crops:	Corn, Soybean, Oat, Cereal Rye, Sudangrass

Purpose of Study:

A late-planted forage cover crop plot was planted near Oak Park, MN. The objective was to evaluate biomass production and forage quality of the annual forage crops planted in prevented planting situations similar to those prevalent in 2019.

Treatments:

Each of the five crops were replicated twice and planted on July 6th, 2020 (Early Planting) and again on August 6th (Late Planting). Crops and planting dates were both chosen based on feedback received from growers in the Central Minnesota region by the Benton County Extension Office. Seeding rates for the forage crops were as follows:

1) Corn at 300,000 seeds/acre
2) Oat at 1.0 million seeds/acre
3) Sudangrass at 30 pound/acre
4) Soybean at 300,000 seeds/acre
5) Cereal rye at 1.3 million seeds/acre

Results: Water ponding plagued the plots throughout the season, which influenced the results from this trial. As a result of the excessive water, there were observational differences between cover crop species. Soil crusting and stand-establishment issues were the most problematic in the early-planted cereal rye plots. Weeds took advantage of the poor rye stand (Figure 1), and suppressed biomass production in the cereal rye plots (Table 1). Similarly, early-planted oats emerged slowly due to water issues. Eventually the stands did fill in despite some areas of standing water. The early-planted soybean emergence was better, but biomass production was hindered by deer feeding on these plots. The soybeans reached the R2 growth stage by September 1st and R4 by October 5th. In terms of biomass production, corn and sudangrass planted in early July produced significantly more biomass compared to the other cover crop species (Table1). The early-planted corn reached R1 by September 1st but did not progress past R2 before October 5th. By September 1st, sudangrass was into its reproductive phase with seed heads just beginning emergence.

Figure 1. Photos of plot appearance on the September 1st biomass harvest date for the plots planted July 6th

For Additional Information:
Nathan Drewitz and Jared Goplen

Project Resources Provided by:
Byron Seeds and Dairyland Laboratory-Sauk Rapids,

Late-Planted Forage Cover Crops (continued) — Central MN

Below-freezing temperatures after September 1^{st} caused the corn and sudangrass plants to begin senescence. By the biomass collection on October 13^{th}, wind had caused substantial greensnap in both the early-planted corn and sudangrass crops (Figure 2). This greensnap caused significant biomass loss, as noted by the October 13th sampling date (Table 1). The oat, cereal rye, and soybean plots had less greensnap, and managed to maintain most of the accumulated biomass until October 13th. By October 5th, soybean had issues with freezing damage in addition to substantial deer feeding. Unlike the corn and sudangrass, soybean did not suffer substantial greensnap. In a typical year, when cover crops on prevented plant acres cannot be harvested for forage until November 1st, selecting species that can sustain wind and other stressors that late in the year will need to be considered. Without a significant difference in biomass yields for early season forage cover crops on October 13^{th} (Table 1), other important factors such as quality and ease of harvest should factor into cover crop species selection. Especially if harvest is not allowed until after November 1^{st}, both corn and sudangrass may be at higher risk of losing biomass due to greensnap when compared to small grains or soybeans. Forage quality analyses are currently pending, and will provide additional information on forage species selection.

Table 1. Harvested biomass by crop for the July 6^{th} planting date.

	Biomass Harvest Date	
Crop	September 1^{st}	October 13^{th}
	t/acre	
Sudangrass	2.37a	1.09
Corn	2.32a	1.22
Soybean	0.99b	1.05
Oat	1.03b	0.79
Cereal Rye	0.28c	0.63
LSD ($P \leq 0.05$)	0.66	NS

Figure 2. Photos of plot appearance on the October 5^{th} biomass harvest date for the plots planted July 6^{th}

The late-planted forages also had excessive moisture issues that influenced results. Portions of the study area had significant ponding, but plots outside of those areas generally had good stands (Figure 3). On the September 1^{st} biomass harvest date, Sudangrass, Corn, and Soybean biomass yields were double the biomass of the oat and cereal rye plots (Table 2). This is despite the planting date somewhat favoring cool-season crops like cereal rye and oats. This did change by October 13^{th} as sudangrass yields were only greater than oat and cereal rye. All other differences in forage yields on October 13^{th} were non-significant.

Table 2. Harvested biomass by crop for the August 6^{th} planting date.

	Biomass Harvest Date	
Crop	September 1^{st}	October 13^{th}
	t/acre	
Sudangrass	0.23a	0.82a
Corn	0.27a	0.75ab
Soybean	0.25a	0.69ab
Oat	0.08b	0.55b
Cereal Rye	0.11b	0.55b
LSD ($P \leq 0.05$)	0.08	0.22

For Additional Information:
Nathan Drewitz and Jared Goplen

Deer feeding was present on the late-planted soybeans which likely influenced the final biomass yields. Soybeans, corn, and sudangrass all suffered frost damage by October 5th (Figure 4). Both the oats and cereal rye were less effected and continued growth through October 13th. This allowed for an over 5-fold increase in biomass for both forages.

Figure 3. Photos of plot appearance on the September 1st biomass harvest date for plots planted on August 6th

Figure 4. Photos of plot appearance on the October 5th biomass harvest date for the plots planted August 6th

In conclusion, harvest date is an important consideration when selecting forage cover crops. If harvest is possible by early September, corn and sudangrass produced the most biomass with an early planting date, and soybeans joined them when planted late. However, forage quality is likely lower for both corn and sudangrass. Soil drainage should also be considered as oats, cereal rye, and soybeans struggled to emerge through the waterlogged soil in this study. If harvest is delayed into October, differences among species disappeared and other factors such as forage quality and cost should be considered.

For Additional Information:
Nathan Drewitz and Jared Goplen

Corn stalk rot survey – 2020: Northwest Minnesota

Cooperators: Personnel visited fields of cooperating producers in Becker, Clay, Kittson, Mahnomen, Marshall, Norman, Pennington, Polk, Red Lake and Roseau Counties.

Purpose of Study:
During a fall survey of 28 corn fields in Becker, Clay, Kittson, Mahnomen, Marshall, Norman, Pennington, Polk, Red Lake and Roseau counties in NW MN for European corn borer, personnel also assessed stalk strength using a "standard" push-test. Briefly, 20 random plants in each field were pushed at ear height more than 30 degrees from vertical. Plants 'failed' this test by permanently bending or breaking and not returning upright, indicating poor stalk strength.

This survey was not designed to differentiate between stalk quality issues caused by disease or other stressors but rather to assess standability of the 2020 corn crop.

Results:
Developing corn kernels place a high demand on the plant for sugars. Stress slows photosynthesis, reducing the amount of sugar the plant can produce. Different stresses can reduce the rate of photosynthesis: too much or too little moisture, nutrient imbalances, plant injury (ex.: hail, insects, diseases), excessive plant populations, and even long-periods of cloudy weather.

Hybrid genetics and/or high yield potential combined with stress during grain fill can increase the probability of stalk quality issues. Stalk quality tends to decrease the longer the crop remains in the field unharvested.

If a plant is unable to keep up with kernel sugar demand, it can rob sugars from stalk tissue, deteriorating stalk integrity and predisposing it to stalk rotting fungi.

In NW MN, the percentage of plants suffering from stalk rot ranged from a low of 0 percent (10 fields) to a high of 35 percent (2 fields; Figures 1 and 2); 46% of the fields had stalk quality issues that might have impacted harvestability, fewer than in 2018 or 2019.

Crop stressors in 2020 included above normal rainfall. According to NDAWN weather stations in surveyed counties, in June some stations saw 1.5 to 6 inches more rain than normal, in July 2 to 3 inches more than normal and in August 2 inches more rain than normal. Waterlogged soils can impair root function and even kill some roots. Plants may be less able to take up the nutrients required for plant growth and development or as efficiently photosynthesize and produce and accumulate the sugars needed for grain fill.

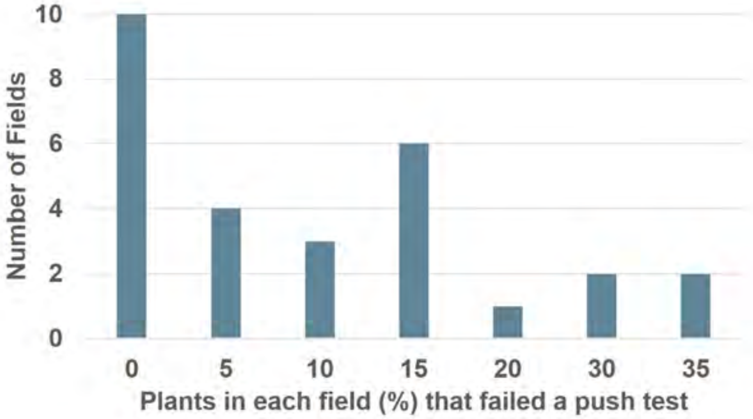

Fig. 1. The percentage of plants failing the push test.

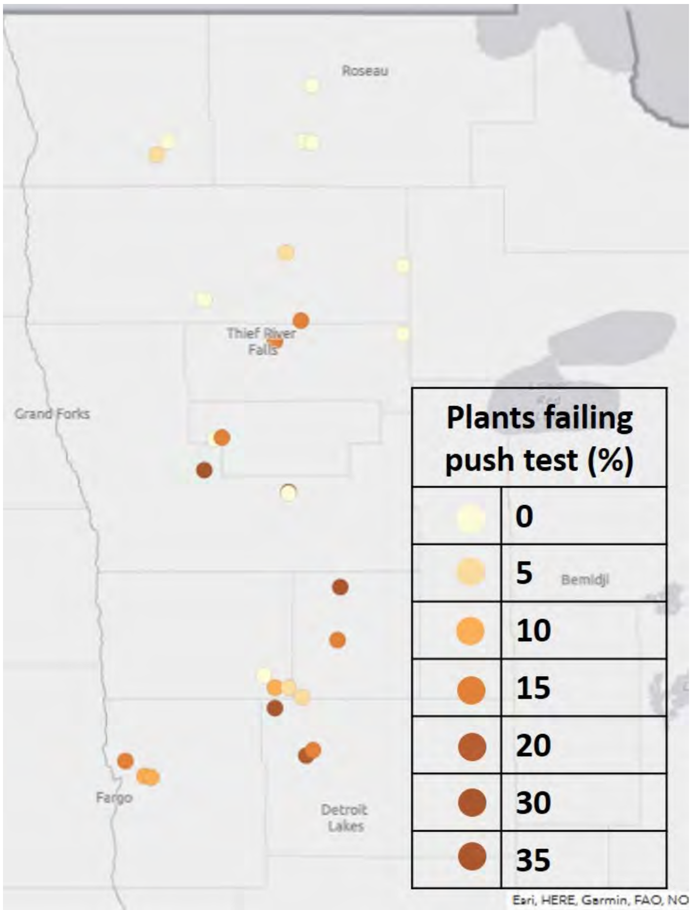

Figure 2. The location of fields surveyed and the percentage of plants failing the push test in each field in 2020.

For Additional Information:
Angie Peltier, Bruce Potter and Bill Hutchison

Project Funding Provided by:
Minnesota Corn Research and Promotion Council

European corn borer survey – 2017-2020: Northwest Minnesota

Cooperators: Cooperating producers and crop advisors in Becker, Clay, Clearwater, Kittson, Mahnomen, Marshall, Norman, Pennington, Polk, Red Lake and Roseau Counties.

Purpose of Study:
European corn borer (ECB) larvae tunnel into stalks and ear shanks (**Figure 1**). Feeding affects the transfer of water and nutrients within the plant and can directly affect yield by reducing kernel weight and number. ECB feeding can indirectly affect yield when tunnels cause stalk breakage, ear drop, or allow the entry of stalk rot and ear mold fungi.

Figure 1. European corn borer (*Ostrinia nubilalis*). Clemson University, USDA Cooperative Extension Slide Series, Bugwood.org.

<u>ECB and Bt corn.</u> More than 25 years ago scientists found a way to transfer a gene from a soil-borne bacterium called *Bacillus thuringiensis* (Bt) into the corn genome. Bt corn was approved for commercial use in 1996. Within the corn plant tissues, this gene produces a protein toxic to corn borer larvae. When ingested by larvae, the protein breaks down to a toxin which kills larvae by allowing mid-gut contents to leak into the rest of the body cavity. Additional Bt traits that target different above- and below-ground insect pests have since been incorporated into some hybrids.

The only way to manage ECB before Bt corn was developed, was to closely monitor ECB moth flights and scout for larvae and egg laying. If ECB populations warrant, foliar insecticide applications can provide control if they are carefully timed as the larvae are only susceptible to insecticides for 10 to 14 days. After that time, 3^{rd} instar larvae begin to tunnel into the stalk or ear shank where they are protected from insecticide applications. This timing can be difficult particularly in areas of the state where both a single generation and multiple generation biotypes of ECB exist. Historically, the single generation (univoltine strain) has predominated in NW Minnesota.

Even the best-timed insecticide application is less effective than growing a hybrid with the Bt trait. Depending on the hybrid and trait package Bt corn can cost up to $20/acre more than conventional seed. In the current economic environment, $20 is a big deal and is a major driver of non-Bt corn hybrid seed purchases. In much of MN, ~80% of corn acres continue to be planted to hybrids with above ground Bt traits. This has resulted in area-wide…..

….suppression of ECB populations, protecting even the non-Bt acres.

<u>Study Objectives</u>. Some objectives of the MN Corn Research & Promotion Council-sponsored 2017-2020 fall ECB survey in NW MN are to answer the following questions:

1) Are there changes in ECB population densities over time?
2) To what extent does the areawide suppression effect occur in the NW?
3) Have any population shifts taken place? ie. is the Bt trait still effective (Bt-resistant corn borer have been found in eastern Canada but fortunately they are a different strain than occurs in MN) and does ECB in NW MN continue to only produce a single generation of larvae each year? Understanding the number of generations per year is essential for managing ECB in non-Bt corn.

Results:

During 2017, 2018, 2019 and 2020, a total of 29, 40, 55 and 28 commercial fields were surveyed in NW MN, respectively (**Figure 2, Table 1**). Among the randomly surveyed fields there were also 11 known non-Bt fields in 2017, 25 in 2018, 36 in 2019 and 8 in 2020. The data presented in Table 1 summarize the per plant average number of ECB larvae in surveyed fields by year and Bt status. In 1995, before the 1996 release of ECB Bt hybrids, an average of 1.16 ECB larvae per plant were found in NW MN corn plants. In 2017 through 2019, randomly surveyed corn fields had an average of 0 to 0.0167 larvae per plant, while the average number of larvae per plant in non-Bt corn fields ranged from 0.0727 to 0.1772 larvae per plant. When compared to randomly surveyed fields, in 2017 there were more than 4.4 times the number of larvae per plant in the non-Bt fields; similarly, when compared to randomly surveyed fields, in 2019 there were 14 times the number of larvae per plant in the non-Bt fields.

ECB population densities were very low in all surveyed fields in 2020. This may indicate that, even at though overall ECB populations are low, they still follow the historical cycle entomologists believe related to a fungal disease and other parasites causing dramatic declines in high ECB populations every 6-7 years.

While higher than number of larvae per plant in fields surveyed at random, the average number of larvae per plant in non-Bt fields is much lower than the traditional economic thresholds levels for ECB (typically estimated at 0.5 larvae/plant).

For Additional Information: Angie Peltier, Bruce Potter, Eric Burkness and Bill Hutchison

Project Funding Provided by:
Minnesota Corn Research and Promotion Council

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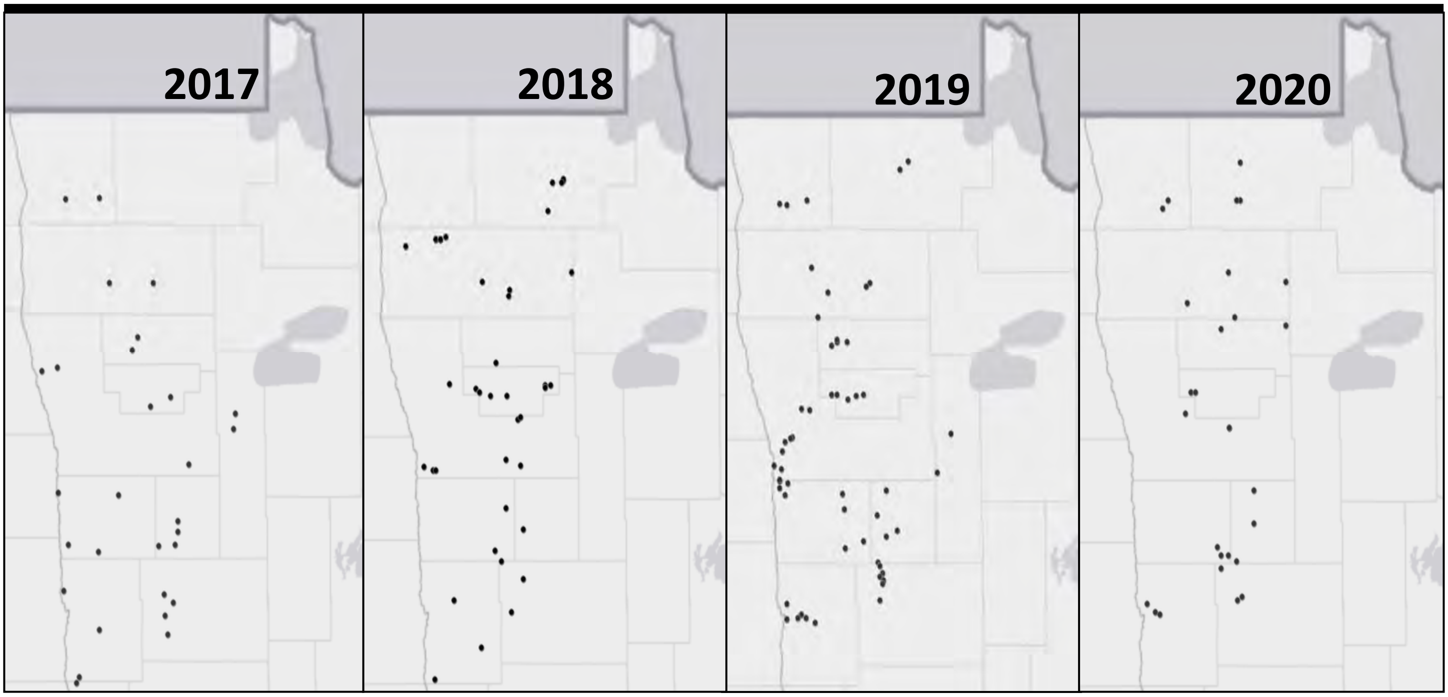

Figure 2. Fields in the northwest crop reporting district surveyed for European corn borer in 2017-2020.

Table 1. NW MN crop reporting district data for ECB larvae in field corn, Minnesota 2017-20. Baseline data for 1995, prior to Bt corn commercialization is also shown (non-Bt fields)*

	Mean #ECB larvae/plant (n)	
	Random fields	**Known non-Bt fields only**
1995	**1.16***	**1.16***
2017	**0.0167 (18)**	**0.0727 (11)**
2018	**0.0000 (15)**	**0.0840 (25)**
2019	**0.0105 (19)**	**0.1472 (36)**
2020	**0.0000 (20)**	**0.0000 (8)**

Bottom line.

While this information provides a '30,000 ft view' of ECB in the region, remember that these are region-wide averages and do not replace scouting of individual fields for making informed, in-season pest management decisions. One positive for those planting non-Bt corn in NW MN, the larvae collected in this region reflect the single-generation type of ECB, meaning that scouting and insecticide management can be confined to a shorter time each year.

Each farmer has a different tolerance for risk. While low populations mean that there is less risk associated with planting corn hybrids without Bt for ECB protection, the risk is not zero.

Want to learn more?

For additional information about the European corn borer and ECB management, visit:
https://extension.umn.edu/corn-pest-management/european-corn-borer-minnesota-field-corn

For Additional Information: Angie Peltier, Bruce Potter, Eric Burkness and Bill Hutchison

Project Funding Provided by:
Minnesota Corn Research and Promotion Council

A new way of managing white mold in soybean

Purpose of Study: White mold in soybeans has always been difficult to manage. The fungus that causes this disease produces long-lived survival structures and has a wide host range, causing economic losses in many crops important to NW MN, including soybean, edible beans, sunflower and canola. Partial resistance in soybean varieties means that in years in which weather favors disease, some yield loss is still likely to occur. Similarly, while there are several protectant fungicides labeled for white mold management, sub-optimal canopy penetration and coverage at the site of infection (flower buds at leaf axils) means that some yield loss likely occurs even with a well-timed application.

While the connection may not initially be apparent, the convergence of recent economic and environmental concerns and the availability of equipment that allows farmers to spoon-feed nitrogen (N) to their crops, paved the way for this soybean white mold management project. With corn producers feeling both an internal pressure to make sure that every last bit of N at least pays for itself and an external pressure to reduce N lost to the environment, some split their N, applying a baseline in the spring and coming back later on to side-dress the remaining N into a standing crop. It is the equipment that allows this in-season side-dressing to take place (think y-drop applicators) that provides an opportunity to research different fungicide application techniques.

In an effort to improve fungicide coverage, we compared deposition, coverage and efficacy when fungicides were applied either within the canopy between rows or in the typical over-the-top fashion. Personnel built a spray boom to position multiple nozzles between rows and within the canopy (**Figure 1**). Chemical-resistant hose, plumbing and sprayer fixtures and junctions were used to fashion the body onto which to affix the nozzle filters and nozzles. Zip ties were used to connect the nozzle body onto the bottom of a square, hollow steel pipe that would ride within the canopy and between rows. Plastic skid plates were bent and riveted to the steel pipe so that the pipe and nozzle body could easily glide through the canopy, minimizing potential plant injury. Details regarding the over-the-top and between-the-row sprayer setups can be found in **Table 1**. Note that while fungicides work best to protect plants when droplet size is small and more plant surfaces are covered, some fungicide labels suggest increasing droplet size for white mold management to ensure sufficient canopy penetration.

Figure 1. Configuration of the tractor-mounted hydraulic-powered plot sprayer used to apply fungicides in this experiment. Note that two different within-the-canopy booms were built to allow application down the center of both 22 (Crookston study site) and 30 inch (Staples study site)-spaced soybean rows. The within-the-canopy nozzle body (black circle/square) rode approximately 12“ from the soil surface and the over-the-top nozzles (white circle/square) rode approximately 8“ above the soybean canopy.

Table 1. Details regarding the nozzle type and details, spray volume, speed, pressure and droplet size of fungicides applied over the top of the canopy and within the canopy. See **Figure 1** for a picture of what both look like.

	Over-the-top	Within-the-canopy
Spray nozzle	TeeJet AI XR11002	TeeJet 110015
Nozzle details	Flat fans riding above the canopy	3 nozzles: 2 flat fans spray vertically toward rows & 1 sprays up at 45° angle under the canopy
Gallons/Acre	10	10
mph	5	5
Pressure	40 psi	40 psi
Droplet size	Very course	Medium

For additional information:
Angie Peltier, Jeff Nielsen, Michael Leiseth, Dean Malvick

Project funding provided by:
Minnesota Soybean Research & Promotion Council

Results:

Treatments. To improve the chance of white mold occurring, some plots were infested with the fungus that causes white mold (*Sclerotinia sclerotiorum, Ss*) and all plots were irrigated weekly after fungicide application. Experimental treatments included an untreated control that was neither infested with *Ss* nor treated with fungicide, a positive control in which plots were infested with *Ss*, but not treated with fungicide, and over-the-top and within-the-canopy fungicide treatments that were infested with *Ss*.

Assessing spray coverage and deposition. Prior to applying fungicides, short (18"-tall, installed) pieces of metal fencing material were pounded into soybean rows in plots that were to have over-the-top or within-the-canopy applications; and small spring-loaded two-sided alligator-type clips were attached to them at 6" and 12" above the soil line. Just before fungicide application, water-sensitive paper was attached to the clips and oriented to sit within the canopy. After application and time for the water-sensitive paper to dry, personnel put on appropriate PPE and retrieved the papers, placing them into pre-labeled Ziplock-type bags to shield them from moisture or humidity. A scanner and USDA-developed software program called "Deposit Scan" were used to objectively analyze spray coverage and deposition on the water sensitive paper.

Data collected. At the beginning flowering (R1) growth stage, 8 oz/A of Endura was applied to the center four rows of six 22 inch-row soybean plots at the Northwest Research and Outreach Center in Crookston and to the center four rows of six 30 inch-row soybean plots at the Central Lakes College Ag and Energy Center in Staples. Data that was collected from these plots included: fungicide coverage and deposition, white mold incidence and severity and harvest moisture and yield.

Yield. Despite doing our best to initiate disease in these experiments, warm temperatures prevailed after treatment, resulting in no disease. Consequently, it was not a surprise that there were no differences observed among treatments for soybean yield (66.7 bu/A average, $P = 0.2869$) and moisture (12.0% average, $P = 0.2307$) at the Staples site and yield (29.8 bu/A average, $P = 0.9644$) and moisture (8.8% average, $P = 0.1882$) at the Crookston site.

Fungicide coverage. The within-the-canopy application resulted in significantly better fungicide coverage within the soybean row 6 inches above the soil line than the over-the-top application in Crookston, but not in Staples (**Table 2, Figure 2**). This same trend was observed 12 inches above the soil line (**Table 3**), with significantly more coverage when applying fungicides within-the-canopy at Crookston and numerically better coverage in Staples compared to over-the-top. We speculate that at the CLC in Staples the thick canopy may have interfered with fungicide penetration at the 6-inch height regardless of application method. More research is needed.

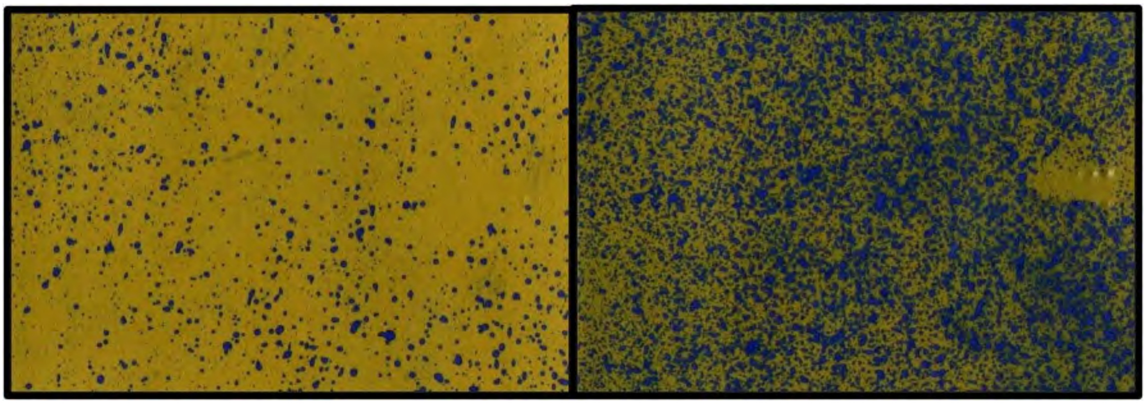

Figure 2. Water sensitive paper that had been placed 6 inches above the soil line in the soybean row before fungicide was applied using either the traditional over-the-top method (left) or the experimental within-the-canopy method (right). A document scanner and the Deposit Scan software was used to impartially assess spray coverage and fungicide deposition. Note that darker areas indicate where fungicide droplets fell on the water sensitive paper.

For Additional Information:
Angie Peltier, Jeff Nielsen, Michael Leiseth, Dean Malvick

Project Funding Provided by:
Minnesota Soybean Research and Promotion Council

Table 2. Coverage (%) and deposition (microL/cm^2) of fungicides applied over-the-top or within-the-canopy captured by water-sensitive paper placed within the R1 soybean canopy at 6 inches above the soil line in 22 inch rows at the NWROC in Crookston and in 30 inch soybean rows at the CLC in Staples. Treatments means within a column followed by different letters are significantly different from one another.

	NWROC, Crookston			CLC, Staples	
	Coverage	Deposition		Coverage	Deposition
Nozzle configuration	%	microL/cm^2		%	microL/cm^2
Over-the-top	14.3 a	1.6 a		20.9 a	3.1 a
Within-the-canopy	55.1 b	31.8 b		20.4 a	2.5 a
P=	0.0357	0.0282		0.9776	0.6825

Table 3. Coverage (%) and deposition (microL/cm^2) of fungicides applied over-the-top or within-the-canopy captured by water-sensitive paper placed within the R1 soybean canopy at 12 inches above the soil line in 22 inch rows at the NWROC in Crookston and in 30 inch soybean rows at the CLC in Staples. Treatments means within a column followed by different letters are significantly different from one another.

	NWROC, Crookston			CLC, Staples	
	Coverage	Deposition		Coverage	Deposition
Nozzle configuration	%	microL/cm^2		%	microL/cm^2
Over-the-top	27.8 a	2.3 a		11.3 a	0.7 a
Within-the-canopy	51.9 b	26.5 a		27.6 a	2.6 a
P=	0.0813	0.4070		0.1996	0.2352

<u>Fungicide deposition.</u> Compared to the traditional over-the-top fungicide application method, there was significantly more fungicide deposited by the within-the-canopy fungicide application method 6 inches above the soil line (**Table 2**). When compared to the traditional over-the-top fungicide application method, there was numerically more fungicide deposition at 12 inches above the soil line in the within-the-canopy plots at both the Staples and Crookston locations (**Tables 2 & 3**).

For Additional Information:
Angie Peltier, Jeff Nielsen, Michael Leiseth, Dean Malvick

Project Funding Provided by:
Minnesota Soybean Research and Promotion Council

NOTES

University of Minnesota Wheat Breeding Program

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

Research Question

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 2019/2020 crossing cycle, 239 crosses were made. The 2020 State Variety Trial, which contained 38 released varieties, 12 University of Minnesota experimental lines, 3 experimental lines from other programs, and 3 long term checks was grown at 15 locations. Another 173 advanced experimental lines were evaluated in advanced yield trials at 10-11 locations and 360 lines were evaluated in preliminary yield trials at 3 locations. A total of 6,864 yield plots were harvested in 2020. 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 2,763 pre-yield trial lines and their FHB resistance and dough mixing properties were predicted based on a training set of 544 lines. The predictions based on DNA sequence information were used to help select the 360 preliminary yield trial lines from the 2,763 candidate lines, therefore avoiding more expensive and time consuming field-based evaluations on more than 2,000 lines with low genetic potential. Data from the yield and disease nurseries are summarized and published in Prairie Grains and the MAES's 2020 Minnesota Field Crop Trials bulletin.

MN-Torgy (Sabin/01S0377-6//Linkert) was released in 2020. MN-Torgy 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. MN-Torgy has acceptable baking quality (4) and good disease resistance, among the best for bacterial leaf streak (3) and moderately resistant to scab (4).

MN15005-4 (Prosper/MN08301-6//Norden) is a candidate for release currently undergoing seed increase in California. MN15005-4 has grain yields comparable to Shelly, straw strength comparable to Linkert, and average grain protein. Disease resistance and baking quality are acceptable.

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 at 3 locations. Advanced yield trials - containing 170-180 experimental lines – are evaluated at 10-11 locations. All yield nurseries are

			Grain Yield		
	Release	% of MN	(% of mean)		
Variety	Yr	acreage	2020	2 Yr	3 Yr
SY Valda	2015	15.9	104	106	107
MN15005-4	-	-	104	104	104
MN-Torgy	2020	-	104	104	104
Shelly	2016	6.2	103	104	104
LCS Cannon	2018	2.1	102	104	104
Lang-MN	2018	1.5	99	100	100
SY Ingmar	2014	2.4	96	97	98
MN-Washburn	2019	4.4	93	97	98
SY McCloud	2019	1.8	95	95	96
WB-Mayville	2011	2.8	93	95	95
Bolles	2015	2.2	94	94	93
Linkert	2013	19.6	91	91	91
WB590	2017	15.7	105	-	-
WB9479	2017	11.9	96	-	-

* values of 1-2 should be considered as resistant. Falling number data was
expected falling numbers based on their PHS rating.

grown as 50-80 sq. ft. plots. Misted, inoculated Fusarium head blight nurseries are grown at Crookston and St. Paul and an inoculated leaf and stem rust nursery is grown at St. Paul. Genomic prediction is used at the pre-yield trial stage to predict the performance of experimental lines based on DNA sequence information of related lines. This allows us to screen a larger number of lines than we could accommodate in our field trials, and can help us find the rare lines that combine all the desired 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 profitability. As an example, a new variety that yields 4% higher will produce 3 extra bushels/acre 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 2020 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

Adeyemo, E., P. Bajgain, E. Conley, A.H. Sallam, and J.A. Anderson. 2020. Optimizing training population size and content to improve prediction accuracy of FHB-related traits in wheat. Agronomy 10, 543; doi:10.3390/agronomy10040543

Anderson, J.A., J.J. Wiersma, S.K. Reynolds, E.J. Conley, R. Caspers, G.L. Linkert, J.A. Kolmer, Y. Jin, M.N. Rouse, R. Dill-Macky, M.J. Smith, L. Dykes, and J.-B. Ohm. 2020. Registration of 'Lang-MN' hard red spring wheat. J. Plant Registrations, in press.

Bajgain P., Y. Jin, T.J. Tsilo, G.K. Macharia, S.E. Reynolds, R. Wanyera, and J.A. Anderson. 2020. Registration of KUWNSr, a wheat stem rust nested association mapping population. J Plant Regist. https://doi.org/10.1002/plr2.20043

ElFatih, A., A. ElDoliefy, A. Kumar, J.A. Anderson, K.D. Glover, S. Mamidi, E.M. Elias, R. Seetan, M.S. Alamri, S.F. Kianian, S. Sapkota, A. Green, and M. Mergoum. 2020. Genetic dissection of Fusarium head blight resistance in spring wheat cv. 'Glenn'. Euphytica 216:71 https://doi.org/10.1007/s10681-020-02610-0

Moghimi, A., C. Yang, and J.A. Anderson. 2020. Aerial hyperspectral imagery and deep neural networks for high-throughput yield phenotyping in wheat. Comp Elec Agric https://doi.org/10.1016/j.compag.2020.105299

Sallam, A.H., E. Conley, D. Prakapenka, Y. Da, and J.A. Anderson 2020. Improving prediction accuracy using multi-allelic haplotype prediction and training population optimization in wheat. G3 10: doi: https://doi.org/10.1534/g3.120.401165

Table 1. Comparison of MN 15005-4, MN-Torgy and the 12 most popular spring wheat varieties grown in MN. Entries are sorted based on grain yield (% of mean) over 43 environments. For traits scored on a 1-9 scale, 1 is best and 9 is worst.

			Straw	Test wt	Protein	Baking		Leaf	Stripe	Bacterial	
	Heading	Height	Strength	(lbs/bu)	(%)	Quality	PHS	Rust	Rust	Leaf Str.	Scab
	d	in.	1-9	2020	2020	1-9	1-9	1-9	1-9	1-9	1-9
	57.6	27.5	5	60.2	14.7	6	2	1	2	3	4
	59.3	26.0	2-3	59.7	14.9	5	2	2	-	5	5
	57.6	27.8	4	60.0	15.2	4	1	3	-	3	4
	58.5	26.3	5	59.5	14.3	5	1	3	1	6	4
	53.3	26.7	4	60.8	14.6	4	3*	3	-	5	5
	58.6	28.9	4	60.3	15.3	3	1	1	-	3	3
	58.5	27.9	4	60.0	15.5	2	2	2	2	3	4
	59.0	27.2	3	59.7	14.7	3	1	1	2	3	4
	56.4	28.3	4	60.9	15.6	3	2*	3	-	5	5
	56.0	25.5	3	60.2	15.7	2	3*	3	3	7	8
	59.5	30.0	4	58.9	16.7	1	1	2	1	4	4
	57.1	26.4	2	60.3	15.7	1	1	3	1	5	5
	55.7	25.3	3	59.9	15.5	-	2	6	-	6	7
	56.1	25.3	3	60.4	16.0	-	2	6	-	6	7

collected from nine 2019 locations. Varieties with an * following their pre-harvest sprouting rating had lowr than

Nitrogen Use Efficiency of Spring Wheat Production System Across Western Minnesota

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Research Question

How much fertilizer-nitrogen application rate, grain yield and protein content and nitrogen losses do vary under spring wheat fields across western Minnesota?

Results

Site description and management

All three seasons had early dry condition (particularly 2018) and extreme wet during the late growing season. All sites have a medium-textured soil and soil pH are neutral

Table 1. Details about crop management and inital soil properties of 26 sites of western Minnesota selected for this study

	Site	Cultivar	Previous crop	Planting date	Harvesting date	BD Mg m^{-3}	pH	OM g kg^{-1}
				2018				
1	Argyle, MN	Linkert	Soybean	Apr. 29	Aug. 11	1.35	8.2	45
2	Crookston, MN	Climax	Soybean	Apr. 29	Aug. 7	1.30	8.2	52
3	Roseau, MN	Linkert	Soybean	May 12	Aug. 15	1.65	8.3	39
4	Red Lake Falls, MN	Linkert	Soybean	May 4	Aug. 7	1.38	8.2	42
5	Grygla, MN	Linkert	Canola	May 13	Aug. 14	1.45	7.5	31
6	Gentilly, MN	Linkert	Soybean	May 3	Aug. 7	1.73	8.1	20
7	St. Hiliaire, MN	Prevail	Soybean	May 5	Aug. 11	1.26	8.3	34
8	Fosston, MN	Rebel	Sugarbeet	Apr. 27	Aug. 17	1.65	7.6	44
9	Ada, MN	Shelly	Soybean	May 4	Aug. 8	1.21	8.0	53
10	Glyndon, MN	Linkert	Soybean	May 2	Aug. 6	1.10	8.3	39
				2019				
1	Argyle, MN	Westbred9590	Soybean	Apr. 25	Jul. 30	1.23	8.2	52
2	Gentilly, MN	Westbred9590	Soybean	May 9	Jul. 30	1.39	7.1	51
3	Dorothy, MN	Linkert	Soybean	May 15	Aug. 5	1.40	8.2	38
4	Mahnomen, MN	Trigger	Soybean	May 10	Aug. 2	1.31	7.1	57
5	Ada, MN	Shelly	Soybean	May 14	Aug. 2	1.65	7.8	37
6	Red lake Falls, MN	Ingmar	Soybean	May 10	Aug. 1	1.37	8.0	29
7	Thief River Falls, MN	Valda	Soybean	May 9	Aug.1	1.24	8.3	42
8	Rustad, MN	Bolles	Soybean	May 7	Jul. 31	1.17	7.8	57
				2020				
1	Argyle, MN	Westbred9590	Soybean	May 11	Aug 12	1.05	8.3	53
2	Gentilly, MN	WestBred 9590	Soybean	May 12	Aug 4	1.25	8.3	20
3	Ada_GM, MN	AgriPro	Soybean	May 4	Aug 4	1.03	8.5	16
4	Ada, MN	Valda	Spring wheat	May 11	Aug 12	0.99	8.6	31
5	Fosston, MN	Rebel	Sugarbeet	May 5	Aug 12	1.06	8.4	23
6	Rustad-no tile, MN	Prosper	Sugarbeet	April 21	July 28	1.14	8.3	30
7	Rustad-Tile, MN	Lang	Sugarbeet	April 25	July 28	1.25	8.5	35

to alkaline with organic matter content ranging between 1.6% (Ada_GM site in 2020) and 5.7% (Mahnomen and Rustad sites in 2019). Soil bulk density value ranged between 0.99 Mg m^{-3} (Ada, MN in 2020) to 1.73 Mg m^{-3} (Gentilly, MN). Soil Olsen-P ranged between 3 ppm (Argyle and Ada_GM in 2020) to 95 ppm (Fosston in 2018). Gentilly site had the lowest soil available K in 2018 and 2019 and Ada_GM site had the lowest available K in 2020. In most cases, soybean was previous crop, but in 2020, three out of eight sites had sugarbeet as previous crop (Table 1). Regarding cultivar, it was mostly Linkert in 2018, but it was more diversified in 2019 and 2020. Planting window ranged between 4th wk. of April to 2nd wk of May. Harvest dates reflect the harvest of sub plots we have established for our study, might not match with harvesting date of growers. Fertilizer-N application rate ranged between 50 lb N ac-1 (Ada in 2018) to 240 lb N ac-1 (Argyle in 2018). Average fertilizer-N application rate was 140, 147, and 166 lb N/ac, respectively in 2018, 2019, and 2020. In 2018, three sites, Roseau, Ada and Glyndon, received fertilizer-N in fall and fertilizer-N was applied in spring for the rest of the sites. In 2019, Argyle, Mahnomen and Thief River Falls received fertilizer-N in spring. In 2020, all sites received fertilizer in spring. Besides NPK, some growers applied sulfur.

Grain yield and protein content

Average wheat grain yield and protein content for three consecutive seasons were 61.0, 58.9 and 61.7 Bu/ac and 14.0, 14.5, and 15.7, respectively during 2018, 2019 and

»

conducted during 2018-2020 growing seasons

NO_3-N (kg ha^{-1})	Olsen-P (g kg^{-1})	K (g kg^{-1})	Fertilizer management
45	6	372	Fall 134 kg ha^{-1} of 13-32-6-6 and 73 kg ha^{-1} of urea
67	26	387	Fall anhydrous NH_3@ 101 kg N ha^{-1} and 11-52-0 @58 kg ha^{-1}, spring Anhydrous NH_3 @84 kg N ha^{-1} and 11-52-0@ 95 kg ha^{-1}
35	14	162	Spring 112 kg N ha^{-1}, 45 kg P_2O_5 ha^{-1} and 45 kg K2O ha^{-1} and top-dress 30-0-0-15S
84	8	233	Fall anhydrous NH_3 @ 90 kg N ha$_{-1}$ and 11-52-0 @ 65 kg ha^{-1}
119	9	142	Fall anhydrous NH_3 @ 162 kg N ha^{-1} and spring 12-40-0 @123 kg ha^{-1}
78	7	60	Fall anhydrous NH_3 @ 146 kg N ha^{-1} and spring 12-40-0 @112 kg ha^{-1}
82	10	129	Fall anhydrous NH_3@ 146 kg N ha^{-1} and a starter 12-40-38 @112 kg ha^{-1}
22	95	171	Fall anhydrous NH_3 @ 170 kg N ha^{-1} and 95 kg ha^{-1} of 11-52-0
131	19	515	Spring 56 kg ha^{-1} of 8-0-10
78	36	134	Spring 149 kg N ha^{-1}, 33.6 kg P_2O_5 ha^{-1}, 22.4 kg K_2O ha^{-1} and 56 kg of 11-52-0 ha^{-1}
43	21	361	Spring 157 kg N ha^{-1} with N serve
78	18	242	Fall urea 145 kg N ha^{-1} and starter (12-40-0-10-1) at the rate112 kg ha^{-1}
79	10	80	Fall anhydrous NH_3 at 151 kg N ha^{-1}
62	19	159	Spring anhydrous NH_3 at 159 kg N ha^{-1} and 84 kg ha^{-1} of 11-52-0
94	24	189	Fall 179 kg N ha^{-1}, 66 kg P_2O_5 ha^{-1}
29	11	97	Fall 134 kg N ha^{-1}
8	11	103	Spring 100 kg N ha^{-1}
20	20	278	Fall 123 kg N ha^{-1}
72	3	279	Spring 325 lb urea ac^{-1}, 80 lb 11-52-0 ac^{-1} and 30 lb ammonium sulfate ac^{-1}
38	6	67	Spring 300 lb urea ac^{-1}, 150 lb MESZ (12-40-0-10-1) ac^{-1}
20	3	59	Spring 307 lb ac^{-1} of urea, 50 lb ac^{-1} of 11-52-0, 100 lb ac^{-1} of MOP and 41 lb ammonium sulfate ac^{-1}
92	7	95	Spring 260 lb ac^{-1} of urea and 80 lb ac^{-1} of 9-42-12
36	10	97	Spring 140 lb anhydrous NH_3 ac^{-1} and 39 lb ac^{-1} of 11-52-0
181	8	181	Spring 190 kg N ha^{-1}, 56 kg P_2O_5 ha^{-1}, 11 kg K_2O ha^{-1} and 16 kg S ha^{-1}
74	5	80	Spring 170 lb N, 40 lb P_2O_5 and 10 lb K_2O ac^{-1}

»

» 2020 (Table 2). The highest grain yield was observed at Fosston (88.5 Bu/ac), Ada (82.8 Bu/ac) and Ada_GM (77.1 Bu/ac) sites; whereas, the highest protein content was observed at Crookston (16.5%) with Climax cultivar, Rustad (15.81%) with Ingmar cultivar, and Rustad-tiled site (18%) with Lang cultivar in 2018, 2019 and 2020, respectively.

Nitrogen losses
Cumulative N_2O-denitrification and NH_3 volatilization losses were ranged between 0.1 to 1.2 lb N_2O-N per ac and 0.4 to 4.4 lb NH_3 per ac. Average cumulative N_2O and NH_3 losses of each season were 1.31 lb N_2O-N per ac and 0.57 lb NH_3 per ac in 2018, 1.83 lb N_2O-N per ac and 0.35 lb NH_3 per ac in 2019, and 0.62 lb N_2O-N per ac and 0.12 lb NH_3 per ac in 2020.

Nitrogen use efficiency
Average N use efficiency was 43, 46 and 41% for three consecutive seasons. The highest N use efficiency was observed at Fosston (78%), Thief River Falls (74%) and Ada_GM (60%) for 2018, 2019, and 2020, respectively. The highest N use efficiency was observed with fall application of fertilizer in 2018 and 2019.

Application and Use

This study indicated that the highest N use efficiency corresponded to highest wheat grain yield (but not protein content) in 2018 and 2020, but not in 2019. But the highest grain yield was not corresponded to highest fertilizer-N application rate. Highest denitrification loss was mostly linked to clay soils in 2018 and 2019. Highest volatilization loss was probably linked to sandy clay soils.

Materials and Methods

This project has been conducted for three growing seasons (2018-2020), total 25 growers' fields were evaluated for nitrogen (N) losses throughout the growing season, grain yield and protein content. Crop and nutrient management information, cultivar selection, previous crop, fertilizer management practices, drainage, and tillage, were collected from growers. Initial soil samples from 0-6" and 6-24" depths were collected for the analyses of basic soil properties. After the planting, a subplot measuring 100 ft by 30 ft were marked and set up for gas (ammonia and nitrous oxide) and nitrate leaching (suction cup lysimeter) measurements were installed. Soil (0-6" depth), water, sponge (for ammonia loss) and air samples were collected on a bi-weekly basis and simultaneously analyzed for available soil inorganic N (ammonia and nitrate), ammonia (NH_3) volatilization loss, nitrate (NO_3) concentration in below rootzone water samples (representing potentially leachable NO_3), and nitrous oxide (N_2O) flux. At the end of growing season, wheat grain was collected from 40 ft transect and grain samples were analyzed for protein content. For each site, N use efficiency was calculated by dividing the grain-N removal with available N (sum of fertilizer-N and soil inorganic N at planting).

Economic Benefit to a Typical 500 Acre Wheat Enterprise

This study revealed that optimum grain yield, protein content and N use efficiency were not related to fertilizer-N application rate. Protein content was more associated with cultivar selection. Denitrification and volatilization losses were related to soil characteristics. Soils prone to losses should adopt fertilizer management practices. Future research studies should design studies based on these findings.

Table 2. Location, texture, applied fertilizer-nitrogen (N), grain yield and protein, percent N use efficiency and cumulative denitrification (N_2O-N) and volatilization (NH_3-N) N losses from 25 field sites under spring wheat production system across western Minnesota during 2018-2020 growing seasons.

	Site	
1	Argyle	
2	Crookston	
3	Roseau	
4	Red Lake Falls	
5	Grygla	
6	Gentilly	
7	St. Hilaire	
8	Fosston	
9	Ada	
10	Glyndon	
1	Argyle	
2	Gentilly	
3	Dorothy	
4	Mahnomen	
5	Ada, MN	
6	Red lake Falls	
7	Thief River Falls	
8	Rustad	
1	Argyle	
2	Gentilly	
3	Ada_GM	
4	Ada	
5	Fosston	
6	Rustad-no tile	
7	Rustad-Tile	

Location	Texture	Applied-N	Yield	Protein	NUE	Cumulative N loss	
		lb N ac-¹	Bu ac-¹	%	%	kg N_2O-N ha-¹	kg NH_3-N ha-¹
2018							
48°18’14” N 96°57’25” W	Clay	240	66.2	14.54	33	1.24	1.16
47°49’5” N 96°40’32” W	Loam	180	39.2	16.5	26	0.88	1.38
48°56’32.5” N 95°56’23.4” W	Sandy clay loam	100	80.0	12.76	75	0.45	1.12
47°50’03.4" N 96°19’53.1" W	Loam	86	53.2	13.18	42	0.45	1.30
48°21’53.3” N 95°37’24.0” W	Sandy loam	157	80.7	12.22	36	0.80	0.89
47°46’47.0” N 96°13’24.8” W	Loamy fine sand	142	39.7	12.65	28	0.23	1.03
47°59’33.3"N 96°13’24.8"W	Sandy loam	142	52.1	13.79	32	0.29	1.00
47°30’38.3” N 95°48’40” W	Clay loam	160	88.5	15.74	78	1.30	4.93
47°23’09.8" N 96°41’06.9"W	Clay loam	50	64.6	13.86	52	0.53	0.73
46°59’00.7"N 96°35'07.2"W	Loam	138	48.3	29	29	0.29	1.21
2019							
48°18’22.6”N 96°56’12.4”W	Sandy clay loam	157	56.8	15.44	45	1.23	1.87
47°47’9.51”N 96°56’45.0”W	Sandy clay loam	162	37.0	12.65	21	0.32	1.48
47°55’14.1”N 96°29’43.3”W	Sandy loam	151	58.7	14.24	38	0.10	1.55
47°30’31.2”N 95°53’56.2”W	Sandy clay loam	168	54.3	10.25	25	0.39	4.26
47°23’44.5”N 96°41’3.12”W	Sandy clay loam	179	82.8	14.92	47	0.14	1.87
47°49’53.2”N 96°14’47.1”W	Sandy loam	134	57.0	14.99	54	0.09	1.65
48°2’3.82”N 96°14’38.9”W	Sandy loam	100	66.8	11.79	74	0.37	1.90
46°43’13.4”N 96°41’51.6”W	Sandy clay loam	123	57.2	15.81	65	0.52	1.87
2020							
46°36’25.2”N 96°36’55.4”W	Silty clay	184	69.2	14.7	39	0.06	0.47
47°46’44.0”N 96°27’30.9”W	Loam	175	66.7	12.2	37	0.05	0.40
47°21’10.6”N 96°25’10.5”W	Sandy loam	169	77.1	15.3	60	0.13	0.40
46°15’12.3”N 96°27’30.2”W	Sandy clay loam	142	44.7	15.7	30	0.06	0.42
47°30’40.8”N 95°48’39.6”W	Sandy clay loam	134	59.4	16.0	55	0.54	0.52
46°43’4.5”N 96°42’7.92”W	Sandy clay	190	68.4	17.9	33	0.08	1.42
46°36’25.2”N 96°36’55.4”W	Sandy clay loam	168	46.2	18.0	34	0.10	1.31

Research on Bacterial Leaf Streak of Wheat

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

Research Questions

Bacterial leaf streak is a foliar disease with significant impact on wheat production in the Upper Great Plains. This project continues our efforts to build resources to mitigate the impact of bacterial leaf streak. The ultimate goals of the project are to deliver economic control, through the development of wheat germplasm with improved resistance and to explore the biology of the bacterial pathogen that incites BLS with the aim of finding additional avenues of disease control.

The specific objectives of this research project were to coordinate the BSL cooperative nursery (BLSCN) facilitating the testing of material from all wheat breeding programs in the region, identify additional sources of resistance to BLS, complete studies examining the host range of the BLS pathogen and variation in pathogen populations, determine where in the wheat seed the bacteria (*Xanthomonas translucens* pv. *undulosa*) are surviving and examine the efficacy of seed treatments in reducing *X. translucens* pv. *undulosa* in association with seed and to validate PCR and LAMP assays as tools to rapidly and reliably identify *X. translucens* pv. *undulosa* in what seed, crop debris and soil.

Results

In 2020 we tested released varieties and advanced lines in a regional cooperative nursery (BLSCN). The 97 entries came from ten wheat breeding programs (3 public [UMN, NDSU, SDSU] and 7 private [BASF, Croplan, Dyna-Gro, Limagrain, Meridian Seeds, Syngenta, 21st Century Genetics) in the Upper Great Plains. The BLSCN was established at four locations; St Paul MN; Crookston, MN; 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 2020 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 2020 we completed a study examining the role that wild grasses and other grass hosts play in the epidemiology of BLS in Minnesota. Finalizing this work including publishing a journal article that was released this month (November 2020) in the journal Phytopathology. In this study we utilized a collection of isolates collected from grassy weeds to examine perennial weeds as a potential source of BLS. Multilocus sequence analysis (MLSA) and typing (MLST) of four housekeeping genes (*rpoD, dnaK, fyuA,* and *gyrB*) was used to examine strains of the pathogen *Xanthomonas translucens* isolated from six weedy grass species, collected in and around naturally infected wheat fields in Minnesota.

X. translucens was isolated from both annual and perennial grasses sampled in and around Minnesota wheat fields. *X. translucens* has previously been demonstrated to overwinter in two perennial grasses, smooth brome and quackgrass, in the Upper Great Plains (Boosalis 1952; Wallin 1946). Of the perennial grasses examined in our study, quackgrass appears the most likely to play a role in BLS epidemiology in Minnesota.

Quackgrass, a perennial weed, was present in and sampled from most (14/16) of the field locations in this study and thus was consequently the most heavily represented host in our study, with 24 samples. *X. translucens* pv. *undulosa* was isolated from most of the quackgrass samples and often multiple strains of *X. translucens* pv. *undulosa* were isolated from a single plant. In contrast, foxtail barley, also a perennial grass, was sampled almost as often as quackgrass, however only four *X. translucens* pv. *undulosa* strains were isolated from the foxtail barley samples compared to the 31 strains isolated from quackgrass. Seven *X. translucens* pv. *undulosa* strains were isolated from four perennial ryegrass samples, however as these perennial ryegrass samples all originated from a single field, so they were insufficient to draw conclusions about the distribution of this pathovar on this host. *X. translucens* pv. *cerealis* was the only pathovar identified on smooth brome, and although this pathovar is capable of causing disease on small grains, it does not appear to be a pathogen of major concern (Bragard et al. 1997; Curland et al. 2018; Fang et al. 1950).

The annual grasses identified in and around wheat fields in this study were wild oat and green foxtail. Eleven *X. translucens* pv. *undulosa* strains were isolated from wild oat. These strains were found in six of eight field locations sampled. Five *X. translucens* pv. *undulosa* strains were isolated from green foxtail, these all originated from one of the five field locations where green foxtail was sampled. The sampling of these annual species in our study was insufficient to draw conclusions on the importance of the pathogen populations present on these hosts because of the small sample size, although it is evident that the annual grasses have the potential to harbor *X. translucens* pv. *undulosa.*

Our study demonstrated that the wheat pathogen, *X. translucens* pv. *undulosa*, is present on both perennial and annual grasses. Our findings suggest that grassy weed hosts, such as quackgrass, should be considered as potential reservoirs for the pathogen, contributing to survival and the population size throughout the growing season.

In this project we also proposed examining, using microscopy and the tracking of tagged *X. translucens* pv. *undulosa* strains, where in the wheat seed the pathogen is localized and to determine the pathways of seed infection. Specifically we want to know if the bacteria are inside the wheat seed and associated with the embryo, or if it is surviving only on the seed exterior. In addition, we planned to validate molecular tools (PCR and LAMP assays) that have been developed to identify *X. translucens* pv. *undulosa*, and determine if these can be used to identify *X. translucens* pv. *undulosa* -contaminated seed lots and to detect the pathogen in crop residues and soil. This information will help us better understand the importance of these potential sources of inoculum and target treatments to eradicate the bacterium from seed lots. We were able to plant, inoculate and harvest wheat plants in the summer of 2020 and thus we have a source of naturally infected seed to undertake this work. The laboratory work was however delayed by the pandemic. Our plan is to continue this research in the fall of 2020 and into 2021.

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.

Materials and Methods

We coordinated the 2020 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. These screening nurseries were also used to identify additional sources of resistance. Annual field screening nurseries are critical to the ultimate goal of the research, developing 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).

Strains of the bacterial pathogen associated with BLS were isolated from weedy grasses that are common in Minnesota wheat fields. Multilocus sequence analysis (MLSA) of four housekeeping genes (*rpoD, dnaK, fyuA*, and *gyrB*) was used to identify 77 strains isolated from six weedy grass species found in and around naturally infected wheat fields in Minnesota, along with wheat and barley. The grasses examined included wild oat (*Avena fatua* L.), smooth brome (*Bromus inermis* Leyss.), quackgrass (*Elymus repens* (L.) Gould), foxtail barley (*Hordeum jubatum* L.), perennial ryegrass (*Lolium perenne* L.), giant foxtail (*Setaria faberi* Herrm.), yellow foxtail (*Setaria pumila* (Poir.) Roem. & Schult.), and green foxtail (*Setaria viridis* (L.) P. Beauv.). MLSA phylogeny was used to identify the strains. All the strains originating from weedy grass species, except smooth brome, were identified as *X. translucens* pv. *undulosa*, whereas strains isolated from smooth brome were determined to be *X. translucens* pv. *cerealis*. *In planta* character states corroborated these identifications on a subset of 41 strains, as all strains from weedy grasses caused water-soaking on wheat and barley in greenhouse assays. Multilocus sequence typing (MLST) was used to evaluate genetic diversity and revealed that sequence types of *X. translucens* pv. *undulosa* originating from weedy grass hosts are similar to those found on wheat.

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 through the BLSCN are available to allow a grower to select wheat varieties for production that are less susceptible to BLS. 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, including BLS. The most recent work suggests that the bacteria that incites BLS has a broad host range and suggests that the control of perennial and annual weeds in and around wheat crops may be helpful in the control of this disease.

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.

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Recommended Future Research

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* pathovars associated with BLS of wheat, other crops and grassy weeds and this work is now published. We are pursuing collaborative research with colleagues 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. This work was started in 2020. This fall we are working to develop a technique to isolate the bacteria from seed and will continue our preliminary work on the PCR and LAMP assays which we have begun, although these tests need further validation.

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Publications

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Table 1: Response to bacterial leaf streak rated on a 1-9 scale (1= no disease and 9 = severe disease) for the forty-three named varieties, of the ninety-seven entries tested in 2020.

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Variety	Location				4 Location Mean
	St Paul - MN	Crookston - MN	Fargo, ND	Brookings - SD	
Boost	3.5	5.0	4.5	4.2	4.3
LCS Trigger	3.0	5.0	5.3	5.7	4.7
MS Ranchero	2.0	3.8	7.5	6.7	5.0
MN-Washburn	3.8	5.5	6.3	4.5	5.0
Bolles	3.5	6.0	6.0	5.3	5.2
CP3055	4.0	5.5	5.8	6.0	5.3
Surpass	3.3	6.0	7.3	4.8	5.3
TCG-Spitfire	3.8	4.8	6.5	6.3	5.3
NDVitPro	4.3	6.0	6.3	4.8	5.3
CP3915	4.0	6.3	5.5	5.7	5.4
MN-Torgy	3.5	4.8	6.3	7.0	5.4
Dyna-Gro Ballistic	4.3	6.3	7.3	4.3	5.5
TCG-Heartand	3.8	6.0	7.8	4.8	5.6
Lang-MN	3.8	6.5	6.3	6.0	5.6
NDFrohberg	4.3	6.0	6.0	6.3	5.6
CP3530	4.3	7.0	7.0	4.5	5.7
TCG-Climax	3.8	5.8	6.0	7.3	5.7
AP Murdock	3.3	5.8	7.3	6.8	5.8
CP3903	5.0	7.0	7.5	3.7	5.8
Prosper	4.0	5.3	7.3	6.7	5.8
SY 611CL2	4.3	5.7	68	6.7	5.8
Shelly	4.5	5.8	7.0	6.2	5.9
Linkert	2.8	6.0	8.5	6.3	5.9
AAC Concord	3.5	6.0	7.3	7.2	6.0
Dyna-Gro Ambush	4.0	7.0	6.8	6.3	6.0
Driver	5.3	6.3	7.8	5.0	6.1
SY McCloud	4.8	6.3	7.3	6.0	6.1
SY Rustler	4.3	7.3	6.8	6.0	6.1
TCG-Wildfire	5.0	7.0	7.0	5.3	6.1
SY Valda	4.5	6.0	7.0	6.8	6.1
SY Ingmar	5.0	7.0	7.3	5.3	6.1
TCG-Glennville	4.8	6.3	7.3	6.3	6.1
LCS Cannon	4.0	7.3	8.0	5.7	6.2
LCS Rebel	5.0	7.5	7.0	5.5	6.3
SY Longmire	4.3	6.8	7.0	7.0	6.3
Dyna-Gro Velocity	4.3	6.5	8.5	6.0	6.3
MS Chevelle	4.5	7.5	7.8	6.2	6.5
TCG-Wildcat	5.8	6.0	8.0	7.0	6.7
MS Barracuda	5.0	7.5	8.0	6.3	6.7
SY Rockford	4.8	5.8	8.5	7.8	6.7
CP3910	4.5	7.3	8.8	6.3	6.7
Dyna-Gro Commander	5.3	7.5	7.8	6.8	6.8
MS Camaro	6.5	7.5	8.5	6.7	7.3

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.

Accelerated Breeding for Resistance to Fusarium Head Blight

Karl Glover, Plant Science Dept., SDSU, Brookings

Research Question

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. Results of the 2020 AYT are presented in the appendix. Thirty-seven experimental breeding lines were tested along with eleven check cultivars during the 2020 growing season. Of the thirty-seven experimental lines, seventeen had FHB disease index (DIS) values that were lower than the test average. Among these entries, eight produced more grain than average. Among the eight, test weight of six entries was higher than average, and protein content of two (SD4873 and SD4885) were also greater than average. SD4873 may be released in November 2021 for Certified seed production in 2022.

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 can also have as many as 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 then 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, 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 2020 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 2020.

ENTRY	DIS INDEX	YIELD (BU/AC)	TW (LB/BU)	PROTEIN (%)	HEADING (D > 6/1)	HEIGHT (INCHES)
BRICK	13.8	45.6	62.0	16.2	17.4	29.8
SD4933	15.0	42.8	62.3	16.2	22.0	29.0
SD4871	15.2	46.0	61.2	16.0	21.1	27.2
SD4873	15.6	54.6	61.0	16.2	23.2	30.6
SD4934	15.6	52.6	61.2	15.3	23.8	29.3
SY-VALDA	15.8	51.1	61.0	15.8	21.7	28.1
DRIVER	15.9	53.4	62.2	15.7	22.8	30.3
SD4951	16.3	49.3	61.2	16.0	21.3	29.0
SD4893	16.4	47.8	61.2	16.7	20.1	28.9
FOREFRONT	16.9	46.4	61.0	16.3	18.8	32.1
PREVAIL	16.9	48.9	60.3	15.4	20.1	28.5
SD4852	17.3	46.5	61.2	16.5	19.5	28.3
FOCUS	17.4	44.8	61.3	16.8	17.2	30.3
SD4870	17.6	46.8	60.2	16.3	22.9	29.6
SD4913	18.0	49.5	59.5	16.2	20.5	28.7
SD4910	18.1	40.8	59.6	17.2	18.9	29.2
SD4843	18.2	53.3	62.2	15.2	22.4	28.7
SD4925	18.3	44.7	60.7	16.8	19.5	27.8
SD4905	18.4	51.5	59.9	16.5	20.8	28.8
SD4957	18.4	52.8	62.0	15.4	22.7	28.8
SD4855	18.5	49.1	61.6	16.2	22.3	29.8
ADVANCE	18.8	51.6	61.7	15.4	22.6	28.7
SD4894	18.9	47.2	60.6	16.5	19.3	29.2
SD4952	19.5	48.5	60.2	15.5	22.2	27.5
LCS-TRIGGER	19.7	58.7	61.4	13.9	27.0	30.6
TRAVERSE	19.8	50.6	57.9	15.3	21.1	31.0
SD4892	19.9	45.3	60.6	15.8	23.1	29.0
SD4924	19.9	47.5	60.8	16.2	17.9	28.3
SD4874	20.2	47.4	60.7	16.5	23.0	29.3
SURPASS	20.2	48.0	59.9	16.4	19.0	28.9
SD4849	20.3	46.9	60.8	16.1	19.7	28.5
SD4848	20.3	45.3	61.8	17.0	22.8	27.8
SD4914	20.3	49.2	59.1	16.2	20.5	28.7
SD4903	20.6	50.3	60.8	15.8	20.3	28.6
BOOST	20.8	47.3	60.7	16.1	23.8	30.2
SD4953	21.0	48.4	60.5	15.8	21.2	27.6
SD4915	21.4	49.6	58.9	16.3	20.1	28.0
SD4932	21.5	45.3	60.6	16.7	22.8	30.5
SD4904	21.8	52.0	59.3	16.0	22.7	29.0

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» *Table 1. continued*

ENTRY	DIS INDEX	YIELD (BU/AC)	TW (LB/BU)	PROTEIN (%)	HEADING (D > 6/1)	HEIGHT (INCHES)
SD4949	23.4	48.6	60.9	16.9	24.4	30.8
SD4930	24.0	54.4	59.9	15.1	23.9	29.6
SD4899	24.4	45.6	60.3	16.4	19.7	29.8
SD4940	25.0	48.3	59.3	17.1	26.4	28.6
SD4937	25.6	49.1	59.2	17.3	26.2	28.2
SD4909	26.6	48.3	59.4	16.0	22.7	28.9
SD4945	27.5	48.9	59.4	16.0	24.5	26.1
SD4944	27.6	49.2	59.8	16.3	26.0	27.7
SD4950	28.0	48.6	61.3	16.6	27.7	31.1
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

Southern Minnesota Small Grains Research and Outreach Project

Jared Goplen, Morris Regional Extension Office

Research Question

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 Becker, Benson, 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, Granite Falls, Le Center, Mora, Rochester, and Slayton, MN. Attendance has been strong in recent years, with 178 farmers and crop consultants attending these seven meetings in 2020, despite winter weather 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 30% increase in attendees planning to increase scouting efforts for small grain insects and diseases. Several of the biggest challenges attendees said they face when growing small grains in Minnesota include weather, marketing, and profitability (Figure 2), which were several of the discussion topics at these meetings.

The summer field days for 2020 were originally planned for the end of June at Benson, Becker, Le Center, New Ulm and Rochester to showcase variety trials. Due to restrictions surrounding Covid 19, summer field days were cancelled. 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 81.8 bu/ac for HRWW and 74.2 bu/ac for HRSW. The Becker location suffered extreme drought in 2020, and averaged only 23.5 bu/ac for HRWW. Without Becker the state average yield for Plots were also used as sentinel plots to monitor disease and insect pests during the growing season (In conjunction with the Minnesota Small Grains Pest Survey).

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 23 and 17 entries, respectively. The spring wheat, oats, and barley variety trials had 38, 17, and 9 entries, respectively. 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 2020 on-farm trials, there was a 21 bu/ac difference between the highest-yielding 10% of varieties and the lowest-yielding 10% of varieties. This 21 bu/ac difference in yield could increase returns by over $115 per acre, or over $58,000 in gross returns for a 500 acre wheat enterprise. All while 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

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» 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 '2020 Minnesota Field Crop Trials' (Also available at https://www.maes.umn.edu/publications/field-crop-trials). The 2019 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, 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.

2. Smith, K., R. Dill-Macky, J.J. Wiersma, M. Smith, B. Steffenson, K. Beaubien, and E. Schiefelbein. 2019. 2019 Barley Field Crop Trials Results. In: 2019 Minnesota Field Crop Trials. Minnesota Agricultural Experiment Station Publication. University of Minnesota, St. Paul, MN.

3. Heuschele, J., R. Dill-Macky, D. von Ruckert, K. Beaubien, J.J Wiersma, and K. Smith. 2019. 2019 Oat Field Crop Trials Results. In: 2019 Minnesota Field Crop Trials. Minnesota Agricultural Experiment Station Publication. University of Minnesota, St. Paul, MN.

4. Wiersma, J.J. and J.A. Anderson. 2019. 2019 Winter Wheat Field Crop Trials Results. In: 2019 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. 2019. 2019 Winter Rye Field Crop Trials Results. In: 2019 Minnesota Field Crop Trials. Minnesota Agricultural Experiment Station Publication. University of Minnesota, St. Paul, MN.

Table 1 – Relative grain yield of Hard Red Spring Wheat varieties at three on-farm trial locations in southern Minnesota in single (2020), and multiple-year comparisons (2018-2020).

	Benson			Kimball[1]	LeCenter		
Entry	**2020**	**2 yr**	**3 yr**	**2 yr**	**2020**	**2 yr**	**3 yr**
	% of mean						
AP Murdock	95	102	-	-	101	110	-
Bolles	98	100	97	90	102	96	97
CP3055	120	-	-	-	99	-	-
CP3530	110	115	111	102	97	102	106
CP3903	99	-	-	-	90	-	-
CP3910	98	98	-	-	88	92	-
CP3915	90	99	-	-	106	104	-
Driver	98	-	-	-	108	-	-
Dyna-Gro Ambush	104	98	109	109	94	96	97
Dyna-Gro Ballistic	113	109	108	106	110	109	110
Dyna-Gro Commander	113	104	-	-	101	101	-
Dyna-Gro Velocity	90	93	-	-	80	84	-
Lang-MN	99	98	101	102	93	97	101
LCS Buster	106	-	-	-	115	-	-
LCS Cannon	94	91	91	114	103	102	98
LCS Rebel	98	99	97	94	107	105	106
LCS Trigger	126	123	119	98	121	121	119
Linkert	100	93	91	101	91	89	82
MN-Torgy	101	105	106	106	112	111	107
MN-Washburn	89	92	93	91	102	105	106
MS Barracuda	94	93	93	109	101	90	86
MS Chevelle	94	92	93	95	88	90	86
MS Ranchero	94	-	-	-	93	-	-
ND Frohberg	100	-	-	-	100	-	-
Prosper	105	104	107	102	116	117	121
Rollag	92	93	92	96	78	79	79
Shelly	109	104	106	98	99	95	97
SY 611 CL2	92	101	-	-	92	90	-
SY Ingmar	95	97	98	100	99	104	104
SY Longmire	90	96	-	-	110	104	-
SY McCloud	91	90	94	102	81	88	89
SY Valda	105	109	111	106	97	102	108
TCG-Heartland	100	100	-	-	94	90	-
TCG-Spitfire	106	115	112	101	126	124	120
TCG-Wildcat	96	-	-	-	106	-	-
WB-Mayville	99	95	92	99	103	100	91
WB9479	89	-	-	-	89	-	-
WB9590	99	-	-	-	102	-	-
Mean (Bu/Ac)	**85.1**	**91.0**	**86.9**	**73.3**	**63.2**	**47.8**	**45.7**
LSD (0.10)	**17**	**11**	**8**	**11**	**13**	**15**	**13**

[1] 2020 Kimball (at the new UMN Becker site) was discarded due to drought. 2-yr data is 2018-2019

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» **Table 2** – Grain yield (% of mean) of Hard Red Winter Wheat varieties in southern Minnesota in 2020.

Entry	Becker	Lamberton	LeCenter	St. Paul	State
	--------------------------- % of mean ---------------------------				
AAC Goldrush	92	94	89	81	97
AC Emerson	83	90	81	79	93
Bobcat	98	89	77	62	97
Flathead	96	87	98	105	99
FourOSix	99	102	96	103	100
Freeman	89	94	100	114	97
Ideal	105	114	110	99	102
Jerry	92	109	89	89	98
Jupiter[1]	104	101	106	123	101
Keldin	107	112	104	109	103
ND Noreen	105	104	91	82	100
Northern	88	95	101	94	96
Oahe	108	100	99	93	102
Redfield	112	102	108	106	104
Ruth	96	91	108	107	99
SY Wolf	100	93	104	102	100
SY Wolverine	101	101	110	103	101
Thompson	103	106	101	104	101
WB1529	86	85	88	93	96
WB4462	107	104	106	108	102
WB4595	121	109	111	108	107
Whitetail[1]	96	110	112	125	100
Winner	112	110	112	110	104
Mean (Bu/Ac)	**23.5**	**80.1**	**108.7**	**115.7**	**81.8**
LSD (0.1)	**11**	**14**	**9**	**8**	**3**
[1] Soft White Winter Wheat					

Figure 1 – Map of Southern Wheat Tour winter workshop attendees by zip code across the 8 locations in southern Minnesota in January - February 2020.

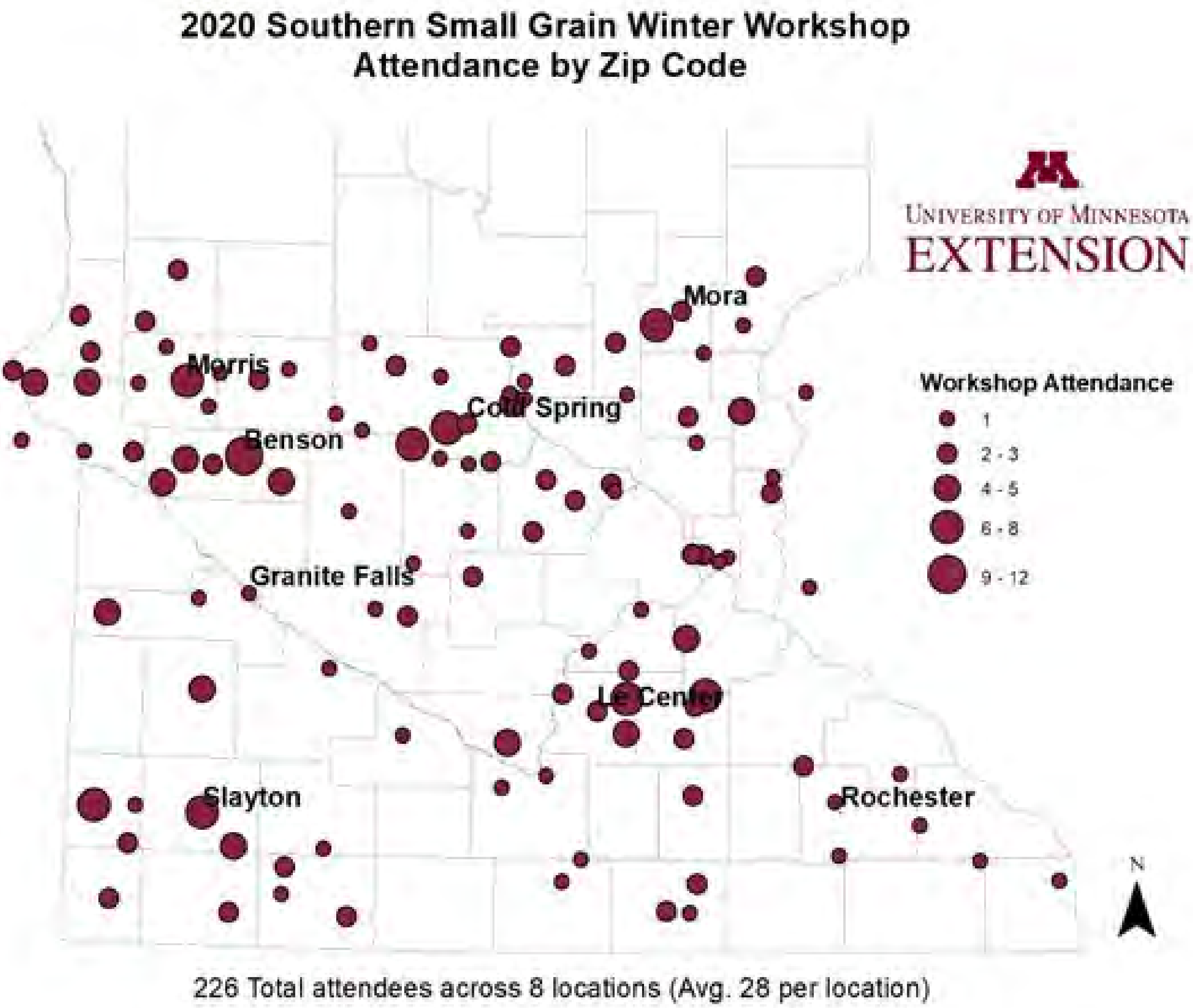

Figure 2 – Most common words included in responses when asked "What is the biggest challenge you face in growing small grains in Minnesota."

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 Question

Recently, many FHB and rust resistance genes were transferred from hard red spring wheat (HRSW) to the newly developed NDSU hard red winter wheat (HRWW) breeding program. Following their transfer, the newly acquired 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 therefore to: Quicken the dissipation of FHB resistance genes within the breeding population and integrate it with improved yield and cold tolerance plus resistance to other prevailing diseases such as leaf, stem and stripe rust, bacterial leaf streak (BLS), tan spot and Septoria nodorum blotch (SNB).

Results

A scheme of the crosses and inbreeding/selection steps aiming to combine multiple disease resistance with winter-hardiness and high yield is provided in Fig. 1. In January 2019, eight crosses were made and 150-200 F_2 seedlings per cross were selected (greenhouse) for seedling resistance to a mix of six leaf rust and four stem rust races. At maturity, the most resistant plants were selected based on height and fertility and the F_3 replanted (greenhouse) in March 2020 for further inbreeding and phenotypic selection. The F_3-derived F_4 was planted in a field trial at Casselton in September, 2020. One hundred families were planted in a checkplot (un-replicated) trial with 2X 2m row plots. Additional single 2m rows were planted of 67 families with insufficient seed. In 2021, the various families will be evaluated in the field for winter-survival, plant height, agrotype, and disease resistance. Following identification of the superior families, 15-20 single spikes will be selected from each chosen family and harvested separately. One to several seeds from each selected spike will then be replanted (greenhouse) for marker screening of targeted resistance genes (Fig. 1). Plants with superior resistance gene pyramids will be chosen and increased for field planting in the fall of 2021.

In North Dakota in recent years, occurrences of stripe rust have become more frequent even though the disease is still fairly uncommon (Friskop, 2015), suggesting that it may become necessary to breed resistant varieties in the future. Resistance breeding has not been done in past years, and it was not expected that many, if any, effective stripe rust resistance QTL would occur in the NDSU hard red winter wheat (HRWW) breeding material. A logical first step was to survey and assess the available genetic variability. If useful resistance is already available, it might be possible to derive markers for such resistance genes that would facilitate its selection and pyramiding.

Annually since 2016, new NDSU HRWW breeding lines are submitted for stripe rust resistance screening in replicated field trials conducted at Central Ferry and Pullman, Washington (care of Dr Kimberly Campbell, USDA-ARS at Washington State University). In 2018 and 2019, respectively, two different sets of 162 and 270 NDSU inbred lines were evaluated for infection type, disease severity, and disease index. The phenotyping results revealed very little resistance to the leading stripe rust race, PSTv-37. Only 8.7% of the lines tested in 2018 had the resistant infection type, and 23% of lines had disease severities less than 40%. In 2019, 7.9% of the lines had the resistant infection type, and 58% of lines were partially resistant based on severity. Genotyping by sequencing was performed by Dr. Xuehui Li's laboratory at North Dakota State University on samples of both sets of lines. In an attempt to identify molecular markers that correlate with resistance in the two winter wheat populations, a genome wide association study (GWAS) was done. The analyses failed to identify stripe rust resistance genes that provide significant resistance to stripe rust race PSTv-37 in the NDSU winter wheat breeding germplasm. Previous marker screening has shown that the race-nonspecific, resistance genes *Yr29* and *Yr18* do occur in NDSU hard red winter wheat germplasm and would provide a low level of resistance to stripe rust race PSTv-37 (Cobo, 2019; Wu, 2015). The race-specific resistance gene *Yr17* also occurs in the germplasm but is not effective against stripe rust race PSTv-37 (Wan et al., 2016). Possible reasons why *Yr29* and *Yr18* were not identified in this study could be that their individual contributions to stripe rust resistance was not big enough to be identified by GWAS, or the frequency at which the two QTL occur in the germplasm is too low. The ability of GWAS to detect minor stripe rust resistance QTL in the NDSU winter wheat germplasm can be improved through more comprehensive phenotyping employing multiple years and multiple races of stripe rust. However, lack of resources and facilities does not make this possible, especially because the disease still shows very sporadic incidence and regular, annual field evaluations within North Dakota are currently not possible. Clearly, it will be necessary to introgress additional resistance genes. If stripe rust infections become more common in North Dakota it is likely that it will be race PSTv-37 or PSTv-52 as these races have already shown the ability to survive and infect wheat in North Dakota. Race specific stripe rust genes that are currently effective against PSTv-37 include *Yr5* and *Yr15* among others and sources with the genes have been included among the 2021 cross parents. Additional new resistance that will be employed, include a B1F5 line 17YR251-4-1 (10X028-0-0-34-103L/2*Jerry) produced by Dr. Campbell. Another four selections from the NDSU 2020 inbred lines showed strong stripe rust resistance in Washington and were therefore included as additional parents.

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 smaller, 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 help 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). The cross number of each cross and parents involved are as follow: 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) and 19K132 (4 X 8). 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 could be useful in 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

Acquire and establish additional FHB resistance genes such as *Fhb6, Qfhb.rwg-5A.1,* and *Qfhb.rwg-5A.2* from HRSW that could supplement the currently employed *Fhb1* and *Qfhs.ifa-5A* resistance in the breeding program.

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

Parent	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*

[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: Select single F_5 plants from within the best yielding F_3-derived F_5 families.
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.

The Role of Water in Fertilizer Loss in Northwest Minnesota
Wheat Production Systems

Lindsay Pease, Dept. of Soil, Water & Climate, U of M, Crookston

Research Question

High-quality wheat production relies on strategic application of fertilizers and good luck with the weather. Fertilizer is a major expense in crop production, so any unintentional losses following heavy rainfall events can add up to a significant expense across all acres. In light of the wet weather during planting and harvest in recent years, this work aims to evaluate the role of water in off-site fertilizer movement for wheat-based rotations in Northwest Minnesota.

Results

Water samples were collected from the Northwest Research & Outreach Center and four satellite locations between May and October 2020. Water quality samples are still being analyzed, so all results are preliminary. At the Northwest Research & Outreach Center, soybeans were grown in 2020 following subsurface drainage installation. No fertilizer was applied following wheat harvest in September 2019. Preliminary findings from the NWROC show TN concentrations increasing between May and July, along with temperatures and rainfall amounts. TN concentrations were significantly higher in tile discharge when compared to surface runoff. TP concentrations did not show any trends with climate conditions in the first three months of data collection. Surface runoff tended to have higher TP concentrations than tile drainage, but this trend was not statistically significant in our preliminary analysis.

Application and Use

In the short term, our goal for this work is to help growers make informed fertilizer applications based on soil moisture and weather conditions. We also hope it will improve our understanding of the potential impact of wheat production on the environment. In the long-term, collection of nitrogen loss data will help to strengthen the position of wheat growers in demonstrating proactive, voluntary efforts toward water quality improvement if faced with increased regulation in the future.

Materials and Methods

One fully-instrumented primary field site was established on a field managed for commercial production at the Northwest Research & Outreach Center in Crookston for intensive monitoring of nitrogen and phosphorus loss in surface runoff, soil moisture, and rainfall. Conduct directed grab sampling from subsurface and surface drainage discharge (when present) was conducted at four on-farm locations. These on-farm sites did not have intensive water monitoring, but improved broader interpretation of findings at primary site. Water samples were analyzed for Total Nitrogen (TN) and Total Phosphorus (TN). Statistical analysis on TN and TP data was conducted using multiple linear regression according to the procedures outlined in Pease et al. (2018) to identify interactions between rainfall, TN loss, and TP loss.

Economic Benefit to a Typical 500 Acre Wheat Enterprise

We are still a ways off from being able to extrapolate the economic effect of rainfall on fertilizer loss. However, the observed nitrogen losses from our monitored soybean field (which had no fertilizer applied) suggests that temperature and rainfall may have played a significant role in N fertilizer loss during the 2020 growing season.

Related Research

Lake Winnipeg Basin 4R Project – A collaborative, international effort between Minnesota, Manitoba, and North Dakota to improve understanding of agricultural management and water quality on a North-South gradient in the Lake Winnipeg Basin. Collaborating institutions include University of Minnesota, North Dakota State University, Minnesota Department of Agriculture, and University of Manitoba.

Minnesota Discovery Farms Project – On-farm water quality monitoring conducted throughout the state of Minnesota. Currently, this effort has limited locations in the Red River Basin region of Minnesota.

References

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

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Melissia Carlson, MN Wheat, On-Farm Research, Red Lake Falls

Research Question

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

During the 2020 growing season, protein maps were collected on fields near Thief River Falls, MN. In-season imagery of select fields with N-rich strips was collected at the targeted growth stages during the season. These fields were also soil-sampled by zone after harvest. These data will be analyzed and compared with previous year's data this winter and through 2021 growing season. Figure 1 shows an example of the protein variability observed within a single field.

Application and Use

Identifying the underlying factors affecting the spatial variability of protein within a field may help guide decisions related to managing yield, protein content, and N-use efficiency. In the future, we hope this research can be used to direct variable rate in-season N applications or other precision agricultural practices that might be developed to optimize both protein and yield in spring wheat.

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. 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. Spatially analysis of the relationships between these data will identify which factors are the most influential on protein content within a field, and determine 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.

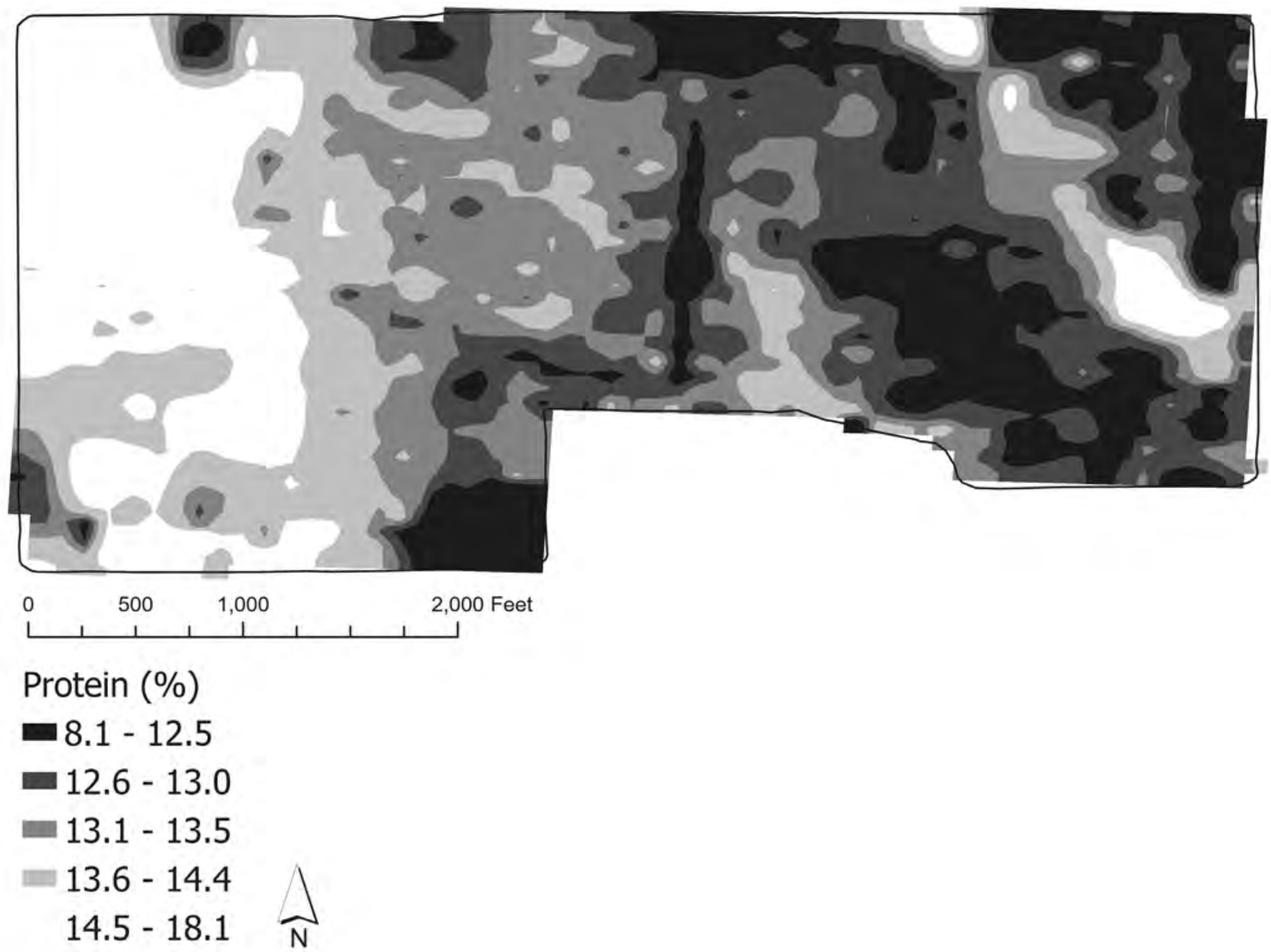

Figure 1. Protein variation across a field near Roseau, MN. A sand ridge resulted in lower yield and higher protein (white), and lower areas on the opposite side of the field were higher yielding with lower protein (black).

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

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Research Question

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

Results

A total of 269 samples from the 2019 F_5 (pre-yield trial) cohort, consisting of 203 F_5 lines, their 51 parents, and a set of 5 checks replicated 3 times, 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. Using regression equations already developed, the water absorption of the samples was calculated and presented in Figure 1. The calculated water absorption figures have been sorted from the highest to the lowest for easy use. The calculated water absorption ranged from 80% for Linkert-gpcB1/MN14105-7 to 41.8% for MN15396-2/MN10261-1. About 47% of the samples reported water absorption of less than 60% while 40% of the samples had water absorptions of between 60% to 70%. The remainder of the samples (about 20%) had water absorptions of over 70%. The water absorption of some of the samples above 70% are perceived to be too high, but that could be due to the model for prediction overestimating the water absorption for these samples. We are currently processing 2020 F5 cohort samples received in September 2020, but processing has been delayed due to the COVID-19 pandemic. In addition, samples from the 2020 New Zealand winter nursery, representing the 360 preliminary yield trial lines in 2020 could not be processed this year due to COVID restrictions.

Application and Use

This data, along with grain protein and test weight data from three 2020 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 360) will be advanced for Advanced yield trials in 2021. 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.

Materials and Methods

Grain from 269 2019 F_5 cohort samples harvested from St. Paul 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.

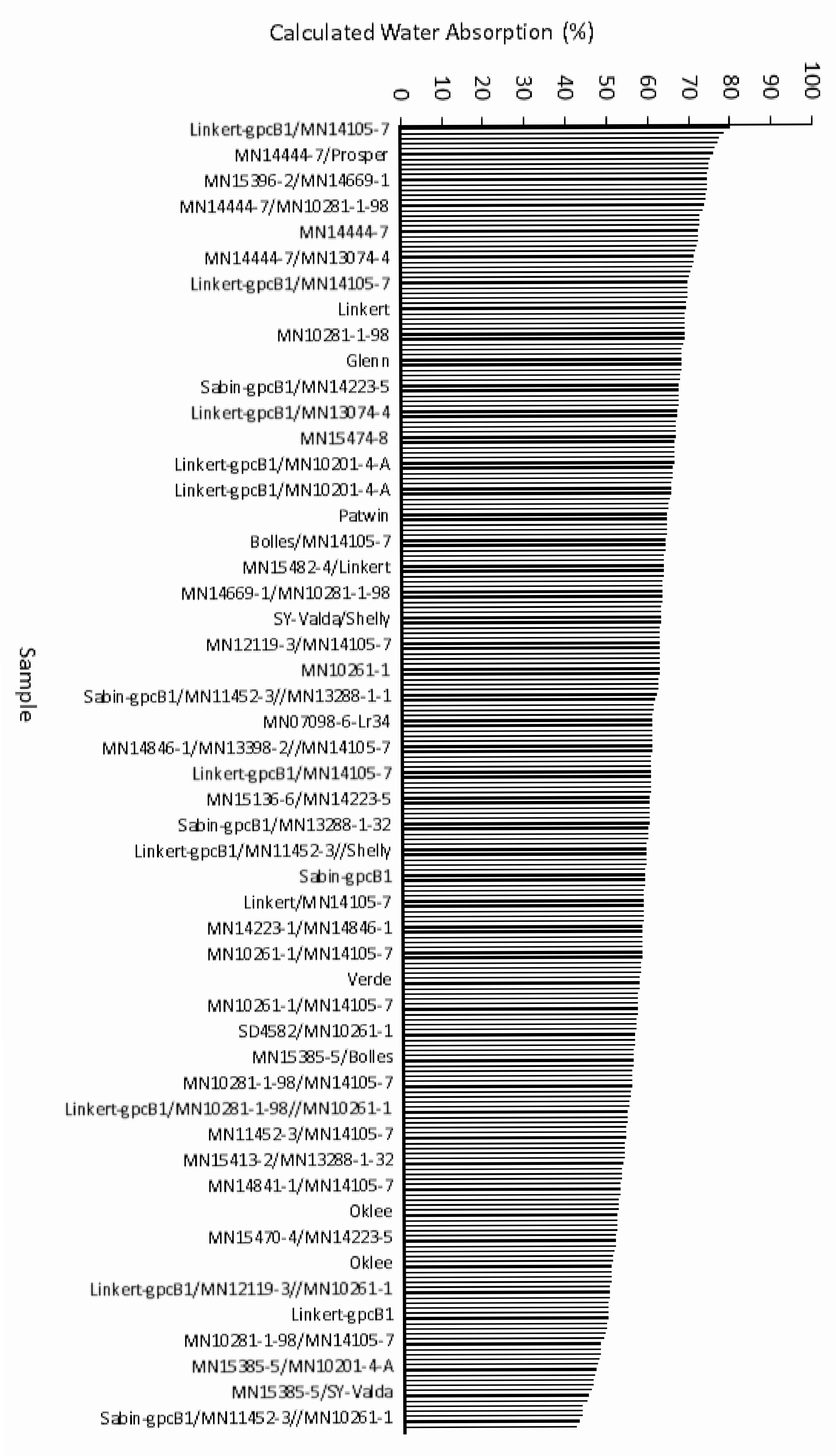

Figure 1. Calculated Water absorption of samples.

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

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

Research Question

In northwestern Minnesota, the period between small grain harvest in the fall and planting soybeans the following spring offers the best conditions for cover crop establishment. When considering the establishment of cover crops into this cropping system, the key research questions are: 1) what cover crops are the most effective to plant after wheat (or other small grains) if soybean is planted the following spring, and 2) if planting rye after wheat, when is the best time to terminate it, relative to when soybean is planted the following spring, in order to maximize the potential benefits of a green cover and minimize any yield drag that might be associated with it?

Results

We are still analyzing the results from 2020. 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 within a week or two of planting soybeans. At least at one location, soybean establishment was reduced when rye termination was delayed due to dry soil conditions at the time of planting. These results differed from those in 2019 probably due to the wetter spring conditions in 2019. Soybean yields were only obtained in one of the primary experiments in 2020.

Application and Use

The data collected to date suggest the following: 1- delaying the termination of rye until soybean planting (or after planting) in the spring greatly increases the accumulation of rye biomass and ground cover. With greater biomass there is greater potential for suppressing weeds, reducing excess soil moisture and reducing nitrate levels that might increase the likelihood of iron deficiency chlorosis in the developing soybean crop. In our research, however, we did not observe a reduction in IDC with a preceding rye cover crop. 2- Though a well-developed rye cover crop at the time of planting soybean may allow for earlier sowing in a wet year as the growing rye has the potential to lose soil moisture compared to a bare soil, in a "dry" spring, the reduction in soil moisture may be excessive and reduce soybean emergence and yield. We observed a yield drag in one experiments this year when soybean was planted into a "green" rye or winter wheat crop. This could be partly explained by reduced soybean emergence. 3- Cover crop biomass is a key indicator of how successful the cover crop will be in modifying the soil environment and providing a benefit to the cropping system. When the environment is not conducive to the establishment of cover crops as was the case in the fall of 2019, their benefit in the system is greatly reduced since they will produce little biomass prior to freeze up and their regrowth will be delayed the following spring.

Materials and Methods

We established the rye termination trials in fields of rye that had been planted the fall before, near Comstock, MN and Chaffee, ND. 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.

A second experiment was established in two locations in September 2019. 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 spring were measured. Cover crops were terminated just prior to planting soybeans in the spring of 2020. Data on cover and biomass in the fall; 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 were made. Check plots where no cover crops were planted were also included.

Economic Benefit to a Typical 500 Acre Wheat Enterprise

We have not yet identified a quantifiable benefit from any of the interventions that we tested. Some results suggest that a rye cover crop that is terminated late may produce a yield drag on soybeans in dry springs. This finding would suggest there is a need to carefully monitor spring weather conditions and alter rye termination timing based on early spring weather conditions in order to balance the benefits with the risks of this practice. Weed suppression by a rye cover crop may produce an economic benefit particularly if there are weed species that are resistant to commonly used herbicides.

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.

Figure 1. Effect of termination timing of rye on residue levels and soybean growth, Comstock, MN, 2020.

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

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Research Question

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; Monnens and Sadok 2020).

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 high-throughput phenotyping system (the GraPh platform, Tamang and Sadok, 2018) enabling ‘high-fidelity’ screening of whole-plant canopy conductance, we are in a unique position to achieve this challenging goal. Such an effort is nearly impossible to undertake in the field because of various confounding weather variables (such as time-of-day effects, rapid variation in windspeed, passage of clouds, changes in temperature, plant microclimate, etc.) that add substantial noise to the data and reduces the likelihood of detecting genetic loci. In the first three years of this research, we: 1) Adapted the GraPh platform to enable high-throughput phenotyping of wheat mapping populations, 2) Screened twice the parents of the Minnesota Nested Association Mapping Population (MNAMP), a highly diverse group of wheat lines consisting of RB07 and 25 other exotic lines, developed by Brian Steffenson, 3) Phenotyped three times families from the MNAMP whose parents exhibited the greatest contrast in canopy conductance from the recurrent parent RB07, 4) Identified several quantitative trait loci (QTL) controlling canopy conductance in those families and 5) Initiated an effort to confirm those QTL in a breeding population developed by wheat breeder Jim Anderson (145 recombinant inbred lines, or RILs, from a cross between MN-adapted parental lines MN99394-1-2 and MN99550-5- 2). Our goals this year were two-fold: i) phenotype a third and final time the RIL population to confirm the major QTL detected and ii) initiate an effort to confirm their effects in the field.

Results

Due to the outbreak of the COVID-19 pandemic, the third iteration of the high-throughput phenotyping effort was not possible this year. The mapping population was successfully planted and maintained for a period of time, but due to the need for multiple researchers to operate the plants and the phenotyping system at the same time, safety regulations prevented this effort. However, this turned out to be a minor setback since data analysis of the last 2 phenotyping efforts indicate that the data are quite consistent across the two runs, which makes the lack of this 3rd iteration much less problematic. Therefore, we were able to conduct a joint QTL analysis of data collected over all years, leading to the identification of a finalized list of robust, large-effect QTLs.

Based on the list of QTL confirmed, we selected 44 genotypes from the mapping populations harboring contrasting alleles for the large-effect QTL detected for field-based validation. The goal was to see if genotypes containing the favorable QTL alleles perform as would be predicted under field conditions. In addition, we took the additional precaution to use genotypes that were not part of the populations that were previously phenotyped, which greatly minimizes the risk of obtaining artefactual results. The selected genotypes were grown in the field on the St. Paul campus of the University of Minnesota in single row plots. This location was chosen since it will facilitate the screening of a relatively large number of genotypes and resolve equipment logistical issues (see below) while allowing for implementation of the strict COVID-mandated physical distancing rules. In this field experiment, we used a relatively low-throughput platform (compared to GraPh), but with highly advanced technology for measuring canopy conductance consisting of three portable gas exchange systems (LiCor LI-6800) that were recently acquired by the Sadok lab. While the results are currently being analyzed, the preliminary analyses indicate that contrasting alleles at these QTL confer differences in canopy conductance under field conditions, consistent with our hypothesis. This key validation step means that the identified QTL controlling canopy conductance alter plant behavior in the field in ways that are predicted by theory and the wheat breeding program can start to integrate these loci in elite breeding germplasm to validate their effect on grain yield. Overall, this strategy, developed through the support of the MWR&PC has attracted global, international attention as attested by peer-reviewed publications and invitations to present research findings as well as talks in international conferences (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 developed, we have an opportunity to breed for next-generation, MN-adapted wheat, containing genes to yield potential by enhancing canopy conductance.

Materials and Methods

For this research, the plants were grown under naturally fluctuating conditions in field plots at the Agricultural Experiment Station in the St. Paul campus of the University of Minnesota. Throughout the summer season, three portable gas exchange systems were deployed in the field on a total of 44 genotypes to measure transpiration rate, stomatal conductance, photosynthetic rate and leaf temperature. In parallel, environmental conditions (solar radiation, windspeed, precipitation, temperature, relative humidity and evaporative demand) were recorded by a local weather station and other canopy sensors, in order to enable normalization of the results and minimize 'environmental noise' in the dataset. Measurements were stopped right before the flag leaf started senescing since this process interferes strongly with gas exchange measurements.

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 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 2019; Schoppach et al. 2020; Monnens and Sadok 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 is being been leveraged as a proposal to be submitted to the Foundation for Food and Agriculture Research (FFAR).

Recommended Future Research

With this round, we have finalized our effort of identifying major genetic loci controlling canopy conductance in wheat. However, based on the field data assembled this summer, we have uncovered promising evidence enabling us to develop a drone-based approach to rapidly screen at much higher throughput (hundreds/thousands of lines) for traits related to canopy temperature, photosynthesis and overall canopy health. Developing this field-based phenomics pipeline would result in a valuable infrastructure to support the U of M breeding program to evaluate nurseries and advanced trials for various abiotic and biotic stresses that often negatively impact canopy health. Our goal for next year is to develop such a method based on field trials.

Publications

Peer-reviewed publication from this project in international scientific journals: [Support of MWR&PC acknowledged in the paper/oral presentation]

1.Monnens, D., and W. Sadok. 2020. Whole-plant hydraulics, water saving, and drought tolerance: a triptych for crop resilience in a drier world. Annual Plant Reviews Online (in press)

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» 2. 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)

3. Sadok, W. 2020. Combining eco-physiology, phenomics and crop modeling to enhance daytime and nighttime water-saving in cereal crops. Invited talk at the Interdrought VI Conference*, Mexico City, Mexico, March 12, 2020. [Talk delivered remotely]. *Organized every 4 years.

4. 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.

5. 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.

6. 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.

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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.

Minnesota Small Grains Pest Survey and Wheat Stem Sawfly Surveillance

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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) Evaluate current, adapted HRSW varieties for resistance to stem cutting by wheat stem sawfly.

Results

Pest and Disease Survey

The 2020 pest and disease survey was cancelled due to the Covid19 pandemic. The PI wrote eight weekly small grains related disease and pest updates during the months of June and July for Minnesota Crop News based on personal observation and correspondence with farmers and crop consultants throughout the region. The PI also updated Minnesota Association of Wheat Grower's disease risk forecasting tool and the National Scab Prediction Tool commentaries weekly during the months of June and July.

Wheat Stem Sawfly Surveillance

The 2020 wheat stem sawfly surveillance was also cancelled due to the Covid19 pandemic. Anecdotal evidence suggests that the WSS continues to spread from the heart of the Valley in all directions. There were, however, few reports of excessive lodging / stem clipping on field edges.

Wheat Stem Sawfly Screening Nursery

Emergence of WSS adults was monitored using five emergence cages in the WSS resistance screening nursery at the Northwest Research and Outreach Center in 2020. The emergence cages were placed on May 29th and monitoring started three days later. After the initial sampling date on June 1st, cages were sampled every Monday, Wednesday, and Friday throughout the month of June and the first two weeks of July (Figure 1). Emergence of the adult males had just started on the first sampling date. Emergence of female adults peaked approximately 21 days after the peak emergence of male adults. The greatest daily counts equated to more than 160,000 adults emerging per acre over a two day period and over 625,000 flies emerging per acre during the season. Emergence at this level means at least 20% of the stems in the field the previous cropping season were invested by WSS (assuming a stand of 1,250,000 wheat plants per acre, each with an average of 2.5 tillers per plants and no mortality of the WSS larvae over the winter due to tillage or physical factors).

Little to no stem clipping was observed in the dedicated WSS screening nursery. Preliminary results of the stem dissection indicate that, on average, nearly one third of the stems had evidence of wheat stem sawfly feeding and thus successful oviposition (Table 1). One third of the infested stems showed signs that the WSS larvae were parasitized. There was no correlation between the presence of WSS larvae in the stems and heading date, meaning that no varieties escaped WSS infestations. There were no statistically significant differences among the tested varieties for the percentage of WSS infested stems that had been parasitized. This means there does not appear to be an effect of heading date or other varietal characteristics that favor or hinder parasitism.

WB Gunnison was used as a check variety. The variety was developed by WestBred and released in Montana in 2011. WB-Gunnison is a hollow stemmed variety, but has high yields in Montana under wheat stem sawfly pressure due to relative non-preference in small plot nursery trials. SY Longmire is a 2019 release from AgriPro/Syngenta that expresses the stem solidness trait. The stem solidness trait of SY Longmire was only partially expressed this past season in this screening nursery as indicated by the stem solidness score (Table 1) (an average of 1 = semi-solid stem, and an average of 2 = solid stem).

Applications/Use

It is premature to conclude that WSS non-preference is present in the current HRSW varieties that are adapted to Minnesota and eastern North Dakota. SY Longmire expresses the stem solidness trait at least partially but the number of infested stems was not different than many other HRSW varieties in the trial.

Materials and Methods

A duplicate of the HRSW variety performance evaluation trial was seeded on May 15th, 2020 near Crookston, MN in a field that has been continuous wheat for the past three years. Wheat Stem Sawfly emergence was monitored in the trial 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 the WSS resistance screening nursery on the Northwest Research and Outreach Center in Crookston, MN.

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» The number of adult male or female WSS were counted every Monday, Wednesday and Friday for six weeks starting on June 3, 2020. 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 and before sample collection bottles were placed back in the emergence traps. The insects caught on the cheesecloth were separated and individual WSS were identified and counted.

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 percentage of WSS-infested stems that had an emergence hole or a parasitoid cocoon.

Economic Benefit to a Typical 500 Acre Wheat Enterprise

The expansion of the area where WSS is readily found in field edges continues to be a concern in the heart of the Red River Valley. The absence of any substantial stem clipping in the variety evaluation trial for a second year in a row is a cause for optimism. 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 screening of adapted HRSW varieties for resistance to WSS.

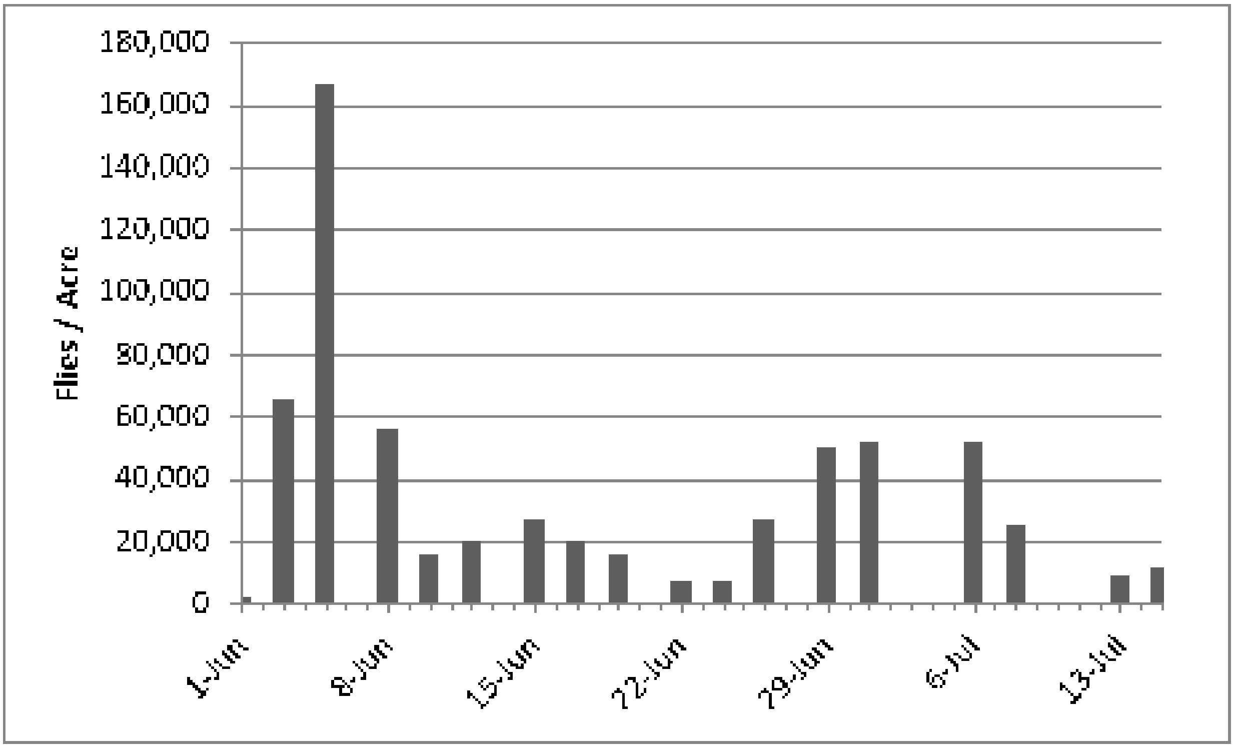

Figure 1 – The estimated number of adult wheat stem sawfly (Cephus cintus Norton) that emerged per acre in the WSS screening nursery at the Northwest Research and Outreach Center between June 1st and July 15th, 2020.

Table 1. Percentage of stems of HRSW varieties adapted to Minnesota that were infested by wheat stem sawfly (WSS) (Cephus cintus Norton) and the percentage of the WSS infested stems in which the WSS larvae had been parasitized in a dedicated screening nursery at the Northwest Research & Outreach Center near Crookston in 2020.

Variety	Level of Sawfly Infestation (%) (lower=better)	Sawfly Larvae Parsitized by Predators (%) (higher=better)	Stem Solidness Score First Node[1] (0=hollow, 2=solid)	Stem Solidness Score Second Node (0=hollow, 2=solid)
AP Murdock	33	21	0.03	0.05
Bolles	30	27	0.04	0.01
CP3055	19	25	0.17	0.14
CP3530	31	31	0.04	0.03
CP3903	29	28	0	0.07
CP3910	42	36	0.14	0.02
CP3915	38	28	0	0.01
Driver	28	35	0	0.04
Dyna-Gro Ambush	43	30	0.03	0.01
Dyna-Gro Ballistic	12	32	0.03	0.09
Dyna-Gro Commander	40	50	0	0.1
Dyna-Gro Velocity	23	25	0.11	0.02
Lang-MN	39	41	0.1	0.07
LCS Cannon	51	33	0.01	0.13
LCS Rebel	30	17	0.07	0.15
LCS Trigger	2	63	0.1	0.02
Linkert	41	23	0.07	0.03
MN-Torgy	24	27	0.1	0.03
MN-Washburn	41	26	0	0.01
MS Barracuda	54	22	0.07	0.17
MS Chevelle	21	39	0.16	0.03
MS Ranchero	20	33	0.3	0.02
ND Frohberg	28	16	0.01	0.04
Prosper	28	38	0.04	0
Shelly	26	35	0.03	0.13
SY 611 CL2	38	31	0	0.06
SY Ingmar	30	34	0.01	0.01
SY Longmire (solid stem)	34	21	0.63	0.37
SY McCloud	32	29	0	0.18
SY Valda	45	43	0.01	0.13
TCG-Heartland	33	21	0.03	0.1
TCG-Spitfire	22	32	0.13	0
TCG-Wildcat	25	37	0.01	0.06
WB9479	30	27	0	0.02
WB9590	28	37	0.03	0.01
WB-Gunnison (hollow stem)	23	33	0.06	0.26
WB-Mayville	42	29	0.07	0.1
Mean	**31**	**31**		
p-value	**0.02**	**NS**	**0.03**	**NS**
LSD(0.1)	**22**	**-**	**0.18**	**-**

[1] The average stem solidness of ten randomly selected stems at anthesis in which each stem was scores as having either a hollow stem (0), semi-solid stem (1), or solid stem (2)

Influence of Phosphorus and Potassium Applications in a Multi-Year Spring Wheat-Soybean Crop Rotation

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Melissa Carlson, MN Wheat On-Farm Research Network

Research Objectives

Goal: To determine optimum levels of Phosphorus (P) and Potassium (K) in a high yield, long term sequence of spring wheat and soybeans in northwest Minnesota.

1. Establish long term crop rotation trials (4 year minimum) in wheat and soybeans using a combination of small plot replicated research trials and on-farm research sites.

2. Conduct small plot replicated research to determine the influence of elevated levels of P and K on wheat and soybean growth, development and yield.

3. Partner with the MN Wheat On-Farm Research Network (OFRN) to evaluate enhanced P and K fertility utilizing large on-farm research trial methodologies to determine if current P and K recommendations provide adequate fertility in a high yield wheat-soybean crop rotation.

Materials and Methods

The objective of this research is to establish two small plot replicated research sites and five on-farm locations in 2019 and continue for four years. A complete analysis will be conducted on collected soil and tissue samples to determine potential nutrient interaction with elevated applied levels of P & K. For the small plot experiments, various treatments with 0-46-0 and 0-0-60 and will be applied broadcast and incorporated prior to seeding. Small plot treatments are outlined below in Table 4.

Five on-farm field locations were established near Elbow Lake, Roseau, and Baudette, MN, with replicated, field-length strips with four treatment replications at each site.

Treatments included:
- Treatment 1: Control – The producer’s current P + K fertility program
- Treatment 2: Elevated P + K - control rate + an additional 50 units of P and K each

Results

The second year of this four year project was successfully completed. In 2020, there was one on-farm wheat site and 4 soybean sites harvested. The two small plot experiments on the Magnusson research station were successfully harvested, and the yield results are presented below in Table 1 and 2. For the large on-farm plots, the Baudette and Elbow Lake locations completed the second year of the study, while the three Roseau locations completed their first year this season. Large plot yield summaries are shown in Table 3.

Table 4. Small plot P and K fertility treatments.

P	P+K	P+K
• 0-46-0 @ 20 units;	0-0-60 @ 20 units;	0-46-0 + 0-0-60 @ 20 units of each
• 0-46-0 @ 40 units;	0-0-60 @ 40 units;	0-46-0 + 0-0-60 @ 40 units of each
• 0-46-0 @ 60 units;	0-0-60 @ 60 units;	0-46-0 + 0-0-60 @ 60 units of each
• 0-46-0 @ 80 units;	0-0-60 @ 80 units;	0-46-0 + 0-0-60 @ 80 units of each
• 0-46-0 @ 100 units;	0-0-60 @ 100 units;	0-46-0 + 0-0-60 @ 100 units of each
• Untreated control		

Table 1. Wheat response 'Linkert' to various rates of phosphorus and potassium at the U of MN Magnusson Research Farm in 2020.

	Treatment¹ P & K	Yield² Bu/Acre	Test Wt./Bu	Protein³
1	0-20-0	73	63.0	14.7
2	0-40-0	75.8	62.3	14.6
3	0-60-0	72.8	62.3	14.5
4	0-80-0	69.8	62.7	14.3
5	0-100-0	67.8	62.7	14.0
6	0-0-20	70.5	62.1	14.4
7	0-0-40	69.3	62.9	14.6
8	0-0-60	69.5	63.1	14.5
9	0-0-80	70.3	62.4	14.9
10	0-0-100	71.3	63.1	14.5
11	0-20-20	70.5	63.0	14.5
12	0-40-40	74.8	62.1	14.2
13	0-60-60	73.3	61.7	14.4
14	0-80-80	76	62.8	14.6
15	0-100-100	74	62.6	14.4
16	0-0-0	67	62.6	14.7
LSD @5%level		7.4	1.3	0.7
LSD @10%level		6.2	1.1	0.5
CV(%)		7.2	1.5	3.2

¹ Pounds P and K applied/acre
² Yield corrected to 12% moisture
³ Dry matter basis
Linkert wheat seeded @ 120#/acre 5/21/2020
160-0-0 applied and incorporated to all plots

Wheat yields corrected 12% moisture ranged from 67 to 76 bu/ac. The lowest yield is the trial was 67 bu/ac from the untreated plots. At the 10% confidence level, the combination of P & K produced more grain yield than the single products alone, especially at 40, 60, 80 and 100 units of each produce. The P alone rates of 20, 40 and 60 produced more grain yield than 80 or 100 units. Wheat yield response was flat from potassium applied alone. Test weight ranged from 61.7 to 63.1 #/bu. Protein ranged from 14 to 14.9%. As a general statement with the single products as P level increased protein level decreased, but as K levels increased protein levels increased. However, with the combination of P & K protein level was relatively flat.

Table 2. Soybean response 'Asgrow AG005X8' to various rates of phosphorus and potassium at the U of MN Magnusson Research Farm in 2020.

P&K Treatment¹		Yield² Bu/Acre	Test Wt./ Bu	Protein³	Oil³
1	0-20-0	64.8	57.7	38.7	20.9
2	0-40-0	69.0	57.7	38.9	20.7
3	0-60-0	65.0	57.8	38.8	20.9
4	0-80-0	65.5	57.8	38.2	21.2
5	0-100-0	69.0	57.8	38.6	20.9
6	0-0-20	61.0	57.7	38.5	20.9
7	0-0-40	69.0	57.7	38.5	20.9
8	0-0-60	63.2	57.8	38.5	21
9	0-0-80	66.3	57.7	38.3	21.0
10	0-0-100	66.5	57.6	38.6	20.9
11	0-20-20	69.8	57.6	38.6	20.9
12	0-40-40	68.3	57.9	38.5	20.9
13	0-60-60	69.3	57.8	38.6	21.0
14	0-80-80	63.5	57.7	38.5	21.0
15	0-100-100	63.8	57.6	39.0	21.0
16	0-0-0	61.0	57.7	39.1	20.7
LSD @5%level		8.3	NS	0.4	0.4
LSD@10%level		6.5	0.3	0.4	0.3
CV(%)		7.8	0.4	0.8	1.3

¹ Pounds P and K applied/acre
² Yield corrected to 13% moisture
³ Dry matter basis
Asgrow AG005x8 soybeans seeded at 225,000#/ac on 5/21/2020

Soybean yields, corrected to 13% moisture, ranged from 61 to 69.8 bu/ac. The untreated plots gave an average yield of 61 bu/ac. Generally, with the single rate of P & K, soybean yields increased as fertilizer rate increased. However, with the combination of P & K, soybeans yields were better from 20, 40 and 60 compared to 80 or 100 units of each product. Test weight ranged from 57.6 to 57.9 3/bu. Protein ranged from 38.2 to 39.1%. The untreated plots averaged 39.1% which was the highest in the trial, but the yield of 61 bu/ac was the lowest. This relationship between protein and yield has been well documented in previous trials in wheat. Oil content ranged from 20.7 to 21.2%. The untreated plots averaged 20.7% oil which was the lowest in the trial. All fertility treatments tended to increase soybean oil content.

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» Application/Usee

With the recent increase in wheat yield trends and the potential to increase in soybean yield trends, the soil levels of P and K may be a limiting factor for plant growth, development and yield, however thus far we have seen a limited response to increa

Related Research

This project is a collaborative research effort funded jointly by the MN Wheat Research and Promotion Council, the MN Soybean Research and Promotion Council, and the MN Agricultural Fertilizer Research and Education Council.

Recommended Future Research

We plan to continue this project for an additional 2-3 years until each site completes four years of the experiment. Plot sizes were one or two passes of the fertilizer application equipment (70 or 140 feet) wide by the length of the field to accommodate the cooperator's production practices and equipment. Yield was measured by combing one pass through each plot and weighing the grain in a weigh wagon or calibrated grain cart.

Table 3. Preliminary yield results from three of the on-farm plot locations in 2020. Control treatments were fertilized at the producer's rate of P and K, while the Treatment plots added an additional 50 units each of P and K to the control rate.

Baudette Soybean	Treatment	Yield (bu/ac)	Protein (%)	Oil (%)	Moisture (%)	TW (lbs/bu)
	Control Treated	54.1 54.9	33.6 33.8	18.1 17.9	14.1 14.2	59.5 59.6
	Treatment Yield Gain CV (%)	NS 3.0%	NS 0.8%	NS 0.9%	NS 0.8%	NS 0.4%
Roseau Soybean	Treatment	Yield (bu/ac)	Protein (%)	Oil (%)	Moisture (%)	TW (lbs/bu)
	Control Treated	30.7 34.4				
	Treatment Yield Gain CV (%)	3.8 9.3%				
Elbow Lake Wheat	Treatment	Yield (bu/ac)	Protein (%)	Oil (%)	Moisture (%)	TW (lbs/bu)
	Control Treated	41.9 42.2		-- --		
	Treatment Yield Gain CV (%)	NS 10.7%				
	* Location had early season damage from misapplied chemical					
Soybean	Treatment	Yield (bu/ac)	Protein (%)	Oil (%)	Moisture (%)	TW (lbs/bu)
2 Locations	Control Treated	42.4 44.6				
	Treatment Yield Gain CV (%)	NS 26.6%				

NOTES

2020 Wheat, Barley, and Oats Variety Performance in Minnesota

- Preliminary Report 24

Preface: Jochum Wiersma

As for the twenty-twenty season itself: itwill be remembered for lots of reasons, the small grains growing season not beingone of them. Everyone was hoping if not praying for a stellar 2020 growing season to make up for lost ground that was the 2019 growing season. As we near the end of October it is safe to say that, with a few exceptions here and there, for small grains it was just a mediocre year.

The absurdly wet fall of 2019 not only left crop standing in the field it also meant that little fall tillage was completed and even less fertilizer was applied. Those two factors alone meant that small grains planting was delayed even after conditions turned favorable. This delay was illustrated by the planting progress of sugar beets versus spring wheat; a third of the sugarbeet acres versus a mere six percent of the spring wheat acres were seeded in the last week of April as milder and drier weather allowed field work to start in earnest across Minnesota. That same week nearly half of the state's corn acres were seeded too. Dry but cooler conditions halted planting progress in NW Minnesota as producers had to wait for last fall's soggy mess to further dry out. By May 9th, 40% of the spring wheat acreage had been seeded, which was slightly ahead of last year's pace but more than 25% behind the 5-year average. By May 23th, we passed the 90% completion rate.

The month of May finished with above normal temperatures and this trend continued for much of the growing season. With only 17% of the spring wheat crop jointed by May 31st, the crop as a whole was some 10 days behind the 5-year average. This gap narrowed to just 4 days by mid-June and by the 28th of June the spring wheat's crop development had surpassed the 5-year average. All this did not bode well for the yield potential of the crop. Whilst a swath on either side of the diagonal from Lake Traverse on the South Dakota border to Duluth suffered drought stress, parts on either side of this swath saw torrential rains and thunderstorms in rapid succession. By the end of July the northern end of the Red River Valley and adjacent area to the east had received one and half to two times their normal rainfall for the growing season. With the rains also came higher dew points.

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. The decision to apply a fungicide to suppress FHB was not a question of 'if' but a question of 'when'. It was not hard to find FHB in the yield trials across Minnesota. The field severities were nowhere near disastrous but high enough in some of the more susceptible varieties that you would be faced with discounts upon delivery of the grain to the elevator because the DON content would have exceeded the 2 ppm limit. Severities in the commercial fields I scouted and some of the comments I received from crop consultants indicated that FHB severities were generally low and even a bit lower compared to 2019. Data from US Wheat Associates' US Hard Red Spring Wheat Regional Quality Report bears that out as the average DON content dropped from 0.7 ppm in 2019 to 0.2 ppm in 2020. This is a testament to the efficacy of the fungicides and the importance of selecting varieties with better ratings for FHB. 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.

USDA-NASS' initial spring wheat yield forecast on July 1st was 57 bu/acre for Minnesota. This was 5 bushels lower than their July 2019 forecast. And while USDA-NASS corrected their forecast upwards with 1 bu/acre one month later, I was more pessimistic and felt that 57 bu/acre was even a bit optimistic. In the September Small Grains Summary USDA-NASS reported Minnesota's average spring wheat yield as 53 bu/acre, more than 20% lower compared the record set in 2017 and 4 bushels lower than last year's state average.

The story was the same if not worse for barley as most of the acreage is in the northern Red River Valley. The state's average barley yield dropped to 47 bu/acre, a 40% decline from just two years ago. Oats fared much better; a few dry days in southern Minnesota allowed some of the oats to be seeded as early as April 1st. Planting progress stayed ahead of the 5-year average. Eventually USDA-NASS reported the state's average oat yield to be 66 bu/acre, up 4 and 9 bu/acre compared to 2019 and 2018, respectively. More widespread adoption of fungicides to control crown rust help partially explain this upward yield trend.

The quality of the spring wheat crop was less variable than last year. Problems with Hagberg Falling numbers were limited to a small area in the heart of the Red River Valley as the average HFN test score of 396 seconds is well above the market's minimum threshold and more in line with historical averages. The US Hard Red Spring Wheat Regional Quality Report also showed that Minnesota's crop had, on average, a slightly higher test weight but with a lower vitreous kernel count and 0.6 percentage points lower grain protein content, resulting in an overall grade of #1 Northern Spring (NS).

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 2020 Wheat, Barley, and Oat Variety Performance in Minnesota Preliminary Report 24 is presented under authority granted by the Hatch Act of 1887 to the Minnesota Agricultural Experiment Station to conduct performance trials on farm crops and interpret data for the public.

VARIETY CLASSIFICATIONS

Varieties are listed in the tables alphabetically. 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 2020 Directory', available through the Minnesota Crop Improvement Association office in St. Paul or online at http://www.mncia.org

INTERPRETATION OF THE DATA

The presented data are the preliminary variety trial information for single (2020) and multiple year (2018-2020) comparisons in Minnesota. The yields are reported as a percentage of the location mean, with the overall mean (bu/acre) listed below. Two-year and especially one-year data are less reliable and should be interpreted with caution. In contrast, averages across multiple environments, whether they are different years and/or locations, provide a more reliable estimate of mean performance and are more predictive of what you may expect from the variety the next growing season. The least significant difference or LSD is a statistical method to determine whether the observed yield difference between any two varieties is due to true, genetic differences between the varieties or due to experimental error. If the difference in yield between two varieties equals or exceeds the LSD value, the higher yielding one was indeed superior in yield. If the difference is less, the yield difference may have been due to chance rather than genetic differences, and we are unable to differentiate the two varieties. The 10% unit indicates that, with 90% confidence, the observed difference is indeed a true difference in performance. Lowering this confidence level will allow more varieties to appear different from each other, but also increases the chances that false conclusions are drawn.

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SPRING WHEAT

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

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» Linkert maintained its first place rank at just over a fifth of the acreage. SY Valda maintained its second place rank while WB 9479 and WB 9590 moved up to third and fourth place, and Shelly was fifth. The endurance of Linkert and the rapid ascend of WB 9479 and WB 9590 are indicative of the weight producers place on straw strength when choosing varieties.

First-time entrants in the 2020 trials were AP Murdock (was also tested in 2019 under its experimental designation), CP3055, CP3903, Driver, LCS Buster, MS Ranchero, TCG-Wildcat, and ND Frohberg. Testing of Boost, CP3888, CP3939, Dyna-Gro Caliber, LCS Breakaway, MS Camaro, ND-VitPro, Surpass, and TCG-Climax was discontinued. WestBred continues to not test any HRSW varieties in the University of Minnesota variety trial system. WB Mayville, WB 9479, WB 9590, however, were included in the testing in 2020 as they occupied more than 5% of the acreage in 2019.

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 66 bu/acre in 2020. This average compares to a southern average of 63 bu/acre in 2019 and a three-year average of 65 bu/acre. The eight northern locations averaged 75 bu/acre in 2020 compared to 77 bu/acre last year and 80 bu/acre for the three-year average. LCS Trigger, LCS Buster, and LCS Cannon together with AP Murdock, Dyna-Gro Ballistic, and SY Valda are among the highest yielding varieties in single and multi-year comparisons in both the north and southern portions of the state. 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 results in lower grain yield potential. Linkert continues to be rated superior for straw strength, whilst Rollag and MS-Washburn are the only two other public releases that have a lodging rating of 3. Private releases that have a lodging rating of 3 include CP3910, Dyna-Gro Velocity, MS Barracuda, all entries in the variety trials of both 21st Century Genetics (TCG) and WestBred.

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. CP3915, Dyna-Gro Ballistic, Lang-MN, LCS Rebel, LCS Trigger, MN-Torgy, MN-Washburn, ND Frohberg, SY Ingmar, SY Valda, and TCG-Spitfire provide the best resistance against BLS.

LCS Trigger, Lang-MN, 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 single and mutiple year comparisons.

The average yield across the twelve testing locations was 95 bu/acre in 2020. In 2020, the Crookston location was lost due to excessive precipitation late in the season. The highest yields this year were recorded in Oklee (123 bu/A) while the lowest grain yields were recorded in Strathcona (54 bu/A).

We have been testing fewer six-row varieties as the malting and brewing industries increasingly favor two-row varieties. Last year we did not test Rasmusson and Quest so only 2020 data is presented. Rasmusson and AACSynergy were the highest yielding varieties based on the 2020 state average (Table 10). The six-row varieties were more resistant to lodging while Conlon was the most prone to lodging. Grain protein content varied between 11.4% and 13.1%. 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 only obtained good data in 2020 which is not presented since it is only a single year of data. It is notable that Pinnacle is highly susceptible to net blotch. The varieties with the best resistance to Fusarium head blight, expressed as lower concentrations of vomitoxin or DON, are Quest and 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 good to oats and resulted in higher yield averages across the state. Trial locations included Becker, Lamberton, Le Center, Rochester, Morris and Waseca in southern Minnesota and Crookston, Fergus Falls, Roseau, and Stephen in northern Minnesota. The trails near Kimball were moved a little east to the University of Minnesota's Sand Plains Research Farm near Becker. In addition, entries were evaluated for disease resistance to crown rust, barley yellow dwarf virus (BYDV), and smut in dedicated, inoculated nurseries. Damage from wildlife caused yield trials near Morris to be abandoned, while extreme drought eliminated Becker.

The newest varieties available this year are Esker 2020 and Rushmore. Esker 2020 has improved crown rust resistance, a maturity similar to Deon, and moderate grain quality. Rushmore also has improved crown rust resistance, a maturity later than Deon, and has a white husk.

The results of the variety evaluations are summarized in Tables 13 to 17. The origin and agronomic characteristics of the tested oat varieties are listed in Table 13. Maturity, height, and test weight data are presented s statewide averages from 2018-2020 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.

Crown rust continues to be a major limiting factor to oat production in Minnesota that must be managed to achieve optimal yield. Buckthorn (Rhamnus cathartica L.), the alternate host of crown rust is widespread in Minnesota, allowing for a persistent and particularly aggressive pathogen population. Rust in all yield trials was managed through treatment with a propiconazole-based fungicide when the flag leaf was fully extended (Feekes 9) to evaluate the yield potential with little to no disease. Crown rust and other disease resistance ratings are listed in Table 14. All disease scores were converted to a 1-9 scale. Where a score of 1 is very resistant and a score of 9 is very susceptible. Crown rust resistance was evaluated in the Buckthorn Nursery in St. Paul managed by the USDA-ARS Cereal Disease Laboratory. The most economical way of controlling crown rust is through resistant varieties; 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 and Sumo continue to be the best varieties for crown rust resistance.

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 (rating > 3) should be selected with caution particularly in the southern Minnesota, where aphids are more common early in the season. A seed treatment and certified seed should be used to manage smut.

Choose the varieties with the lowest disease ratings in an organic production system and plant as early as possible to reduce the risk of yield losses caused by BYDV or crown rust.

For grain production, lodging and grain quality traits should be considered when choosing a variety (Table 13). Oat varieties with high protein and low oil are preferred in the food market. High test weight, as a proxy for milling yield, is very important in both the food and feed markets. Contactyour local elevator or buyer and ask whether they prefer particular varieties.

Tables 15 through 17 present the relative grain yield of the tested varieties in single and multiple year comparisons. MN-Pearl continues to be the top yielding variety in statewide averages for 2020 and in multi-year comparisons. However, Rushmore and Hayden surpassed MN-Pearl in yield in a few locations this past season. Based on the yield data from this year, MN-Pearl, Hayden and Rushmore are recommend for both northern and southern regions of Minnesota. In general, earlier maturing varieties perform better in southern Minnesota because flowering can occur when it is cooler. In these locations, a variety maturing similar to Sumo or Saddle may be a good choice. In northern locations varieties that mature later such as Hayden or Deon may be prudent.

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Table 1. Origin and agronomic characteristics of hard red spring wheat varieties in Minnesota in single-year (2020) and multiple-year comparisons.

Entry	Origin[1]	Legal Status	Desired Stand (Plants/Acre)[2]	Days to Heading[3]	Height Inches[3]	Straw Strength[4]
Linkert	2013 MN	PVP (94)	1.3	57.1	26.4	2
CP3910	2019 CROPLAN by WinField United	PVP (94) (pending)	1.3	54.8	26.7	3
Dyna-Gro Velocity	2020 Dyna-Gro	PVP (94)	1.4	56.7	27.1	3
MN-Washburn	2019 MN	PVP (94) (pending)	1.3	59.0	27.2	3
MS Barracuda	2018 Meridian Seeds	PVP (94)	1.3	54.1	26.9	3
Rollag	2011 MN	PVP (94)	1.3	57.2	26.6	3
TCG-Heartland	2019 21st Century Genetics	PVP (94), Patend pending	1.5	55.8	26.4	3
TCG-Spitfire	2016 21st Century Genetics	PVP (94)	1.5	59.9	29.4	3
TCG-Wildcat	2020 21st Century Genetics	Patend pending	1.5	58.5	29.0	3
WB-Mayville	2011 WestBred	PVP (94)	1.3	56.0	25.5	3
WB9479	2017 WestBred	Patented, PVP(94)	1.3	56.1	25.3	3
Bolles	2015 MN	PVP (94)	1.3	59.5	30.0	4
CP3915	2019 CROPLAN by WinField United	PVP (94) (pending)	1.3	58.3	28.2	4
Driver	2020 SDSU	PVP (94) (pending)	1.3	58.2	29.9	4
Dyna-Gro Ambush	2016 Dyna-Gro	PVP (94)	1.4	55.5	28.3	4
Dyna-Gro Commander	2019 Dyna-Gro	PVP (94)	1.4	55.8	28.6	4
Lang-MN	2017 MN	PVP (94)	0.9	58.6	28.9	4
LCS Cannon	2018 Limagrain Cereal Seeds	PVP (94)	1.3	53.3	26.7	4
MN-Torgy	2020 MN	PVP (94) (pending)	1.3	57.6	27.8	4
SY 611 CL2[5]	2019 AgriPro/Syngenta	PVP (94) (pending)	1.3	57.3	26.4	4
SY Ingmar	2014 AgriPro/Syngenta	PVP (94)	1.3	58.5	27.9	4
SY Longmire[6]	2019 AgriPro/Syngenta	PVP (94) (pending)	1.3	58.0	28.1	4
SY McCloud	2019 AgriPro/Syngenta	PVP (94) (pending)	1.3	56.4	28.3	4
AP Murdock	2020 AgriPro/Syngenta	PVP (94) (pending)	1.3	56.5	26.5	5
CP3530	2015 CROPLAN by WinField United	Patented	1.3	58.9	31.4	5
Dyna-Gro Ballistic	2018 Dyna-Gro	PVP (94)	1.1	58.1	29.7	5
LCS Buster	2020 Limagrain Cereal Seeds	PVP (94) (pending)	1.3	61.2	30.1	5
LCS Trigger	2016 Limagrain Cereal Seeds	PVP (94)	1.3	61.2	30.5	5
MS Chevelle	2014 Meridian Seeds	PVP (94)	1.3	56.1	27.0	5
Shelly	2016 MN	PVP (94)	1.3	58.5	26.3	5
SY Valda	2015 AgriPro/Syngenta	PVP (94)	1.3	57.6	27.5	5
LCS Rebel	2017 Limagrain Cereal Seeds	PVP (94)	1.3	55.8	30.6	6
Prosper	2011 NDSU	PVP (94)	1.3	58.4	29.9	6
CP3055	2020 CROPLAN by WinField United	PVP (94) (pending)	1.3	62.9	30.1	3–4
CP3903	2019 CROPLAN by WinField United	PVP (94) (pending)	1.3	56.0	28.3	4–5
MS Ranchero	2020 Meridian Seeds	PVP (94) (pending)	1.3	56.7	28.9	4–5
ND Frohberg	2020 NDSU	PVP (94) (pending)	1.3	58.6	29.7	4–5
WB9590	2017 WestBred	Patented, PVP(94)	1.3	55.7	25.3	3
Mean				57.5	28.1	

[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

[3] 2020 data

[4] 1-9 scale in which 1 is the strongest straw and 9 is the weakest. Based on 2014-2020 data. The rating of newer entries may change by as much as one rating point as more data are collected.

[5] SY 611 CL2 has tolerance to Beyond® herbicide.

[6] SY Longmire has solid stems.

Table 2. Grain quality of hard red spring wheat varieties in Minnesota in single-year (2020) and multiple-year comparisons.

	Test Weight (Lb/Bu)		Protein (%)[1]		Baking	Pre-Harvest
Entry	2020	2 yr	2020	2 yr	Quality[2]	Sprouting[3]
AP Murdock	59.7	59.9	14.7	14.2	–	1
Bolles	58.9	59.2	16.7	16.1	1	1
CP3055	55.1	–	13.1	–	–	2–3
CP3530	59.5	59.8	15.2	14.5	3	1
CP3903	60.2	–	15.2	–	–	2–3
CP3910	60.7	60.5	14.9	14.4	–	2*
CP3915	60.5	60.3	14.9	14.4	–	1
Driver	60.5	–	14.7	–	–	2–3
Dyna-Gro Ambush	61.4	61.4	15.2	14.8	2	3*
Dyna-Gro Ballistic	59.3	59.3	14.1	13.9	5	3*
Dyna-Gro Commander	59.9	60.1	15.0	14.6	–	1
Dyna-Gro Velocity	60.7	60.9	15.9	15.2	–	2
Lang-MN	60.3	60.8	15.3	14.9	3	1
LCS Buster	57.3	–	12.7	–	–	5
LCS Cannon	60.8	61.2	14.6	14.1	4	3*
LCS Rebel	61.2	61.2	15.2	14.8	3	5
LCS Trigger	60.0	60.0	12.8	12.3	7	2
Linkert	60.3	60.4	15.7	15.3	1	1
MN-Torgy	60.0	60.3	15.2	14.7	4	1
MN-Washburn	59.7	59.9	14.7	14.2	3	1
MS Barracuda	60.0	60.2	15.3	14.9	4	3
MS Chevelle	59.5	59.5	14.2	13.7	5	4
MS Ranchero	58.4	–	14.7	–	–	4
ND Frohberg	60.4	–	15.1	–	–	4
Prosper	59.5	59.8	14.3	13.7	5	1
Rollag	60.3	60.5	15.7	15.3	6	1
Shelly	59.5	59.5	14.3	13.9	5	1
SY 611 CL2	60.4	60.7	15.2	14.7	–	2*
SY Ingmar	60.0	60.1	15.5	15.1	2	2
SY Longmire	59.5	59.4	15.3	14.8	–	2*
SY McCloud	60.9	61.2	15.6	15.1	3	2*
SY Valda	60.2	60.2	14.7	14.1	6	2
TCG-Heartland	61.0	60.9	15.8	15.3	–	2
TCG-Spitfire	59.9	59.0	14.2	13.8	2	3*
TCG-Wildcat	60.6	–	15.4	–	–	1
WB-Mayville	60.2	60.3	15.7	15.2	2	3*
WB9479	60.4	–	16.0	–	–	2
WB9590	59.9	–	15.5	–	–	2
Mean	59.9	60.2	14.9	14.5		
No. Environments	10	21	10	22		

[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 nine 2019 locations. Varieties with an * following their pre-harvest sprouting rating had lower than expected falling numbers based on their PHS rating.

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

Entry	Leaf Rust	Stripe Rust[2]	Stem Rust[3]	Bacterial Leaf Streak[4]	Other Leaf Diseases[5]	Scab[6]
AP Murdock	3	–	1	4	6	7
Bolles	2	1	2	4	3	4
CP3055	2	–	2	4	4	5–6
CP3530	3	3	1	4	4	4
CP3903	3	–	1	2–3	4	4–5
CP3910	3	–	1	6	5	6
CP3915	1	–	1	2	5	4–5
Driver	3	–	1	3–4	5	3–4
Dyna-Gro Ambush	2	–	2	5	4	4
Dyna-Gro Ballistic	3	–	3	3	5	4–5
Dyna-Gro Commander	2	–	1	4	6	5
Dyna-Gro Velocity	3	–	1	6	7	6
Lang-MN	1	–	2	3	4	3
LCS Buster	2	–	1	4	3	4
LCS Cannon	3	–	2	5	7	5
LCS Rebel	6	–	2	3	4	4
LCS Trigger	1	–	2	2	3	3
Linkert	3	1	1	5	4	5
MN-Torgy	3	–	1	3	3	4
MN-Washburn	1	2	1	3	3	4
MS Barracuda	6	–	2	7	5	5
MS Chevelle	3	1	1	6	6	5
MS Ranchero	1	–	1	6–7	3	3–5
ND Frohberg	3	–	1	3	4	3–4
Prosper	6	5	2	4	4	4
Rollag	4	1	2	7	6	3
Shelly	3	1	2	6	4	4
SY 611 CL2	3	–	5	4	4	4
SY Ingmar	2	2	2	3	5	4
SY Longmire	5	–	1	3	5	7
SY McCloud	3	–	1	5	5	5
SY Valda	1	2	1	3	4	4
TCG-Heartland	3	–	2	5	5	7
TCG-Spitfire	4	–	2	3	4	5
TCG-Wildcat	3	–	3	6–7	7	6–8
WB-Mayville	3	3	3	7	7	8
WB9479	6	–	2	6	5	7
WB9590	6	–	2	6	6	7

[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 entries may change as more data is collected.

[5] Combined rating of tan spot and septoria.

[6] Varieties showing a ratings range are based on initial data. With further testing, a single numerical rating will be assigned

NOTES

Table 4. Relative grain yield of hard red spring wheat varieties in northern Minnesot

Entry	Crookston 2020	Crookston 2 Yr	Crookston 3 Yr	Fergus Falls 2020	Fergus Falls 2 Yr	Fergus Falls 3 Yr	Hallock 2020	Hallock 2 Yr
AP Murdock	107	108	–	96	99	–	99	106
Bolles	94	98	97	90	91	91	94	96
CP3055	95	–	–	112	–	–	110	–
CP3530	92	96	96	95	99	100	112	106
CP3903	93	–	–	97	–	–	108	–
CP3910	98	103	–	97	99	–	103	106
CP3915	103	104	–	99	103	–	90	95
Driver	99	–	–	104	–	–	115	–
Dyna-Gro Ambush	105	104	100	98	100	99	104	101
Dyna-Gro Ballistic	107	108	105	105	109	111	102	106
Dyna-Gro Commander	94	97	–	100	101	–	102	104
Dyna-Gro Velocity	93	92	–	96	95	–	95	96
Lang-MN	99	98	99	99	98	99	102	98
LCS Buster	103	–	–	114	–	–	111	–
LCS Cannon	98	100	100	96	100	101	89	98
LCS Rebel	97	101	101	101	97	97	106	102
LCS Trigger	114	116	114	118	115	113	127	118
Linkert	92	92	92	93	92	92	95	97
MN-Torgy	106	101	104	105	105	104	93	100
MN-Washburn	98	99	99	98	101	102	97	99
MS Barracuda	94	97	98	95	94	96	94	95
MS Chevelle	95	101	102	97	100	100	115	109
MS Ranchero	101	–	–	93	–	–	108	–
ND Frohberg	93	–	–	103	–	–	87	–
Prosper	109	109	106	108	109	108	105	103
Rollag	77	87	85	89	91	89	91	97
Shelly	107	106	106	107	111	110	109	110
SY 611 CL2	102	102	–	102	103	–	90	99
SY Ingmar	95	95	97	106	100	100	89	92
SY Longmire	97	100	–	95	101	–	92	97
SY McCloud	91	92	95	99	97	99	103	98
SY Valda	103	104	107	103	99	101	107	109
TCG-Heartland	102	99	–	100	97	–	87	89
TCG-Spitfire	108	106	108	105	104	104	90	94
TCG-Wildcat	102	–	–	100	–	–	95	–
WB-Mayville	85	88	89	89	90	93	89	89
WB9479	110	–	–	96	–	–	103	–
WB9590	113	–	–	99	–	–	120	–
Mean (Bu/Acre)	70.1	74.7	71.4	83.7	83.4	88.8	66.8	76.3
LSD (0.10)	7.6	6.5	6.1	6.5	6.6	4.6	17.7	8.0

ta locations in single-year (2020) and multiple-year comparisons (2018-2020).

	Oklee			Perley			Roseau		
3 Yr	2020	2 Yr	3 Yr	2020	2 Yr	3 Yr	2020	2 Yr	3 Yr
–	111	110	–	110	112	–	107	108	–
93	90	91	91	100	95	93	94	91	93
–	115	–	–	78	–	–	107	–	–
103	100	98	98	104	106	106	94	98	98
–	90	–	–	108	–	–	92	–	–
–	92	101	–	106	104	–	83	98	–
–	87	95	–	95	95	–	117	114	–
–	106	–	–	111	–	–	98	–	–
101	103	104	106	107	96	96	92	90	94
106	104	109	107	107	104	106	118	114	113
–	99	100	–	91	104	–	98	104	–
–	89	88	–	90	88	–	99	100	–
98	95	98	96	96	98	97	102	100	103
–	126	–	–	120	–	–	122	–	–
101	102	104	104	113	115	111	92	99	100
101	91	96	98	109	108	109	110	108	105
111	116	119	115	125	119	119	118	118	117
97	92	93	92	90	88	90	90	89	91
101	106	105	102	94	97	103	102	105	102
98	97	101	98	97	100	104	73	85	92
97	100	103	103	82	93	92	87	93	97
110	97	98	101	98	94	98	114	110	108
–	102	–	–	100	–	–	110	–	–
–	98	–	–	93	–	–	92	–	–
105	109	108	109	101	96	102	107	104	107
96	94	93	92	92	95	93	84	82	84
107	104	105	105	94	96	96	90	102	103
–	109	106	–	99	95	–	105	102	–
96	102	100	100	96	102	99	104	102	99
–	91	98	–	95	85	–	90	92	–
98	101	98	98	97	96	93	97	97	97
111	100	103	107	108	102	104	96	109	107
–	92	93	–	114	110	–	95	92	–
96	103	104	104	106	109	107	100	107	105
–	96	–	–	100	–	–	109	–	–
92	89	91	94	107	109	105	80	90	91
–	104	–	–	83	–	–	91	–	–
–	104	–	–	109	–	–	105	–	–
83.5	81.0	72.5	80.6	67.4	67.7	70.1	88.3	86.9	87.4
6.6	12.0	9.7	6.1	18.6	12.3	9.0	18.7	14.0	9.9

Table 5. Relative grain yield of hard red spring wheat varieties in southern Minnesota locations in single-year (2020) and multiple-year comparisons (2018-2020).

	Benson			Kimball[1]	Lamberton			Le Center			Morris[2]		St. Paul			Waseca		
Entry	**2020**	**2 Yr**	**3 Yr**	**2 Yr**	**2020**	**2 Yr**	**3 Yr**	**2020**	**2 Yr**	**3 Yr**	**2020**	**2 Yr**	**2020**	**2 Yr**	**3 Yr**	**2020**	**2 Yr**	**3 Yr**
AP Murdock	95	102	–	–	110	114	–	101	110	–	103	103	109	112	–	115	123	–
Bolles	98	100	97	90	86	88	81	102	96	97	97	99	98	99	97	94	99	102
CP3055	120	–	–	–	96	–	–	99	–	–	127	–	82	–	–	81	–	–
CP3530	110	115	111	102	104	112	116	97	102	106	93	104	102	107	106	95	104	108
CP3903	99	–	–	–	91	–	–	90	–	–	87	–	99	–	–	92	–	–
CP3910	98	98	–	–	106	102	–	88	92	–	102	105	119	108	–	105	102	–
CP3915	90	99	–	–	97	96	–	106	104	–	101	97	85	90	–	87	84	–
Driver	98	–	–	–	96	–	–	108	–	–	103	–	102	–	–	107	–	–
Dyna-Gro Ambush	104	98	97	109	104	111	107	94	96	97	111	107	109	112	105	111	114	108
Dyna-Gro Ballistic	113	109	108	106	105	104	102	110	109	110	104	111	105	102	103	104	108	107
Dyna-Gro Commander	113	104	–	–	102	101	–	101	101	–	114	112	107	107	–	120	114	–
Dyna-Gro Velocity	90	93	–	–	94	99	–	80	84	–	82	88	97	91	–	92	94	–
Lang-MN	99	98	101	102	97	100	99	93	97	101	102	102	101	101	103	103	106	115
LCS Buster	106	–	–	–	108	–	–	115	–	–	115	–	102	–	–	120	–	–
LCS Cannon	94	91	91	114	112	111	111	103	102	98	116	106	120	115	114	114	114	111
LCS Rebel	98	99	97	94	102	100	96	107	105	106	93	97	106	98	97	114	110	104
LCS Trigger	126	123	119	98	110	114	115	121	121	119	133	118	104	104	107	128	117	121
Linkert	100	93	91	101	89	88	87	91	89	82	89	90	100	99	99	83	91	82
MN-Torgy	101	105	106	106	107	107	109	112	111	107	109	109	100	101	100	95	107	114
MN-Washburn	89	92	93	91	105	101	102	102	105	106	90	97	92	100	99	107	101	101
MS Barracuda	94	93	93	109	107	106	107	101	90	86	90	89	113	113	109	105	102	93
MS Chevelle	94	92	93	95	102	100	97	88	90	86	100	105	105	101	98	102	101	94
MS Ranchero	94	–	–	–	91	–	–	93	–	–	102	–	114	–	–	102	–	–
ND Frohberg	100	–	–	–	96	–	–	100	–	–	107	–	103	–	–	103	–	–
Prosper	105	104	107	102	108	106	103	116	117	121	101	110	106	101	104	99	95	103
Rollag	92	93	92	96	92	85	78	78	79	79	112	92	93	85	83	93	92	83
Shelly	109	104	106	98	108	104	106	99	95	97	113	108	99	104	104	95	102	102
SY 611 CL2	92	101	–	–	88	92	–	92	90	–	91	100	100	93	–	88	97	–
SY Ingmar	95	97	98	100	92	92	95	99	104	104	91	87	92	99	100	93	99	102
SY Longmire	90	96	–	–	94	92	–	110	104	–	91	91	88	88	–	75	71	–
SY McCloud	91	90	94	102	97	93	92	81	88	89	90	93	105	102	102	89	94	89
SY Valda	105	109	111	106	105	113	108	97	102	108	99	101	98	99	100	108	111	108
TCG-Heartland	100	100	–	–	96	93	–	94	90	–	84	91	100	104	–	103	101	–
TCG-Spitfire	106	115	112	101	101	106	110	126	124	120	129	118	98	101	102	92	95	98
TCG-Wildcat	96	–	–	–	105	–	–	106	–	–	98	–	102	–	–	100	–	–
WB-Mayville	99	95	92	99	93	92	94	103	100	91	92	99	109	108	106	97	103	94
WB9479	89	–	–	–	96	–	–	89	–	–	89	–	97	–	–	101	–	–
WB9590	99	–	–	–	109	–	–	102	–	–	95	–	108	–	–	105	–	–
Mean (Bu/Acre)	85.1	91.0	86.9	73.3	63.2	47.8	45.7	78.0	68.4	64.8	48.1	57.1	74.3	73.1	72.3	46.6	44.1	44.4
LSD (0.10)	16.7	11.1	8.2	11.6	13.4	14.9	12.5	12.8	9.2	9.7	16.8	15.3	8.0	11.5	8.6	12.8	14.3	20.5

Table 6. Relative grain yield of hard red spring wheat varieties in Minnesota in single-year (2020) and multiple-year comparisons (2018-2020).

	State			North			South		
Entry	**2020**	**2 Yr**	**3 Yr**	**2020**	**2 Yr**	**3 Yr**	**2020**	**2 Yr**	**3 Yr**
AP Murdock	107	109	–	109	108	–	105	110	–
Bolles	94	94	93	92	93	93	95	96	94
CP3055	102	–	–	102	–	–	101	–	–
CP3530	101	104	103	100	101	100	101	108	108
CP3903	94	–	–	95	–	–	94	–	–
CP3910	98	101	–	95	101	–	103	102	–
CP3915	96	99	–	97	101	–	94	95	–
Driver	103	–	–	104	–	–	101	–	–
Dyna-Gro Ambush	103	102	101	103	100	100	105	106	103
Dyna-Gro Ballistic	106	107	107	106	108	107	107	107	107
Dyna-Gro Commander	103	103	–	99	102	–	108	106	–
Dyna-Gro Velocity	91	92	–	91	92	–	90	92	–
Lang-MN	99	100	100	100	99	99	98	100	102
LCS Buster	113	–	–	116	–	–	110	–	–
LCS Cannon	102	104	104	98	102	103	109	106	105
LCS Rebel	102	101	100	102	102	101	103	101	98
LCS Trigger	118	116	114	118	117	114	119	115	113
Linkert	91	91	91	90	91	92	93	93	91
MN-Torgy	104	104	104	104	103	103	104	106	106
MN-Washburn	93	97	98	91	96	98	97	98	98
MS Barracuda	97	99	99	94	97	99	102	100	99
MS Chevelle	98	99	99	98	100	102	98	98	96
MS Ranchero	104	–	–	107	–	–	99	–	–
ND Frohberg	97	–	–	94	–	–	101	–	–
Prosper	106	105	106	106	105	106	106	104	106
Rollag	92	91	89	92	92	92	92	88	86
Shelly	103	104	104	102	105	105	104	103	104
SY 611 CL2	97	100	–	101	102	–	92	97	–
SY Ingmar	96	97	98	98	98	98	94	96	98
SY Longmire	91	93	–	91	95	–	92	90	–
SY McCloud	95	95	96	96	96	97	93	94	95
SY Valda	104	106	107	105	107	108	102	106	106
TCG-Heartland	98	97	–	98	96	–	97	97	–
TCG-Spitfire	104	105	105	101	103	103	108	109	108
TCG-Wildcat	102	–	–	103	–	–	101	–	–
WB-Mayville	93	95	95	89	92	93	99	99	96
WB9479	96	–	–	99	–	–	93	–	–
WB9590	105	–	–	106	–	–	103	–	–
Mean (Bu/Acre)	71.1	71.1	72.9	74.9	76.2	79.7	66.0	64.8	65.2
LSD (0.10)	4.9	3.2	2.5	6.5	3.9	2.9	7.2	5.1	4.3
No. Environments	14	29	43	8	16	23	6	13	20

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

	North						South						State					
	2020		2-year		3-year		2020		2-year		3-year		2020		2-year		3-year	
Entry	Conv	Int	Conv	Int	Conv	Int	Conv	Int	Conv	Int	Conv	Int	Conv	Int	Conv	Int	Conv	Int
AP Murdock	84.6	91.5	87.0	90.7	–	–	56.8	55.0	55.5	59.5	–	–	70.7	73.2	71.3	75.1	–	–
Bolles	74.4	72.9	75.8	74.8	75.4	74.2	55.0	56.2	51.0	54.8	49.1	52.1	64.7	64.6	63.4	64.8	63.4	64.1
CP3055	80.6	86.1	–	–	–	–	61.9	68.6	–	–	–	–	71.3	77.3	–	–	–	–
CP3530	73.8	85.8	78.6	88.2	77.2	86.0	53.3	56.7	54.0	58.8	52.7	56.6	63.5	71.3	66.3	73.5	66.1	72.6
CP3903	73.3	81.6	–	–	–	–	49.4	51.9	–	–	–	–	61.4	66.8	–	–	–	–
CP3910	71.0	79.7	81.0	85.8	–	–	52.1	52.1	51.9	52.6	–	–	61.6	65.9	66.4	69.2	–	–
CP3915	87.7	86.4	88.4	87.2	–	–	57.9	55.9	52.4	56.0	–	–	72.8	71.2	70.4	71.6	–	–
Driver	77.9	73.2	–	–	–	–	58.8	54.7	–	–	–	–	68.4	63.9	–	–	–	–
Dyna-Gro Ambush	77.7	76.6	77.9	75.7	76.6	76.7	56.8	54.6	53.7	58.0	51.1	54.6	67.3	65.6	65.8	66.8	65.0	66.7
Dyna-Gro Ballistic	89.4	81.3	89.9	89.7	86.8	88.9	59.5	63.5	57.7	64.0	55.3	61.4	74.4	72.4	73.8	76.8	72.5	76.4
Dyna-Gro Commander	76.3	77.3	81.3	83.1	–	–	59.6	57.3	56.2	56.5	–	–	68.0	67.3	68.8	69.8	–	–
Dyna-Gro Velocity	76.3	68.6	78.0	80.0	–	–	44.8	45.5	44.9	48.6	–	–	60.6	57.0	61.4	64.3	–	–
Lang-MN	79.8	79.9	80.2	83.3	81.0	82.4	53.6	56.2	52.2	57.8	51.1	57.7	66.7	68.0	66.2	70.5	67.4	71.1
LCS Buster	90.1	86.7					64.7	62.9					77.4	74.8	–	–	–	–
LCS Cannon	74.7	78.5	80.1	83.2	79.4	82.7	60.3	57.1	54.3	55.5	50.8	52.3	67.5	67.8	67.2	69.4	66.4	68.9
LCS Rebel	82.9	77.2	84.4	79.1	81.7	79.1	56.3	56.6	52.7	57.6	51.1	55.1	69.6	66.9	68.5	68.3	67.8	68.2
LCS Trigger	92.1	84.7	94.8	93.9	91.9	94.2	69.4	71.6	62.1	68.8	59.3	66.0	80.8	78.1	78.4	81.3	77.1	81.4
Linkert	71.9	79.5	73.0	80.2	72.2	78.8	49.9	51.2	46.6	49.0	42.7	46.8	60.9	65.4	59.8	64.6	58.8	64.2
MN-Torgy	82.6	80.9	83.4	86.6	81.9	85.9	61.7	53.0	57.7	55.2	54.3	54.3	72.1	67.0	70.5	70.9	69.3	71.5
MN-Washburn	66.6	90.4	74.0	88.5	75.4	87.6	54.4	52.5	52.8	55.7	51.1	54.5	60.5	71.5	63.4	72.1	64.3	72.6
MS Barracuda	71.3	71.0	76.9	77.3	77.3	77.8	54.0	50.6	46.9	49.5	43.8	47.5	62.7	60.8	61.9	63.4	62.1	64.0
MS Chevelle	83.3	79.6	85.7	87.2	83.4	86.3	51.8	57.8	51.6	55.5	47.6	53.2	67.6	68.7	68.7	71.4	67.1	71.2
MS Ranchero	84.1	77.7	–	–	–	–	54.0	46.1	–	–	–	–	69.0	61.9	–	–	–	–
ND Frohberg	73.5	73.5	–	–	–	–	57.9	55.5	–	–	–	–	65.7	64.5	–	–	–	–
Prosper	85.4	85.9	86.0	91.4	84.7	89.6	60.9	61.7	59.0	63.6	58.1	62.4	73.1	73.8	72.5	77.5	72.6	77.2
Rollag	64.1	75.4	68.3	77.2	67.1	74.7	51.9	51.4	45.1	50.2	42.8	48.1	58.0	63.4	56.7	63.7	56.1	62.6
Shelly	76.9	88.3	83.9	90.0	83.1	87.6	58.4	51.1	53.2	55.1	51.2	53.5	67.7	69.7	68.5	72.6	68.6	72.1
SY 611 CL2	82.2	83.2	82.5	89.5	–	–	51.0	52.0	49.9	52.3	–	–	66.6	67.6	66.2	70.9	–	–
SY Ingmar	79.2	78.5	79.9	80.3	77.7	80.4	53.6	54.4	49.8	54.5	48.6	52.7	66.4	66.4	64.8	67.4	64.5	67.8
SY Longmire	73.4	79.9	77.3	83.4	–	–	56.5	55.4	50.6	53.7	–	–	64.9	67.6	63.9	68.6	–	–
SY McCloud	74.9	77.9	76.8	81.1	76.4	80.5	47.5	46.9	47.6	49.0	45.7	48.0	61.2	62.4	62.2	65.1	62.4	65.7
SY Valda	78.5	84.6	86.2	90.4	85.2	89.5	54.4	53.8	52.9	55.5	52.4	54.2	66.5	69.2	69.5	73.0	70.2	73.5
TCG-Heartland	77.9	82.6	77.0	83.1	–	–	50.0	46.5	47.4	49.6	–	–	63.9	64.5	62.2	66.4	–	–
TCG-Spitfire	82.0	89.4	85.9	91.6	84.5	89.8	71.4	67.3	63.4	63.8	59.9	61.2	76.7	78.4	74.6	77.7	73.3	76.8
TCG-Wildcat	83.7	85.3	–	–	–	–	57.2	57.3	–	–	–	–	70.4	71.3	–	–	–	–
WB-Mayville	65.0	72.8	72.1	78.9	71.5	78.3	55.0	54.1	52.3	53.9	47.6	49.1	60.0	63.5	62.2	66.4	60.7	65.0
WB9479	78.5	77.4	–	–	–	–	49.7	48.4	–	–	–	–	64.1	62.9	–	–	–	–
WB9590	86.0	87.5	–	–	–	–	55.5	55.6	–	–	–	–	70.8	71.5	–	–	–	–
Mean (Bu/Acre)	78.5	80.8	80.9	84.5	79.5	83.4	56.0	55.2	52.6	55.7	50.8	54.3	67.2	68.0	66.7	70.1	66.5	70.2
LSD (0.10)	10.7	11.0	6.6	7.2	4.7	5.1	8.5	7.2	5.7	5.2	5.1	4.8	6.8	6.8	4.4	4.6	3.5	3.6
No. Environments	2	2	4	4	6	6	2	2	4	4	5	5	4	4	8	8	11	11

Table 8. Origin and agronomic characteristics of barley varieties in multiple-year comparisons (2018-2020).

Variety	Orgin[1]	Years of Release	Legal Status	Days to Heading	Plant Height	Straw Strength[2]	Plump	Protein
				(days)	(inches)	(1-9)	(%)	(%)
2-row								
AAC Synergy	AAFC	2012	Yes	54	31	5	93	12.0
Conlon	AC	1996	Yes	51	29	8	92	13.0
ND Genesis	ND	2015	Yes	55	32	5	95	11.5
Pinnacle	ND	2007	Yes	53	30	5	97	11.4
6-row								
Lacey	MN	2000	Yes	52	33	3	93	12.3
Quest	MN	2010	Yes	52	34	6	85	12.6
Rasmusson	MN	2008	Yes	51	31	4	90	12.0
Robust	MN	1984	Expired	52	35	3	93	12.7
Tradition	ABI	2003	Yes	53	34	3	91	13.1
No Enviro-ments				10	8	5	6	6

1 Agriculture and Agri-Food Canada (AAFC), North Dakota State University (ND), University of Minnesota (MN), Anheuser-Busch InBev (ABI)

2 1-9 scale where 1=most resistant, 9=most susceptible

Table 9. Disease reactions of barley varieties in multiple year comparisons (2018-2020).

Variety	Don [1]	Spot Blotch [1]	Stem Rust [1,2]	Bacterial Leaf Streak [1]
	---------- (1-9) ----------			
2-row				
AAC Synergy	7	3	5	4
Conlon	3	9	4	5
ND Genesis	4	4	7	4
Pinnacle	5	5	8	6
Pinnacle	7	3	5	4
6-row				
Lacey	6	2	6	4
Quest	3	3	4	5
Rasmusson	7	3	7	5
Robust	8	1	5	4
Tradition	4	3	5	5
No. of Environments	4	3	3	4

[1] Trait measured on a scale from 1-9 where 1=resistant and 9=susceptible. Deoxynivalenol (DON) is the mycotoxin produced by the Fusarium head blight pathogen.
[2] 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 (2020) and multiple-year comparisons (2018-2020).

Variety	Crookston	Hallock		Oklee		Perley		Roseau	Stephen		Strathcona	
	2 yr[2]	2020	3 yr	2020	3 yr	2020	3 yr	2 yr [2]	2020	3 yr	2020	3 yr
	----------(% of mean)----------											
2-row												
AAC Synergy	98	116	106	108	104	97	102	102	100	102	188	122
Conlon	93	98	96	86	92	92	92	94	117	100	15	69
ND Genesis	100	91	99	107	107	108	101	105	101	98	70	103
Pinnacle	113	97	107	101	102	110	94	105	111	109	138	111
6-row				-	-	-	-	-	-	-	-	-
Lacey	105	84	90	95	97	87	98	104	103	100	100	104
Quest[1]	-	84	-	97	-	93	-	-	92	-	119	-
Rasmusson[1]	-	101	-	96	-	85	-	-	87	-	140	-
Robust	91	99	96	96	98	102	101	96	96	94	59	93
Tradition	101	130	105	115	100	125	112	95	92	97	71	98
Mean (bu/acre)	124	93	100	123	110	98	90	106	85	114	54	94
LSD (0.05)	22	34	22	22	15	23	18	11	27	15	27	32

[1] Line was tested for yield in 2020 only. Refer to 2018 and prior years' reports for additional data
[2] Trial data is from 2019 and 2018 only.

Table 11. Relative grain yield of barley varieties in southern Minnesota locations in single-year (2020) and multiple-year comparisons (2018-2020).

Variety	Fergus Falls		Lamberton	Le Center		New Ulm		Rochester		St Paul	
	2020	3 yr	2020[2]	2020	3 yr	2020	2 yr[3]	2020	2 yr[4]	2020	3 yr
	(% of mean)										
2-row											
AAC Synergy	106	97	113	106	107	115	107	99	101	121	113
Conlon	89	72	78	88	96	94	97	72	73	65	56
ND Genesis	104	113	94	108	110	98	104	91	98	111	109
Pinnacle	105	111	93	105	93	95	101	102	105	112	101
6-row											
Lacey	94	103	109	96	99	100	98	109	114	111	113
Quest[1]	94	-	74	104	-	91	-	96	-	95	-
Rasmusson[1]	108	-	119	103	-	114	-	112	-	104	-
Robust	95	96	99	85	91	84	85	110	101	95	102
Tradition	106	109	120	106	104	110	107	109	109	87	105
Mean (bu/acre)	112	80	69	107	93	69	63	107	92	87	81
LSD (0.05)	13	19	10	11	24	13	13	15	20	11	19

[1] Line was tested for yield in 2020 only. Refer to 2018 and prior years' reports for additional data.
[2] Trial data is from 2020 only.
[3] Trial data is from 2020 and 2018 only.
[4] Trial data is from 2020 and 2019 only.

Table 12. Relative grain yield of barley varieties in a single-year (2020) and multiple year comparisons (2018-2020)

Variety	State			North			South		
	2020	2yr	3yr	2020	2yr	3yr	2020	2yr	3yr
	(% of mean)								
2-row									
AAC Synergy	112	107	105	115	106	105	109	107	105
Conlon	84	85	86	87	88	91	81	81	76
ND Genesis	100	105	103	98	104	102	102	105	106
Pinnacle	105	104	105	108	107	106	102	100	102
6-row									
Lacey	98	101	102	93	98	99	103	105	106
Quest[1]	94	-	-	95	-	-	93	-	-
Rasmusson[1]	104	-	-	98	-	-	109	-	
Robust	94	95	96	94	94	96	95	96	96
Tradition	108	104	103	111	102	101	106	106	108
Mean (bu/acre)	91	88	95	91	94	104	91	81	81
LSD (0.05)	10.5	7.0	5.6	20.9	11.3	7.6	9.7	7.8	8.1
No. Environments	11	22	32	5	12	19	6	10	13

[1] Line was tested for yield in 2020 only. Refer to 2018 and prior years' reports for additional data.

Table 13. Origin and agronomic characteristics of oat varieties in Minnesota in multiple-year comparisons (2018-2020).

Variety	Origin	Year of Release	Legal status	Seed Color	Days to Heading	Plant Height	Straw Strength[3]	Test Weight	Grain Protein[4,5]	Grain Oil[4,5]	Grain Beta-glucan[4,5]
					(days)	(inches)	(1-9)	(lbs/bu)	(%)	(%)	(%)
Antigo	WI	2017	Pending	Yellow	53.4	34.0	3.0	37.7	19.4	6.9	6.0
Badger	WI	2010	PVP(94)	Yellow	52.8	35.7	3.3	33.8	16.9	6.2	5.3
Deon	MN	2014	PVP(94)	Yellow	56.9	35.7	3.3	35.1	16.1	6.6	5.5
Esker[1]	WI	2006	PVP(94)	White	53.9	34.1	2.6	34.8	17.2	5.8	5.6
Esker 2020[1]	WI	2020	Pending	Yellow	55.1	34.3	3.0	33.5	16.8	5.6	6.1
Hayden	SD	2015	PVP(94)	White	57.0	36.8	4.1	36.1	15.1	7.2	5.7
MN Pearl	MN	2018	Pending	White	57.4	38.5	3.0	35.4	14.5	7.2	5.2
Newburg	ND	2011	PVP(94)	White	58.1	38.5	4.6	34.0	15.8	6.7	6.7
Reins	IL	2016	PVP(94)	White	53.7	32.6	1.7	36.1	16.6	6.0	5.5
Rushmore[1]	SD	2020	Pending	White	58.5	37.0	3.7	35.0	15.6	7.9	5.8
Rockford[1]	ND	2008	PVP(94)	White	55.2	34.3	2.7	36.4	16.7	5.8	5.5
Saber	IL	2010	PVP(94)	Yellow	53.5	33.5	3.0	34.6	16.4	5.5	5.8
Saddle	SD	2018	Pending	White	52.9	34.0	1.6	36.0	16.6	6.1	5.2
Shelby 427	SD	2011	PVP(94)	White	54.1	36.0	3.7	36.3	15.9	6.9	5.2
Streaker[2]	SD	2016	PVP(94)	Hulless	55.0	34.5	4.6	41.6	16.7	6.9	5.8
Sumo	SD	2017	Pending	White	52.3	34.4	2.7	36.5	18.2	5.6	5.3
Warrior[1]	SD	2019	Pending	White	55.7	32.2	1.7	35.2	16.6	6.2	5.2

[1] Line tested in 2019 and 2020 [2] Hulless oat [3] 1-9 scale where 1=most resistant, 9=most susceptible [4] 12% Grain moisture
[5] Trait measured in 2019 for 3 locations

Table 14. Disease characteristics of oat varieties.

Variety	Crown Rust[1]	Loose Smut[2]	BYDV[3]
	(1-9)	(1-9)	(1-9)
Antigo	4	3	7
Badger	6	1	5
Deon	3	1	4
Esker	5	2	5
Esker 2020	4	1	6
Hayden	5	1	3
MN Pearl	5	1	6
Newburg	5	4	3
Reins	6	1	6
Rockford	6	3	3
Rushmore	4	2	4
Saber	5	5	6
Saddle	4	2	5
Shelby 427	5	2	6
Streaker	5	1	3
Sumo	4	1	7
Warrior	3	2	6

[1] Tested in 2018, 2019, and 2020 with a mixed race population of crown rust; 1 = most resistant, 9 = most susceptible
[2] Tested in 2018 and 2019; 1 = most resistant, 1 = most susceptible
[3] Tested in 2015, 2016, and 2018; 1 = most resistant, 1 = most susceptible

Table 15. Relative grain yield of oat varieties in northern Minnesota locations in single-year (2020) and multiple-year comparisons (2018-2020).

Variety		Crookston			Fergus Falls[3]			Roseau			Stephen	
		2020	3yr		2020	3yr		2020	3yr		2020	3yr
		--------------------------------------(% of mean)--------------------------------										
Antigo		100	102		90	96		65	88		86	85
Badger		94	102		87	84		91	98		82	91
Deon		106	100		91	100		115	114		114	115
Esker[1]		103	-		87	-		86	-		86	-
Esker 2020[1]		108	-		83	-		105	-		102	-
Hayden		120	121		112	115		123	109		107	108
MN Pearl		111	110		121	126		112	120		118	118
Newburg		100	101		123	122		84	91		115	106
Reins		99	96		101	92		106	104		102	108
Rockford[1]		97	-		130	-		115	-		101	-
Rushmore[1]		114	-		116	-		117	-		127	-
Saber		113	114		90	100		105	105		108	105
Saddle		90	99		93	91		99	106		106	105
Shelby 427		99	102		96	95		98	98		95	95
Streaker[2]		75	84		102	101		72	75		69	75
Sumo		76	69		61	76		84	92		82	90
Warrior[1]		98	-		117	-		122	-		101	-
Mean (bu/acre)		164	132		145	143		101	118		154	138
LSD (0.1)[4]		25	19		41	33		37	25		28	20

[1] Line was tested in 2020 and 2019 only [2] Hulless oat [3] Location was tested in 2018 and 2020
[4] A large LSD suggests large variability from year to year for the specific location

Table 16. Relative grain yield of oat varieties in southern Minnesota locations in single-year (2020) and multiple-year comparisons (2018-2020).

Variety	Kimball[3]	Lamberton		LeCenter		Rochester[4]		St Paul[5]	Waseca	
	3yr	2020	3yr	2020	3yr	2020	3yr	2020	2020	3yr
	---(% of mean)---									
Antigo	108	105	106	99	97	100	107	85	82	100
Badger	100	99	90	99	98	98	94	73	103	104
Deon	94	113	129	104	105	107	110	110	107	114
Esker[1]	-	105	-	96	-	96	105	102	103	-
Esker 2020[1]	-	112	-	97	-	94	103	101	104	-
Hayden	92	87	99	113	108	112	107	120	109	97
MN Pearl	98	116	133	100	117	108	110	129	119	131
Newburg	97	94	105	102	101	95	94	102	104	87
Reins	117	105	86	91	97	94	107	103	107	111
Rockford[1]	-	87	-	108	-	99	90	89	103	-
Rushmore[1]	-	120	-	118	-	112	113	99	110	-
Saber	101	84	89	118	112	116	115	112	100	93
Saddle	117	95	99	100	108	101	103	98	82	103
Shelby 427	98	74	87	107	102	99	98	105	97	89
Streaker[2]	75	66	70	83	66	72	67	78	79	73
Sumo	104	113	106	81	89	102	94	80	96	97
Warrior[1]	-	125	-	83	-	95	82	114	96	-
Mean (bu/acre)	128	118	105	133	146	138	126	126	122	79
LSD (0.1)[6]	36	21	20	30	21	23	27	12	16	20

[1] Line tested in 2018 and 2019 only
[2] Hulless oat
[3] Location was tested in 2018 and 2019
[4] Location was tested in 2019 and 2020
[5] Location was tested in 2020 only
[6] A large LSD suggests large variability from year to year for the specific location

Table 17. Relative grain yield of oat varieties in Minnesota in single-year (2020) and multiple-year comparisons (2018-2020).

Variety		North				South				State		
		2020	2yr	3yr		2020	2yr	3yr		2020	2yr	3yr
		---(% of mean)--										
Antigo		87	90	92		94	101	102		91	96	97
Badger		88	94	95		94	93	95		91	94	95
Deon		106	105	108		108	111	110		107	109	109
Esker[1]		91	96	-		100	97	-		96	97	-
Esker 2020[1]		99	100	-		101	105	-		100	103	-
Hayden		115	111	113		108	104	103		111	107	108
MN Pearl		116	114	118		114	117	119		115	116	118
Newburg		107	106	104		99	98	98		103	101	101
Reins		102	99	101		99	100	102		100	100	101
Rockford[1]		110	108	-		98	87	-		103	96	-
Rushmore[1]		118	114	-		112	115	-		115	115	-
Saber		104	106	107		107	104	103		106	105	105
Saddle		97	99	101		96	104	105		96	102	103
Shelby 427		97	95	98		97	97	96		97	96	97
Streaker[2]		80	83	83		76	71	70		78	76	76
Sumo		75	76	82		94	94	96		85	86	89
Warrior[1]		108	103	-		102	102	-		105	102	-
Mean (bu/acre)		141	128	132		127	121	116		133	124	123
LSD (0.1)		21	15	13		16	12	11		13	10	8
# of Environments		4	7	11		5	10	14		9	17	25

[1] Line was tested in 2020 and 2019 only
[2] Hulless oat

North Dakota Hard Red Spring Wheat Variety Trial Results for 2020 and Selection Guide

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Hard red spring (HRS) wheat was planted on 6 million acres in 2020, down from 6.6 million in 2019. The average yield of HRS wheat was 48 bushels/acre (bu/a), similar to 2019.

SY Ingmar was the most popular HRS wheat variety in 2020, occupying 19.2% of the planted acreage, followed by SY Valda (12.5%), WB9590 (6.1%), SY Soren (4.1%), Glenn (3.6%) and Faller (3.5%). SY Ingmar, SY Soren and SY Valda were released by Syngenta /AgriPro. WB9590 was released by Westbred/Monsanto. Glenn and Faller 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% 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 2019. 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% 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% level of confidence. The CV stands for coefficient of variation and is expressed as a percentage. The CV is a measure of variability in the trial. Large CVs mean a large amount of variation that could not be attributed to differences in the varieties. Yield is reported at 13.5% moisture, while protein content is reported at 12% moisture content.

Presentation of data for the entries tested does not imply approval or endorsement by the authors or agencies conducting the test. North Dakota State University approves the reproduction of any table in the publication only if no portion is deleted, appropriate footnotes are given and the order of the data is not rearranged. Additional data from county sites are available from each Research Extension Center at www.ag.ndsu.edu/varietytrials/spring-wheat. 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 fund on pages 72 - 80

Table 1. North Dakota hard red spring wheat variety descriptions, agronomic traits, 2020.

						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**
AP Murdock	Syngenta/ AgriPro	2019	26	4	53	NA	NA	NA	NA	5	6
Ambush	Dyna-Gro	2016	27	5	53	1	4	3	4	6	5
Ballistic	Dyna-Gro	2018	28	3	54	NA	5	NA	NA	5	3
Barlow	ND	2009	28	6	52	1	6	4	4	4	4
Bolles	MN	2015	28	4	56	2	3	5	4	6	5
Boost	SD	2016	29	5	56	1	4	3	8	2	5
Commander	Dyna-Gro	2019	27	3	53	NA	4	NA	3	4	5
CP3530	Croplan	2015	30	5	56	1	2	8	6	5	5
CP3903	**Croplan**	**2020**	**27**	**2**	**53**	**NA**	**7**	**NA**	**NA**	**5**	**4**
CP3910	Croplan	2019	26	5	52	NA	1	NA	8	8	6
CP3915	Croplan	2019	27	4	54	NA	1	NA	7	4	5
Dagmar[6]	MT	2019	27	6	53	NA	7	NA	NA	7	7
Driver	SD	2019	28	3	55	NA	1	NA	NA	7	3
Elgin-ND	ND	2012	30	5	53	1	6	5	6	6	4
Faller	ND	2007	28	5	56	1	7	8	7	5	4
Glenn	ND	2005	30	4	52	1	6	4	6	4	4
Lang-MN	MN	2017	28	5	55	1	2	1	4	3	3
Lanning	MT	2017	26	4	54	NA	7	NA	NA	8	6
LCS Buster	**Limagrain**	**2020**	**28**	**6**	**59**	**NA**	**NA**	**NA**	**NA**	**4**	**5**
LCS Cannon	Limagrain	2018	26	4	51	NA	7	NA	5	7	6
LCS Rebel	Limagrain	2017	29	6	52	1	7	4	3	4	5
LCS Trigger	Limagrain	2016	29	5	60	1	1	2	6	3	3
Linkert	MN	2013	25	2	54	1	3	1	4	6	5
MN-Torgy	**MN**	**2020**	**27**	**3**	**54**	**NA**	**4**	**NA**	**NA**	**3**	**3**
MN-Washburn	MN	2019	26	3	56	NA	1	NA	6	5	5
MS Barracuda	Meridian	2018	25	4	51	NA	2	NA	7	7	6
MS Chevelle	Meridian	2014	26	5	53	1	4	3	6	7	6
MS Ranchero	**Meridian**	**2020**	**27**	**5**	**54**	**NA**	**4**	**NA**	**NA**	**6**	**6**
ND Frohberg	**ND**	**2020**	**29**	**4**	**54**	**NA**	**5**	**NA**	**NA**	**4**	**5**
ND VitPro	ND	2016	28	3	53	1	4	3	7	4	4
Shelly	MN	2016	26	4	56	2	6	5	3	7	5
SY 611CL2	Syngenta/ AgriPro	2019	25	5	54	NA	6	NA	4	6	5
SY Ingmar	Syngenta/ AgriPro	2014	27	3	54	1	3	6	6	4	5
SY Longmire[6]	Syngenta/ AgriPro	2019	27	4	54	NA	7	NA	2	6	7

Table 1 continued

						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
SY McCloud	Syngenta/ AgriPro	2019	27	4	54	NA	5	NA	7	8	5
SY Rockford	Syngenta/ AgriPro	2017	27	4	55	NA	6	NA	2	8	6
SY Soren	Syngenta/ AgriPro	2011	25	3	54	1	2	7	2	7	7
SY Valda	Syngenta/ AgriPro	2015	26	4	54	1	2	7	6	6	5
TCG-Heartland	21st Century Genetics	2019	26	3	52	NA	2	NA	5	7	6
TCG-Spitfire	21st Century Genetics	2015	27	3	57	1	5	4	8	4	6
TCG-Wildcat	**21st Century Genetics**	**2020**	**27**	**3**	**55**	**NA**	**5**	**NA**	**NA**	**5**	**NA**
Velocity	Dyna-Gro	2019	27	3	54	NA	2	NA	NA	6	5

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 are 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 2020.
4 Disease reaction scores from 1 to 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 six locations in eastern North Dakota, 2018-2020.

	Carrington		Casselton		Grand Forks	Gwinner	Langdon		Steele Co.		Average	
Variety	**2020**	**3 Yr.**	**2020**	**3 Yr.**	**2020**	**2020**	**2020**	**3 Yr.**	**2020**	**3 Yr.**	**2020**	**3 Yr.**
	----------(bu/a)----------											
AP Murdock	46.5	--	87.7	--	65.7	80.4	87.4	--	81.1	--	74.8	
Ambush	44.5	54.3	69.0	63.7	55.7	66.8	68.1	77.5	68.4	68.5	62.1	66.0
Ballistic	47.7	--	89.1	--	66.3	65.2	73.1	--	68.6	--	68.3	--
Barlow	38.8	50.2	71.6	62.8	48.0	57.6	67.7	76.1	68.1	64.8	58.6	63.5
Bolles	33.2	48.6	67.4	62.5	50.6	53.0	67.9	74.0	71.5	68.2	57.3	63.3
Boost	47.1	53.7	74.6	68.0	57.4	54.9	71.0	77.8	69.5	73.3	62.4	68.2
Commander	29.8	--	80.3	--	60.9	70.2	74.1	--	78.3	--	65.6	--
CP3530	44.9	56.6	86.6	73.5	57.6	77.3	83.1	86.8	79.2	75.7	71.4	73.2

»

» *Table 2 continued*

	Carrington		Casselton		Grand Forks	Gwinner	Langdon		Steele Co.		Average	
Variety	2020	3 Yr.	2020	3 Yr.	2020	2020	2020	3 Yr.	2020	3 Yr.	2020	3 Yr.
	(bu/a)											
CP3903	41.7	--	74.3	--	57.5	71.9	76.9	--	73.9	--	66.0	--
CP3910	41.3	--	72.0	--	53.4	63.6	70.1	--	67.4	--	61.3	--
CP3915	53.0	--	78.8	--	61.3	72.0	80.0	--	77.7	--	70.5	--
Dagmar	45.9	--	74.8	--	57.5	64.0	66.0	--	69.4	--	62.9	--
Driver	49.4	--	79.9	--	60.8	70.0	72.7	--	74.6	--	67.9	--
Elgin-ND	48.3	53.5	78.9	69.7	55.0	65.5	66.1	78.5	62.6	63.8	62.7	66.4
Faller	53.6	60.3	82.2	73.6	63.7	81.2	80.6	87.3	78.0	75.7	73.2	74.2
Glenn	35.5	46.3	69.6	60.2	48.0	57.5	73.6	74.8	70.4	64.2	59.1	61.4
Lang-MN	51.7	56.6	78.7	68.1	57.7	55.2	72.3	76.1	68.9	67.2	64.1	67.0
Lanning	36.6	--	75.1	--	53.2	63.1	57.1	--	63.6	--	58.1	--
LCS Buster	44.5	--	85.2	--	61.2	68.0	73.4	--	81.5	--	69.0	--
LCS Cannon	37.9	49.6	88.3	71.1	53.0	68.2	73.3	81.4	75.4	--	66.0	--
LCS Rebel	43.7	52.4	70.9	65.9	63.3	65.7	75.5	83.1	76.6	73.7	66.0	68.8
LCS Trigger	48.9	58.9	82.6	76.1	76.0	66.8	80.6	92.5	76.5	80.6	71.9	77.0
Linkert	43.8	52.5	72.1	64.5	48.6	64.2	68.5	70.9	69.3	64.7	61.1	63.1
MN-Torgy	56.3	--	81.0	--	60.7	68.8	70.4	--	79.8	--	69.5	--
MN-Washburn	42.0	48.0	75.9	--	54.2	82.2	77.8	79.6	73.0	--	67.5	--
MS Barracuda	35.3	47.6	83.0	70.4	54.2	70.2	65.6	80.7	61.8	62.3	61.7	65.2
MS Chevelle	34.2	54.2	78.3	69.8	57.6	73.0	74.6	84.6	62.5	65.6	63.4	68.5
MS Ranchero	50.5	--	78.2	--	60.4	52.2	61.8	--	51.8	--	59.2	--
ND Frohberg	47.4	57.3	73.9	--	53.1	65.2	73.4	80.8	75.9	--	64.8	--
ND VitPro	27.3	44.3	72.5	63.4	54.0	54.5	76.2	75.8	67.6	63.9	58.7	61.9
Shelly	53.3	56.2	90.4	75.3	60.8	74.0	57.7	76.0	67.7	67.4	67.3	68.7
SY 611CL2	29.5	46.8	81.4	--	54.9	70.3	77.7	81.6	74.7	--	64.8	--
SY Ingmar	35.2	51.9	73.3	68.9	60.1	65.6	77.1	83.1	77.2	69.9	64.7	68.4
SY Longmire	44.4	52.5	75.9	--	55.6	72.6	78.1	--	70.7	--	66.2	--
SY McCloud	36.6	47.0	76.7	--	48.0	72.7	75.9	79.0	73.5	--	63.9	--
SY Rockford	40.4	53.1	86.1	--	49.7	60.0	54.8	--	54.8	52.7	57.6	--
SY Soren	36.6	50.8	77.4	67.3	49.6	66.4	70.6	76.2	75.7	66.1	62.7	65.1
SY Valda	49.0	58.3	83.6	72.9	54.7	76.1	78.8	86.5	78.0	76.3	70.0	73.5
TCG-Heartland	37.3	--	78.4	--	50.0	64.6	66.5	--	71.8	--	61.4	--
TCG-Spitfire	47.7	56.2	74.0	69.4	63.5	81.4	79.9	83.4	83.2	78.8	71.6	71.9
TCG-Wildcat	41.6	--	75.0	--	60.4	66.3	73.6	--	84.8	--	67.0	--
Velocity	40.9	--	70.5	--	52.4	67.5	70.1	--	66.8	--	61.4	--
Mean	42.3	52.5	78.2	68.4	56.8	66.9	71.2	--	71.9	68.7	64.9	67.8
CV%	13.9	--	6.6	--	11.6	11.0	8.1	--	10.1	--	--	--
LSD 0.05	8.2	--	8.4	--	6.7	12.0	8.1	--	11.8	--	8.9	4.6
LSD 0.10	6.9	--	7.0	--	5.6	9.7	6.8	--	9.9	--	7.5	3.8

Table 3. Yield of hard red spring wheat varieties grown at four locations in western North Dakota, 2018-2020.

	Dickinson		Mandan		Minot		Williston		Average	
Variety	**2020**	**3 Yr.**	**2020**	**3 Yr.**	**2020**	**3 Yr.**	**2020**	**3 Yr.**	**2020**	**3 Yr.**
	(bu/a)									
AP Murdock	42.0	--	44.7	--	59.7	--	28.0	--	43.6	--
Ambush	40.8	49.6	42.9	43.2	59.9	64.1	28.7	--	43.1	--
Ballistic	48.5	--	52.6	--	65.3	--	31.8	--	49.6	--
Barlow	43.5	49.6	43.0	41.2	52.1	60.2	25.9	46.0	41.1	49.3
Bolles	38.6	47.3	40.7	41.6	59.1	62.2	28.0	44.2	41.6	48.8
Boost	42.3	49.2	44.5	43.3	58.6	65.2	28.5	43.6	43.5	50.3
Commander	40.7	--	44.5	--	66.7	--	29.5	--	45.4	--
CP3530	44.4	53.2	45.9	44.3	67.8	69.0	31.2	--	47.3	--
CP3903	42.2	--	42.0	--	60.6	--	30.1	--	43.7	--
CP3910	40.7	--	45.3	--	70.1	--	27.5	--	45.9	--
CP3915	44.5	--	47.9	--	55.6	--	30.4	--	44.6	--
Dagmar	44.8	--	40.5	--	51.6	--	28.6	--	41.4	--
Driver	45.4	--	50.7	--	65.0	--	28.7	--	47.5	--
Elgin-ND	43.8	50.4	51.6	46.4	60.9	64.8	30.2	53.6	46.6	53.8
Faller	46.8	56.7	48.3	45.3	63.8	74.5	36.5	51.6	48.9	57.0
Glenn	37.3	48.5	42.0	44.3	55.8	59.1	29.2	47.9	41.1	50.0
Lang-MN	42.6	51.7	48.8	46.7	58.2	62.1	29.8	44.1	44.9	51.2
Lanning	44.4	54.3	47.4	43.5	56.4	66.2	30.6	51.9	44.7	54.0
LCS Buster	52.2	--	54.0	--	75.9	--	32.6	--	53.7	--
LCS Cannon	44.4	49.4	41.5	42.9	56.3	61.3	26.7	46.1	42.2	49.9
LCS Rebel	44.4	51.3	46.8	45.2	60.2	61.0	34.1	50.6	46.4	52.0
LCS Trigger	51.6	58.2	50.2	45.1	73.0	75.1	34.3	54.4	52.3	58.2
Linkert	40.1	48.7	45.1	42.2	56.5	61.1	28.4	46.1	42.5	49.5
MN-Torgy	45.4	--	48.2	--	61.3	--	32.1	--	46.8	--
MN-Washburn	40.1	51.2	40.4	42.7	54.6	60.8	29.0	--	41.0	--
MS Barracuda	36.4	41.4	43.6	42.8	59.6	68.7	27.9	44.6	41.9	49.4
MS Chevelle	46.9	56.3	41.7	42.6	69.0	67.7	28.7	49.7	46.6	54.1
MS Ranchero	47.5	--	49.1	--	59.6	--	31.6	--	47.0	--
ND Frohberg	41.2	48.4	45.2	--	59.9	60.5	28.7	--	43.8	--
ND VitPro	38.9	47.7	46.1	43.4	52.3	56.2	28.2	48.5	41.4	49.0
Shelly	45.9	54.8	48.7	45.9	64.3	68.1	32.1	52.6	47.8	55.4
SY 611CL2	44.2	--	44.3	43.4	68.7	68.9	36.8	--	48.5	--
SY Ingmar	43.3	50.7	39.9	42.8	55.9	58.4	29.9	43.9	42.3	49.0
SY Longmire	43.0	51.4	45.1	43.4	63.5	63.8	32.9	--	46.1	--
SY McCloud	39.9	48.9	41.5	39.9	53.3	61.7	26.5	--	40.3	--
SY Rockford	47.5	55.4	49.6	44.6	64.6	72.5	31.4	52.2	48.3	56.2
SY Soren	40.5	50.3	39.4	39.3	61.7	65.0	28.5	46.3	42.5	50.2
SY Valda	46.6	52.2	51.5	46.3	52.1	61.8	31.0	51.2	45.3	52.9
TCG-Heartland	41.0	--	42.1	--	55.9	--	34.5	--	43.4	--

»

Table 3 continued

	Dickinson		Mandan		Minot		Williston		Average	
Variety	2020	3 Yr.	2020	3 Yr.	2020	3 Yr.	2020	3 Yr.	2020	3 Yr.
	---(bu/a)---									
TCG-Spitfire	47.7	55.5	48.7	45.5	68.9	68.1	33.1	54.5	49.6	55.9
TCG-Wildcat	47.3	--	38.9	--	65.7	--	32.8	--	46.2	--
Velocity	40.4	--	38.2	--	55.0	--	28.7	--	40.6	--
Mean	43.3	51.2	44.8	43.6	59.9	64.6	30.0	48.7	45.0	52.2
CV%	7.6	--	14.0	--	10.3	--	9.6	--	--	--
LSD 0.05	4.6	--	8.8	--	10	--	4.7	--	4.3	3.7
LSD 0.10	3.8	--	7.4	--	8.4	--	3.9	--	3.6	3.1

Table 4. Protein at 12% moisture of hard red spring wheat varieties grown at 10 locations in North Dakota, 2020

Variety	Carrington	Casselton	Grand Forks	Gwinner	Langdon	Steele Co.	Dickinson	Mandan	Minot	Williston	Avg.
	---(%)---										
Ambush	17.8	15.0	16.0	16.0	15.6	15.8	16.7	14.3	14.9	20.1	16.2
AP Murdock	16.3	14.4	15.1	14.4	14.0	14.7	15.8	14.3	14.0	18.4	15.1
Ballistic	17.0	14.1	15.2	15.1	15.1	15.1	16.1	13.9	13.9	18.7	15.4
Barlow	17.4	14.8	15.6	15.4	15.6	15.5	15.7	14.8	14.4	17.5	15.7
Bolles	19.4	16.4	17.6	17.0	16.6	16.8	18.5	17.2	16.7	17.9	17.4
Boost	16.9	14.8	16.1	15.1	14.8	15.8	17.0	15.1	14.9	18.2	15.9
Commander	19.3	14.7	15.0	15.1	14.7	14.8	16.7	14.7	14.4	18.0	15.7
CP3530	17.5	15.5	16.1	14.9	15.3	16.0	15.7	14.7	14.0	15.6	15.5
CP3903	16.5	14.9	16.0	15.0	14.9	15.7	16.3	15.0	15.3	18.4	15.8
CP3910	16.6	14.0	15.8	15.1	15.1	15.4	16.2	15.1	14.7	18.3	15.6
CP3915	16.2	14.9	15.7	15.2	14.9	15.1	16.4	14.4	13.7	17.8	15.4
Dagmar	16.2	15.0	16.0	15.7	16.2	16.0	16.3	15.3	15.1	17.9	16.0
Driver	16.3	14.6	15.3	15.1	14.5	15.0	15.7	13.9	13.8	17.4	15.2
Elgin-ND	16.4	14.3	15.1	14.7	14.7	15.2	15.7	14.2	14.7	18.1	15.3
Faller	16.1	13.4	14.6	14.3	14.1	14.6	16.0	13.8	13.6	18.5	14.9
Glenn	18.1	15.4	16.0	15.3	15.2	15.6	16.6	15.0	15.2	18.0	16.0
Lang-MN	16.3	15.7	16.5	16.6	15.6	16.4	16.1	14.9	14.0	17.2	15.9
Lanning	18.8	15.1	16.6	16.5	16.6	16.2	16.7	14.9	14.3	18.6	16.4
LCS Buster	16.6	12.8	13.1	13.0	12.8	13.0	13.9	12.2	12.2	19.2	13.9
LCS Cannon	17.9	14.3	15.1	15.0	14.8	14.8	15.3	14.8	13.9	18.3	15.4
LCS Rebel	16.9	15.0	16.1	14.8	15.4	15.7	16.7	15.6	14.0	15.4	15.6
LCS Trigger	15.8	13.1	13.2	13.3	12.6	13.5	14.4	12.1	12.2	18.3	13.8
Linkert	17.8	15.1	15.8	15.6	15.8	15.4	17.5	15.0	15.9	15.3	15.9
MN-Torgy	16.3	15.4	15.9	16.0	15.5	15.5	15.8	14.1	13.7	17.2	15.5
MN-Washburn	17.2	14.3	16.4	15.2	14.4	16.0	15.5	13.7	13.6	17.4	15.4
MS Barracuda	17.8	15.4	16.3	15.4	15.8	16.2	17.0	16.3	15.0	17.3	16.2
MS Chevelle	17.5	13.4	14.8	14.3	14.3	14.7	14.6	13.7	12.7	16.2	14.6
MS Ranchero	15.7	14.5	15.0	15.9	15.4	15.3	15.2	14.3	12.9	18.5	15.3
ND Frohberg	17.1	14.3	15.8	14.8	14.7	15.1	16.8	15.2	15.4	18.3	15.7

Table 4 continued

Variety	Carrington	Cas-selton	Grand Forks	Gwinner	Langdon	Steele Co.	Dickinson	Mandan	Minot	Williston	Avg.
	(%)										
ND VitPro	19.4	14.8	16.2	15.6	15.1	15.8	17.0	15.7	15.1	16.6	16.1
Shelly	16.7	14.0	14.8	14.2	16.1	15.1	15.3	14.1	13.7	17.9	15.2
SY 611CL2	19.3	14.5	15.4	15.3	14.9	15.3	16.4	15.0	14.5	18.1	15.9
SY Ingmar	18.2	15.0	15.9	15.3	15.2	15.2	16.7	15.6	15.5	17.6	16.0
SY Longmire	17.8	14.8	15.9	15.3	15.2	15.3	16.0	15.4	14.9	17.2	15.8
SY McCloud	18.4	15.5	15.9	15.0	15.1	15.0	17.5	15.8	14.9	18.2	16.1
SY Rockford	17.8	14.5	16.1	15.9	15.8	15.8	16.1	15.2	13.4	17.3	15.8
SY Soren	18.6	14.8	15.8	15.5	15.1	14.9	16.9	15.0	15.4	18.2	16.0
SY Valda	16.3	14.2	15.4	14.7	14.2	15.3	15.0	14.1	13.5	19.1	15.2
TCG-Heartland	18.5	15.1	15.9	15.4	15.7	15.5	17.1	15.3	15.0	18.4	16.2
TCG-Spitfire	16.7	13.7	15.0	14.8	14.0	14.2	14.7	13.2	14.0	17.8	14.8
TCG-Wildcat	17.5	14.8	16.0	14.9	15.2	15.0	16.2	15.6	14.7	15.6	15.6
Velocity	17.7	15.7	16.7	16.0	16.1	16.5	17.0	14.8	15.4	17.3	16.3
Mean	17.4	14.7	15.6	15.2	15.1	15.3	16.2	14.7	14.4	17.7	15.6
CV%	5.1	--	1.5	2.4	3.0	1.8	3.6	3.3	5.5	2.3	--
LSD 0.05	1.3	--	0.3	0.6	0.6	0.3	0.8	0.7	1.3	0.6	0.5
LSD 0.10	1.0	--	0.3	0.5	0.5	0.3	0.7	0.6	1.0	0.5	0.4

Table 5. Test weight of hard red spring wheat varieties grown at 10 locations in North Dakota, 2020.

Variety	Carrington	Casselton	Grand Forks	Gwinner	Langdon	Steele Co.	Dickinson	Mandan	Minot	Williston	Avg.
	(lb/bu)										
Ambush	62.6	60.0	58.6	58.2	59.6	58.0	61.3	61.5	61.8	59.8	60.2
AP Murdock	61.5	57.0	57.9	58.0	59.7	57.8	60.5	61.2	59.5	59.3	59.2
Ballistic	61.8	59.1	58.2	57.7	56.7	56.7	61.0	61.7	59.6	58.9	59.1
Barlow	62.4	59.6	58.9	59.0	59.3	58.8	62.2	62.1	61.4	60.0	60.4
Bolles	60.4	58.0	57.8	57.2	58.8	57.2	60.4	60.2	59.9	58.4	58.8
Boost	62.2	58.7	58.7	58.1	59.7	58.2	60.7	60.7	60.1	58.2	59.5
Commander	59.5	59.5	58.1	58.6	59.2	57.6	61.1	61.0	60.5	60.1	59.5
CP3530	61.3	56.9	58.4	58.7	60.1	58.8	61.0	62.2	60.3	59.4	59.7
CP3903	62.2	60.0	59.6	59.4	62.1	59.6	61.8	62.2	59.7	60.2	60.7
CP3910	63.4	59.4	58.3	58.2	58.6	56.9	62.2	63.1	61.0	60.4	60.1
CP3915	63.4	60.3	58.8	59.4	61.1	60.4	62.0	62.4	60.6	60.1	60.8
Dagmar	61.8	58.5	57.8	57.7	58.9	57.7	61.0	60.8	58.3	59.0	59.2
Driver	63.9	58.7	59.7	59.1	60.0	59.7	62.6	62.5	61.8	60.6	60.9
Elgin-ND	62.2	57.7	58.3	58.1	59.1	55.8	61.0	61.8	59.4	58.6	59.2
Faller	61.9	58.3	57.9	57.8	59.7	57.7	60.8	61.5	59.6	58.4	59.4
Glenn	61.8	61.1	59.2	59.9	62.5	59.6	62.6	62.4	61.0	60.9	61.1
Lang-MN	62.9	58.0	58.3	57.9	60.7	58.4	61.6	62.0	61.3	59.0	60.0
Lanning	60.0	56.1	56.6	55.8	55.1	55.6	60.4	61.1	59.2	59.1	57.9
LCS Buster	61.1	54.7	57.3	55.6	57.0	57.3	60.8	61.6	59.4	58.3	58.3
LCS Cannon	63.4	59.7	58.9	58.9	59.8	58.7	62.7	62.9	61.6	61.3	60.8
LCS Rebel	62.8	60.5	59.1	60.5	61.5	59.1	61.9	61.8	62.1	60.0	60.9

»

Table 5 continued

Variety	Carrington	Casselton	Grand Forks	Gwinner	Langdon	Steele Co.	Dickinson	Mandan	Minot	Williston	Avg.
	--(lb/bu)--										
LCS Trigger	62.1	56.2	58.9	59.2	60.2	58.8	61.7	62.4	61.0	59.6	60.0
Linkert	61.2	59.3	58.5	58.0	59.8	58.7	60.9	62.1	60.5	59.3	59.8
MN-Torgy	63.2	58.7	59.3	58.1	59.1	58.9	61.5	62.4	60.8	60.0	60.2
MN-Washburn	61.7	58.6	58.6	58.7	60.0	59.3	61.2	61.6	60.1	59.2	59.9
MS Barracuda	61.3	59.1	57.4	57.6	57.9	55.0	60.9	60.6	60.2	59.4	58.9
MS Chevelle	60.8	58.7	57.0	57.3	58.1	55.8	61.7	61.5	60.5	59.5	59.1
MS Ranchero	61.3	56.4	56.1	54.6	54.6	53.7	60.3	60.4	58.9	58.7	57.5
ND Frohberg	62.6	58.5	58.5	59.1	61.0	58.8	61.4	61.6	61.5	59.3	60.2
ND VitPro	59.9	60.6	60.1	60.1	62.2	59.1	61.8	62.4	60.8	60.4	60.7
Shelly	63.0	59.2	58.7	57.2	55.5	56.5	61.8	60.1	59.9	60.2	59.2
SY 611CL2	61.5	58.7	58.9	58.5	60.4	58.1	61.9	63.2	61.6	60.5	60.3
SY Ingmar	61.1	60.5	59.5	59.1	60.6	59.1	62.1	61.8	61.2	60.6	60.6
SY Longmire	62.5	58.3	58.5	58.7	59.4	58.1	61.5	62.3	60.5	60.0	60.0
SY McCloud	62.0	59.7	58.3	59.4	61.2	59.3	61.7	62.3	60.7	61.3	60.6
SY Rockford	60.7	56.1	53.6	53.7	54.9	51.8	59.8	60.1	59.2	58.7	56.9
SY Soren	61.5	58.1	57.9	57.6	59.5	58.1	61.3	61.9	60.5	60.1	59.6
SY Valda	63.1	60.1	58.2	58.9	59.9	58.6	61.8	61.8	60.3	59.8	60.3
TCG-Heartland	62.5	60.7	58.3	59.5	59.8	58.6	61.7	62.6	61.1	60.1	60.5
TCG-Spitfire	61.2	58.3	57.8	57.7	60.1	58.5	61.5	61.8	60.8	59.4	59.7
TCG-Wildcat	61.8	59.9	59.5	59.4	60.5	59.7	62.0	61.9	61.6	60.0	60.6
Velocity	62.2	58.5	58.6	58.9	60.3	59.0	61.7	61.3	61.2	59.7	60.1
Mean	61.9	58.7	58.3	58.2	59.1	57.9	61.4	61.6	60.3	59.5	59.8
CV%	1.3	2.0	2.1	1.0	1.8	2.1	0.7	1.5	1.2	0.6	--
LSD 0.05	1.1	1.9	1.4	0.9	1.5	2.0	0.6	1.3	1.2	0.5	2.5
LSD 0.10	0.9	1.6	1.2	0.8	1.2	1.7	0.5	1.1	1.0	0.5	2.1

Table 6. Quality data from 2019 eastern North Dakota 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	62.5	75	36.3	390	14.4	67.4	61.2	12.5	958
Barlow	62.4	70	34.6	339	14.4	69.7	65.8	10.1	946
Bolles	61.4	70	36.4	392	15.2	66.1	63.0	22.3	948
Boost	60.9	74	35.5	389	14.1	67.8	64.0	8.1	885
Commander	61.5	64	34.9	389	13.7	69.0	61.9	8.2	901
CP 3530	60.8	45	34.8	418	13.7	69.1	62.1	8.7	976
CP 3910	61.4	65	32.2	368	14.0	68.9	58.3	12.5	998
CP 3915	61.8	79	31.0	397	14.1	71.4	62.5	10.5	968
Elgin-ND	60.9	62	35.0	354	14.0	68.0	64.1	8.8	941
Faller	61.8	56	39.7	398	13.4	68.8	64.1	7.7	913
Glenn	64.0	91	34.5	354	14.6	66.6	63.5	13.0	1,008
Lang-MN	62.6	91	32.5	433	14.3	68.5	63.4	9.8	934
LCS Cannon	61.6	30	32.1	366	13.7	69.9	61.7	11.1	995
LCS Rebel	62.6	74	35.2	369	14.5	70.4	63.2	10.8	1,013
LCS Trigger	60.9	74	34.4	433	12.5	69.6	63.1	6.6	796
Linkert	61.5	67	37.4	408	14.5	66.6	62.5	15.3	1,005
MN-Torgy	61.6	62	34.1	343	14.6	68.2	61.9	11.3	915
MN-Washburn	61.1	86	34.5	384	13.8	71.1	61.1	11.0	955
MS Barracuda	61.3	75	36.7	364	14.6	68.4	63.6	9.3	986
MS Chevelle	61.5	55	34.2	340	12.9	67.7	62.2	10.0	950
ND Frohberg	62.2	67	38.2	333	13.7	67.7	64.4	11.6	963
ND VitPro	63.1	91	34.3	385	14.3	68.5	64.3	9.7	953
Shelly	61.2	31	33.9	393	13.0	70.3	59.9	12.1	919
SY 611 CL2	62.5	38	35.0	403	13.9	67.0	66.9	6.8	886
SY Ingmar	61.4	65	31.6	386	13.8	68.3	61.6	10.6	970
SY Longmire	62.0	63	34.9	386	13.9	68.0	63.1	7.7	954
SY McCloud	62.5	57	37.8	305	14.1	67.7	64.7	8.5	959
SY Rockford	60.6	57	36.2	390	13.7	67.7	62.5	10.4	954
SY Soren	62.0	45	32.7	397	14.4	67.7	62.5	8.2	994
SY Valda	61.5	77	35.2	376	12.9	69.1	60.9	7.3	905
TCG-Heartland	62.7	65	35.8	407	14.2	69.3	61.9	13.5	944
TCG-Spitfire	60.9	50	36.1	305	13.4	68.0	63.0	8.4	976
TCG-Stalwart	59.2	81	35.0	380	14.6	68.4	62.8	9.4	979

[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 requiresgreater than 75% vitreous kernels.

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

[4] Falling Number - Expressed in seconds at a 14% 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% 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% 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 2019 western North Dakota 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	61.8	42	38.3	393	16.4	66.0	62.7	10.7	975
Barlow	61.7	59	35.9	370	16.0	67.8	66.3	16.1	1,003
Bolles	60.2	53	37.1	446	17.8	64.4	65.4	30.7	990
Boost	60.3	55	37.4	424	15.7	66.8	65.3	8.5	988
Commander	61.3	40	38.4	401	15.9	67.0	64.1	7.5	905
CP 3530	60.8	30	37.7	380	15.1	69.0	65.4	10.9	965
CP 3910	62.6	81	34.8	363	16.2	69.4	61.9	13.5	1,015
CP 3915	62.5	88	34.3	422	16.3	70.7	64.5	15.0	960
Elgin-ND	60.7	50	34.1	391	15.7	66.9	65.5	9.6	975
Faller	60.5	36	38.1	400	14.6	68.3	63.2	12.2	955
Glenn	63.3	92	35.6	352	16.4	65.8	65.8	14.0	988
Lang-MN	61.5	81	36.0	395	16.4	67.3	66.1	9.5	918
Lanning	61.2	81	39.4	372	16.3	65.4	64.6	10.4	903
LCS Cannon	62.7	51	36.6	338	15.7	69.6	64.0	12.7	985
LCS Rebel	62.0	60	38.3	384	15.7	68.5	64.2	12.7	930
LCS Trigger	61.1	59	33.4	439	13.1	68.4	63.5	10.2	728
Linkert	61.1	59	39.6	430	16.9	65.1	65.7	20.2	1,000
MN-Torgy	61.6	46	35.7	449	15.8	66.3	63.5	19.0	858
MN-Washburn	61.0	94	33.0	431	15.0	69.4	61.8	18.0	883
MS Barracuda	61.4	56	41.7	447	16.7	67.4	65.7	12.2	1,013
MS Chevelle	61.1	45	34.5	367	14.6	67.8	64.0	11.2	970
ND Frohberg	61.8	56	39.0	426	16.0	65.7	68.6	13.3	980
ND VitPro	62.9	92	35.9	409	16.5	66.6	65.6	9.7	998
Shelly	61.4	35	37.8	470	15.2	70.0	61.6	25.7	878
SY 611 CL2	63.0	78	37.2	417	16.0	65.4	69.3	8.2	890
SY Ingmar	61.9	55	34.8	412	16.4	66.6	64.9	12.2	1,063
SY Longmire	61.9	47	36.8	447	16.0	67.8	65.4	12.3	993
SY McCloud	62.4	46	40.8	340	16.4	66.3	67.3	10.9	940
SY Rockford	60.0	41	36.9	452	15.3	66.3	66.4	11.4	905
SY Soren	61.7	32	34.0	413	16.6	67.1	64.8	10.3	1,038
SY Valda	60.9	67	37.3	380	15.1	67.2	62.8	9.6	933
TCG-Heartland	62.5	49	39.6	421	16.3	68.1	64.9	17.3	918
TCG-Spitfire	60.9	53	36.0	366	14.8	67.3	65.0	14.6	935
TCG-Stalwart	60.4	54	38.1	426	16.5	68.4	64.5	15.5	973

[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 requiresgreater than 75% 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% 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% 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% 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 Durum Variety Trial Results for 2020 and Selection Guide

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Durum was planted on 910,000 acres in North Dakota in 2020, up 26% from 2019. The average yield was 39 bushels per acre (bu/a), down from 42.5 last year. The most commonly grown varieties in 2020 and the percent of the acreage they occupied were Joppa (29%), Divide (20%), ND Riveland (11%), VT Peak (9%), Carpio (7%) and Alkabo (6%).

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/variety trials/durum. Use data from multiple locations and years when selecting a variety.

North Dakota State University Durum Tables
1 - 5 can be fund on pages 82 - 88

Table 1. Descriptions and agronomic traits of durum wheat varieties grown in North Dakota, 2020.

	Agent or Origin[1]		Year Released	Height (inches)[2]	Straw Strength[3]	Days to Heading[4]
AC Commander	Can.		2002	25	5	57
Alkabo	ND		2005	27	2	56
Alzada	WB		2004	24	6	54
Ben	ND		1996	28	4	56
Carpio	ND		2012	27	5	58
CDC Verona	Can.		2010	27	5	58
Divide	ND		2005	27	5	58
Grenora	ND		2005	26	5	55
Joppa	ND		2013	27	5	57
Lebsock	ND		1999	27	3	55
Maier	ND		1998	27	5	56
Mountrail	ND		1998	27	5	57
ND Grano[6]	ND		2017	27	5	57
ND Riveland[6]	ND		2017	29	4	57
Pierce	ND		2001	28	5	56
Rugby	ND		1973	29	5	56
Strongfield[6]	Can.		2004	26	6	58
Tioga	ND		2010	29	4	57
VT Peak	Viterra		2010	28	6	56

[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 several locations in 2020.

[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 2020.

[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.

Reaction to Disease[5]				
Stem Rust	Leaf Rust	Foliar Disease	Bact. Leaf Streak	Head Scab
1	1	6	NA	NA
1	1	5	7	6
1	1	8	NA	9
1	1	4	7	8
1	1	5	6	5
1	1	4	NA	8
1	1	5	7	5
1	1	5	7	6
1	1	5	7	5
1	1	5	7	6
1	1	5	NA	8
1	1	5	7	8
1	1	8	7	6
1	1	4	7	5
1	1	6	7	8
1	1	4	NA	8
1	1	6	NA	8
1	1	5	7	6
1	NA	NA	NA	NA

Table 2. Yield of durum wheat varieties at six Research Extension Centers in North Dakota, 2018-2020.

	Carrington		Langdon		Dickinson	
Variety	**2020**	**3 Yr.**	**2020**	**3 Yr.**	**2020**	**3 Yr.**
	-------------------------------------(bu/a)---------------------------------					
AC Commander	33.4	38.8	58.6	66.0	39.2	47.0
Alkabo	32.0	40.7	79.7	75.6	39.4	49.8
Alzada	32.1	33.5	47.5	53.9	35.4	41.4
Ben	31.7	38.2	74.5	72.7	36.1	48.4
Carpio	39.0	48.2	77.0	79.9	36.4	47.1
CDC Verona	37.8	44.9	61.3	69.5	41.7	51.9
Divide	30.2	43.4	78.0	78.5	38.3	50.1
Grenora	35.8	43.8	83.5	80.2	39.5	49.0
Joppa	28.4	43.8	75.9	80.3	41.5	52.8
Lebsock	30.2	39.1	74.9	73.9	38.0	50.4
Maier	28.4	36.9	61.5	70.0	35.1	46.8
Mountrail	33.7	41.6	70.2	75.1	40.9	52.6
ND Grano	38.0	45.5	75.2	76.2	38.7	52.4
ND Riveland	41.8	51.6	79.2	79.9	38.3	48.1
Pierce	34.9	42.1	75.5	78.6	37.8	47.3
Rugby	38.9	44.2	62.6	67.2	36.9	48.2
Strongfield	32.2	43.0	61.9	67.5	36.2	48.8
Tioga	30.9	43.2	76.7	78.5	37.6	51.0
VT Peak	23.9	41.0	79.9	77.9	37.7	49.5
Mean	33.3	42.3	71.2	73.8	38.1	49.1
CV %	15.3	--	8.6	--	7.4	--
LSD 0.05	7.7	--	8.8	--	4.0	--
LSD 0.10	6.5	--	7.4	--	3.3	--

	Hettinger		Minot		Williston		Average	
	2020	3 Yr.	2020	3 Yr.	2020	3 Yr.	2020	3 Yr.
	---(bu/a)---							
	23.3	39.4	65.3	56.6	29.5	43.7	41.6	48.6
	22.1	44.6	64.2	58.3	28.2	42.3	44.3	51.9
	16.7	33.5	44.7	46.1	25.1	38.3	33.6	41.1
	20.4	37.5	54.0	59.3	26.9	39.7	40.6	49.3
	20.5	42.0	60.8	65.1	29.3	41.2	43.8	53.9
	25.8	43.2	53.3	55.2	31.2	43.6	41.9	51.4
	19.5	41.5	54.2	62.3	31.6	42.9	42.0	53.1
	22.9	43.0	68.4	59.9	30.7	43.6	46.8	53.2
	21.6	40.8	68.5	66.8	27.4	41.6	43.9	54.3
	20.4	39.5	65.2	62.9	25.5	39.8	42.4	50.9
	18.2	38.9	63.1	58.9	23.2	40.6	38.3	48.7
	23.7	42.8	70.0	68.0	25.9	42.5	44.1	53.8
	24.1	42.4	66.8	68.1	26.5	39.9	44.9	54.1
	22.5	43.9	67.7	61.6	29.4	42.2	46.5	54.5
	21.5	41.1	67.7	60.7	26.1	39.5	43.9	51.6
	23.1	38.1	61.6	56.7	27.5	39.8	41.8	49.0
	21.1	42.3	63.4	59.2	25.5	42.2	40.0	50.5
	20.5	39.0	66.2	63.5	24.2	42.6	42.7	53.0
	24.2	45.4	64.5	64.8	27.7	42.2	43.0	53.5
	21.7	41.0	62.6	60.7	27.4	41.5	42.4	51.4
	10.6	--	6.7	--	11.3	--	--	--
	3.3	--	7.1	--	4.9	--	4.8	2.9
	2.7	--	6.0	--	4.1	--	4.8	2.4

Table 3. Test weight and protein of durum wheat varieties at six Research Extension Centers in North Dakota, 2020.

	Carrington		Langdon		Dickinson		
Variety	**Test Wt.**	**Protein**	**Test Wt.**		**Test Wt.**	**Protein**	
	lb/bu	**%**	**lb/bu**		**lb/bu**	**%**	
AC Commander	58.4	16.5	54.7		60.2	15.4	
Alkabo	58.7	16.0	59.8		60.4	14.1	
Alzada	58.8	16.3	54.1		58.9	14.6	
Ben	58.8	16.7	59.5		60.3	15.6	
Carpio	58.9	16.2	59.5		59.7	14.7	
CDC Verona	57.9	16.7	54.9		61.2	15.3	
Divide	57.3	17.0	58.6		60.1	14.9	
Grenora	58.8	16.1	58.4		60.0	15.5	
Joppa	57.9	15.8	58.3		61.1	14.2	
Lebsock	58.6	16.5	60.4		60.8	14.9	
Maier	58.3	17.4	56.0		59.8	15.8	
Mountrail	57.5	16.5	57.4		59.7	14.5	
ND Grano	59.8	16.1	58.2		60.7	15.4	
ND Riveland	59.8	15.8	58.7		60.2	14.9	
Pierce	59.6	16.5	59.1		60.5	15.1	
Rugby	59.0	16.1	57.1		60.5	14.9	
Strongfield	58.0	17.7	56.2		59.9	15.9	
Tioga	57.9	16.2	58.4		59.7	15.2	
VT Peak	56.6	17.1	59.6		61.6	15.4	
Mean	58.7	16.4	58.3		60.2	15.1	
CV %	1.7	2.7	1.8		0.9	3.5	
LSD 0.05	1.3	0.6	1.5		0.8	0.7	
LSD 0.10	1.1	0.5	1.3		0.9	0.6	

Hettinger		Minot		Williston		Average	
Test Wt.	Protein	Test Wt.	Protein	Test Wt.	Protein	Test Wt.	Protein
lb/bu	%	lb/bu	%	lb/bu	%	lb/bu	%
57.0	15.3	58.5	14.6	58.9	18.0	58.0	16.0
58.6	13.8	60.4	13.5	59.3	16.6	59.5	14.8
54.7	15.3	55.3	13.9	58.3	17.1	56.7	15.4
57.8	15.1	59.1	14.4	58.7	17.8	59.0	15.9
57.5	14.6	61.4	13.0	59.4	16.2	59.4	14.9
59.0	15.0	59.5	13.7	58.8	18.6	58.5	15.9
58.4	14.6	60.0	14.3	58.6	17.5	58.8	15.7
57.6	14.5	59.2	13.6	58.9	17.0	58.8	15.3
58.9	14.1	60.3	13.4	58.9	16.8	59.2	14.9
58.4	14.2	60.3	13.8	59.2	16.8	59.6	15.2
57.4	15.7	59.9	14.7	58.5	18.5	58.3	16.4
58.6	13.9	58.9	13.0	58.2	17.4	58.4	15.0
59.2	13.9	60.7	13.5	59.4	17.6	59.7	15.3
58.5	14.3	61.4	13.7	59.0	17.7	59.6	15.3
58.8	14.2	60.7	13.4	59.7	16.2	59.7	15.1
58.2	14.3	59.4	14.5	58.8	18.1	58.8	15.6
57.9	15.1	58.7	15.1	58.5	19.4	58.2	16.6
56.8	14.4	61.5	14.0	59.7	16.9	59.0	15.3
59.2	15.0	61.4	13.7	59.8	17.6	59.7	15.8
58.1	14.6	59.8	13.9	58.9	17.8	58.9	15.5
1.2	2.9	1.8	4.9	0.7	2.1	--	--
1.0	0.6	1.7	1.1	0.6	0.6	1.0	0.4
0.8	0.5	1.5	0.9	0.5	0.5	0.8	0.3

Table 4. Durum wheat variety quality descriptions, milling and processing data averaged for five years (2015-2019) from drill strips (32 locations/years).

Variety	Test Weight	Vitreous Kernels	Large Kernels	Falling Number	Wheat Protein¹	Gluten Index²	Pasta Color³	Spaghetti Firmness⁴	Overall Quality⁵
	(lb/bu)	(%)	(%)	(sec)	(%)		(1-12)	(g-cm)	
Alkabo	61.5	81	56	415	13.8	46	8.5	3.8	good
Alzada	59.5	86	64	505	14.5	84	8.1	4.3	good
Carpio	61.6	79	65	480	14.0	91	8.5	4.1	excellent
Divide	61.2	85	57	473	14.2	73	8.3	3.9	good
Joppa	61.4	86	49	461	13.7	82	8.7	3.9	good
Maier	60.8	87	52	439	14.7	54	8.3	4.1	good
Mountrail	60.6	89	47	456	14.2	25	7.9	3.7	fair
ND Grano	61.5	84	52	477	14.2	66	8.7	4.0	excellent
ND Riveland	61.3	88	62	466	14.2	80	8.5	4.0	excellent
Strongfield	60.6	88	56	468	14.8	66	8.0	4.1	good
Tioga	61.1	84	62	423	14.1	74	8.2	4.1	good
Average	61.0	85	57	460	14.2	67	8.3	4.0	
For all numbered footnotes, refer to bottom of Table 5.									

Table 5. Durum wheat variety quality descriptions, milling and processing data for 2019 at all locations from drill strips.

Variety	Test Weight	Vitreous Kernels	Large Kernels	Falling Number	Wheat Protein¹	Gluten Index²	Pasta Color³	Spaghetti Firmness⁴	Overall Quality⁵
	(lb/bu)	(%)	(%)	(sec)	(%)		(1-12)	(g-cm)	
Alkabo	61.3	79	68	335	13.8	50	7.6	3.5	good
Alzada	59.1	79	72	462	14.6	83	6.9	4.0	good
Carpio	61.7	74	79	447	14.0	93	7.9	3.8	good
Divide	61.4	81	71	439	14.0	80	7.8	3.5	good
Joppa	61.5	84	61	420	13.9	83	8.4	3.6	good
Maier	60.9	85	64	371	14.7	51	7.6	3.7	good
Mountrail	60.5	87	60	393	14.4	22	6.7	3.3	fair
ND Grano	61.4	86	66	418	14.3	69	8.1	3.6	good
ND Riveland	61.1	88	71	437	14.6	85	7.8	3.8	good
Strongfield	60.4	88	70	403	15.3	66	7.0	3.8	good
Tioga	60.7	79	77	352	14.3	78	7.0	3.7	good
Average	60.9	83	69	407	14.4	69	7.5	3.7	

[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] Work required to cut through a strand of spaghetti.
[5] Overall Quality is determined based on agronomic, milling and spaghetti processing performance.

North Dakota Barley, Oat and Rye Variety Trial Results for 2020 and Selection Guide

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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.

Yield is reported on a 14.5%, 14.0% and 14.0% moisture basis for barley, oats and rye respectively. Protein is reported on a 0% moisture basis for all crops in this report. 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 mean that with 95% or 90% 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, appropriate footnotes are given and the order of the data is not rearranged.

North Dakota State University Barley, Oat and Rye Tables # 1 - 10 can be fund on pages 90 - 97

Table 1. 2020 North Dakota barley variety descriptions.

					Rachilla					Reaction to Disease[6]			
Variety	Use[1]	Origin[2]	Year Released	Awn[3] Type	Hair[4] Length	Aleurone Color	Height (inch)	Days to Head	Straw[5] Strength	Stem Rust	Spot-form Net Blotch	Spot Blotch	Net Blotch
Six-rowed													
Tradition	M/F	BARI	2003	S	L	White	23	58	3	8	6	3	7
Two-rowed													
AAC Connect	M/F	Meridian	2017	R	L	White	21	62	3	4	5	4	5
AAC Synergy	M/F	Syngenta	2015	R	L	White	21	63	5	4	3	4	4
CDC Bow	**M/F**	**CDC**	**2016**	**R**	**L**	**White**	**22**	**64**	**3**	**NA**	**NA**	**NA**	**NA**
Conlon[7]	M/F	ND	1996	S	L	White	23	57	7	8	4	6	3
Explorer	M	Secobra	NA	R	L	White	20	61	4	NA	NA	8	4
ND Genesis	M/F	ND	2015	S	L	White	24	61	5	8	4	4	6
Pinnacle	M/F	ND	2006	S	L	White	22	60	6	8	8	4	6

Bolded varieties were tested for the first time this year, so some ratings may change as new data becomes available.

[1] M = malting; F = feed.
[2] BARI = Busch Agricultural Resources Inc.; CDC = Crop Development Centre, University of Saskatchewan.MN = University of Minnesota; ND = North Dakota State University.
[3] R = rough; S = smooth.
[4] 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, 2018-2020.

	Fargo			Carrington			Langdon			Avg. eastern N.D.		
	Test	Yield		Test	Yield		Test	Yield		Test	Yield	
Variety	Wt.	2020	3 Yr.	Wt.	2020	3 Yr.	Wt.	2020	3 Yr.	Wt.	2020	3 Yr.
	(lb/bu)	-----(bu/a)-----		(lb/bu)	-----(bu/a)-----		(lb/bu)	-----(bu/a)-----		(lb/bu)	-----(bu/a)-----	
Six-rowed												
Tradition	48.5	114.5	107.2	46.9	85.9	91.7	46.4	118.7	123.7	47.3	106.4	107.5
Two-rowed												
AAC Connect	48.5	81.3	--	47.1	84.1	--	45.5	127.0	--	47.0	97.5	--
AAC Synergy	49.8	85.3	93.7	47.5	84.8	86.0	46.2	131.9	133.7	47.8	100.7	104.5
CDC Bow	50.1	84.4	--	48.8	74.9	--	48.6	129.9	--	49.2	96.4	--
Conlon	50.3	90.3	83.5	48.1	78.7	77.4	48.4	108.8	110.0	48.9	92.6	90.3
Explorer	48.0	87.4	81.8	48.1	83.3	77.9	43.6	99.4	115.7	46.6	90.0	91.8
ND Genesis	44.3	102.5	100.0	47.3	77.1	72.6	46.7	131.2	131.2	46.1	103.6	101.3
Pinnacle	48.1	94.1	88.5	48.8	83.4	72.2	45.3	105.9	121.2	47.4	94.5	94.0
Mean	48.2	98.6	92.5	47.3	85.1	79.6	46.3	124.1	122.6	47.5	97.7	98.2
CV %	--	8.9	--	0.9	8.6	--	0.9	4.2	--	--	--	--
LSD 0.05	--	14.6	--	0.6	10.4	--	0.6	7.5	--	2.8	22.1	9.5
LSD 0.10	--	12.2	--	0.5	8.7	--	0.5	6.2	--	2.3	18.1	7.8

Table 3. Plump and protein of barley varieties at three locations in eastern North Dakota, 2020.

		Fargo			Carrington			Langdon			Avg. eastern N.D.	
Variety		**Plump**	**Protein**		**Plump**	**Protein**		**Plump**	**Protein**		**Plump**	**Protein**
		(%)	**(%)**		**(%)**	**(%)**		**(%)**	**(%)**		**(%)**	**(%)**
Six-rowed												
Tradition		80.4	11.8		97.3	14.1		89.8	12.9		89.2	12.9
Two-rowed												
AAC Connect		73.1	11.9		97.5	13.4		77.0	12.5		82.5	12.6
AAC Synergy		86.7	11.4		97.6	13.7		85.8	12.1		90.0	12.4
CDC Bow		90.9	11.6		98.5	14.1		92.4	12.5		93.9	12.7
Conlon		94.7	11.8		99.1	13.6		90.2	11.9		94.7	12.4
Explorer		86.3	11.3		98.2	13.7		75.7	12.4		86.7	12.5
ND Genesis		84.4	10.3		97.7	12.5		91.8	10.6		91.3	11.1
Pinnacle		87.8	10.3		98.2	11.8		85.0	11.5		90.3	11.2
Mean		86.5	10.6		98.1	12.9		88.5	11.5		89.8	12.2
CV %		--	--		0.5	2.9		2.4	3.6		--	--
LSD 0.05		--	--		0.7	0.5		3.0	0.6		9.7	0.7
LSD 0.10		--	--		0.6	0.4		2.5	0.5		7.9	0.6

Table 4. Yield and test weight of barley varieties at four locations in western North Dakota, 2018-2020

	Dickinson			Hettinger			Minot			Williston			Avg. western N.D.		
	Test	Yield		Test	Yield		Test	Yield		Test	Yield		Test	Yield	
Variety	**Wt.**	**2020**	**3 Yr.**	**Wt.**	**2020**	**3 Yr.**	**Wt.**	**2020**	**3 Yr.**	**Wt.**	**2020**	**3 Yr.**	**Wt.**	**2020**	**3 Yr.**
	(lb/bu)	---(bu/a)---		(lb/bu)	---(bu/a)---		(lb/bu)	---(bu/a)---		(lb/bu)	---(bu/a)---		(lb/bu)	---(bu/a)---	
Six-rowed															
Tradition	48.6	40.7	77.6	47.6	34.4	74.7	46.5	100.4	101.7	50.2	27.9	51.7	48.2	50.9	76.4
Two-rowed															
AAC Connect	49.1	49.5	--	49.1	43.0	--	45.9	109.2	--	51.4	38.1	66.6	48.9	59.9	--
AAC Synergy	49.4	50.3	88.5	48.9	41.3	82.4	46.7	113.3	107.9	51.4	36.4	69.5	49.1	60.3	87.1
CDC Bow	49.6	47.7	--	49.3	48.7	--	45.4	110.7	--	51.6	36.2	--	49.0	60.8	--
Conlon	49.2	45.7	62.1	47.6	26.5	63.7	48.5	83.7	90.5	51.1	35.5	--	49.1	47.9	--
Explorer	49.1	52.4	91.3	47.9	43.1	76.2	45.5	107.2	106.8	51.7	37.7	65.2	48.5	60.1	84.9
ND Genesis	49.8	50.5	84.7	48.4	47.6	87.5	45.2	119.3	109.0	51.3	40.8	68.3	48.7	64.6	87.4
Pinnacle	50.3	49.2	86.5	49.3	39.2	70.2	45.1	107.5	106.8	52.3	40.2	69.1	49.3	59.0	83.2
Mean	49.4	48.3	81.8	48.5	40.5	75.8	46.1	106.4	103.8	51.4	36.6	65.1	48.8	57.9	83.8
CV %	0.9	7.2	--	1.1	11.5	--	1.5	6.1	--	0.6	10.9	--	--	--	--
LSD 0.05	0.6	5.0	--	0.7	6.8	--	1.1	11.0	--	0.5	6.8	--	1.0	5.9	5.3
LSD 0.10	0.5	4.2	--	0.6	5.7	--	0.9	9.2	--	0.4	5.7	--	0.8	4.9	4.4

Table 5. Plump and protein of barley varieties at four locations in western North Dakota, 2020.

	Dickinson		Hettinger		Minot		Williston		Avg. western N.D.	
Variety	**Plump**	**Protein**	**Plump**	**Protein**	**Plump**	**Protein**	**Plump**	**Protein**	**Plump**	**Protein**
	---(%)---									
Six-rowed										
Tradition	94	13.3	95	16.8	95	13.9	85	14.6	92	14.7
Two-Rowed										
AAC Connect	96	12.9	96	15.1	91	13.2	95	13.9	94	13.8
AAC Synergy	97	11.9	97	14.8	93	12.5	95	13.6	95	13.2
CDC Bow	96	11.8	97	14.7	94	12.8	95	13.4	96	13.2
Conlon	98	12.2	97	15.6	94	13.2	97	13.0	96	13.5
Explorer	97	11.8	98	16.7	90	13.3	95	13.8	95	13.9
ND Genesis	97	10.7	94	12.8	95	10.8	96	11.4	95	11.4
Pinnacle	97	11.4	97	13.4	95	11.5	95	11.5	96	11.9
Mean	97	11.4	96	14.3	94	12.1	95	12.7	95	13.2
CV %	0.8	4.7	0.9	2.5	1.7	4.3	1.0	3.1	--	--
LSD 0.05	1	0.8	1.2	0.5	3	0.9	1.5	0.6	2.6	0.6
LSD 0.10	1	0.6	1	0.4	2	0.7	1.3	0.5	2.2	0.5

Table 6. 2020 North Dakota oat variety descriptions

							Reaction to Diseases				
		Year	Grain	Height	Straw	Days to	Stem	Crown	Barley	Test	
Variety	**Origin[1]**	**Released**	**Color**	**(inch)**	**Strength**	**Heading[2]**	**Rust[3]**	**Rust[3]**	**Y.Dwf[4]**	**Weight**	**Protein[5]**
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	Meridian	2016	White	33	Strong	64	8	6	NA	Good	M
Deon	MN	2013	Yellow	37	Strong	65	8	2	2	V.good	M
Hayden	SD	2014	White	36	Med.	62	8	6	NA	V.good	M
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
ND Heart	**ND**	**2020**	**White**	**39**	**Strong**	**60**	**3**	**6**	**4**	**Good**	**H**
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	6	1	NA	V.good	M

Bolded varieties were tested for the first time this year, so some ratings may change as new data becomes available.

[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 four locations in eastern North Dakota, 2018-2020.

	Fargo			Casselton			Carrington		Langdon			Average Eastern N.D.		
	Test	Yield		Test	Yield		Yield		Test	Yield		Test	Yield	
Variety	Wt.	2020	2 Yr.	Wt.	2020	2 Yr.	2020	3 Yr.	Wt.	2020	3 Yr.	Wt.	2020	2/3 Yr. Avg.
	(lb/bu)	(bu/a)		(lb/bu)	(bu/a)		-----(bu/a)-----		(lb/bu)	-----(bu/a)-----		(lb/bu)	-----(bu/a)-----	
Beach	39.3	70.8	96.3	40.9	69.2	85.8	132.6	124.8	39.9	184.9	166.9	40.0	114.4	118.4
CDC Dancer	37.4	75.1	93.4	39.8	85.0	72.1	139.9	138.0	36.9	191.5	187.4	38.0	122.9	122.7
CDC Minstrel	33.0	82.6	91.5	35.0	93.0	80.2	120.7	125.8	34.5	199.3	185.7	34.2	123.9	120.8
CS Camden	30.0	84.3	96.3	33.9	92.4	76.0	124.2	138.6	33.6	209.1	201.8	32.5	127.5	128.2
Deon	35.4	109.1	111.1	39.2	110.6	92.3	127.1	135.7	36.6	222.8	196.2	37.1	142.4	133.8
Hayden	33.6	82.8	79.9	37.0	82.3	79.4	122.5	132.8	38.0	180.5	175.3	36.2	117.0	116.8
HiFi	29.8	74.4	84.8	35.0	87.3	68.6	123.5	121.3	36.5	187.6	173.8	33.8	118.2	112.1
Hytest	36.2	79.4	94.5	39.6	85.3	87.5	119.3	122.6	38.9	180.9	159.8	38.2	116.2	116.1
Jury	34.4	85.1	78.7	37.8	70.0	69.4	134.6	129.4	35.4	191.2	196.9	35.9	120.2	118.6
Killdeer	31.3	80.1	79.5	34.4	76.0	70.4	107.5	122.8	36.3	199.3	192.1	34.0	115.7	116.2
Leggett	37.3	99.9	114.6	38.2	98.2	106.2	111.5	121.9	36.6	192.8	192.5	37.4	125.6	133.8
ND Heart	35.5	68.2	68.2	37.5	99.6	99.6	130.8	127.2	37.3	193.6	173.8	36.8	123.0	117.2
Newburg	33.6	77.3	77.5	34.4	75.6	53.9	133.4	130.9	34.9	195.2	180.1	34.3	120.4	110.6
Otana	31.9	72.8	69.0	33.1	60.5	63.6	152.4	134.3	35.1	181.4	182.8	33.4	116.8	112.4
Paul[1]	41.6	41.9	38.6	44.3	59.7	40.4	67.3	73.6	44.0	146.3	141.4	43.3	78.8	73.5
Rockford	32.6	72.5	66.4	35.1	71.7	57.6	120.8	123.1	37.7	170.2	171.9	35.1	108.8	104.7
Souris	33.7	65.7	76.7	34.7	59.4	59.5	111.5	121.1	36.7	186.4	172.6	35.0	105.7	107.5
Stallion	36.4	97.6	94.5	38.8	95.0	85.1	152.9	143.7	38.3	170.3	172.8	37.8	128.9	124.0
Warrior	36.8	107.6	117.6	37.1	95.9	97.5	104.4	--	35.8	179.0	--	36.6	121.7	53.8
Mean	34.8	80.5	85.7	37.1	82.0	76.0	122.9	126.0	37.2	192.0	179.1	36.3	118.3	112.7
CV %	3.1	12.2	--	2.7	10.7	--	15.9	--	1.6	3.7	--	--	--	--
LSD 0.05	1.2	14.7	--	1.4	14.5	--	27.5	--	1.0	11.7	--	2.0	17.7	14.7
LSD 0.10	1.1	11.5	--	1.1	11.3	--	23.0	--	0.8	9.8	--	1.7	14.8	12.3

[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% of the weight).

Table 8. Yield and test weight of oat varieties at four locations in western North Dakota, 2018-2020.

	Dickinson			Hettinger			Minot			Williston			Average Western N.D.		
	Test	Yield		Test	Yield		Test	Yield		Test	Yield		Test	Yield	
Variety	Wt.	2020	3 Yr.	Wt.	2020	3 Yr.	Wt.	2020	3 Yr.	Wt.	2020	3 Yr.	Wt.	2020	3 Yr.
	(lb/ bu)	----(bu/a)----		(lb/ bu)	----(bu/a)----		(lb/ bu)	----(bu/a)----		(lb/ bu)	----(bu/a)----		(lb/ bu)	----(bu/a)----	
Beach	39.4	90.3	94.1	33.4	44.9	96.6	41.8	87.6	119.0	45.0	62.4	94.6	39.9	71.3	101.1
CDC Dancer	37.8	83.7	93.7	33.3	45.2	105.7	41.3	112.9	120.9	46.6	64.9	111.0	39.8	76.7	107.8
CDC Minstrel	37.7	93.9	109.1	33.8	47.8	110.3	41.3	102.2	115.4	45.7	65.1	104.4	39.6	77.2	109.8
CS Camden	35.0	98.5	104.1	32.6	56.4	114.8	38.4	117.5	127.2	44.1	71.7	114.7	37.5	86.0	115.2
Deon	36.9	94.5	113.3	34.6	40.0	96.8	42.6	96.2	113.2	45.4	60.1	105.8	39.9	72.7	107.3
Hayden	38.2	93.2	113.3	34.7	48.2	109.2	42.9	96.6	121.4	45.1	60.7	103.0	40.2	74.6	111.7
HiFi	35.9	93.3	106.9	34.0	50.6	102.1	39.8	92.1	109.1	43.5	61.2	101.2	38.3	74.3	104.8
Hytest	38.2	86.9	93.0	36.3	48.7	93.1	43.3	88.8	113.8	44.9	55.9	80.3	40.7	70.1	95.1
Jury	36.3	93.6	103.8	32.9	48.2	100.9	40.3	91.2	105.7	45.7	68.7	113.1	38.8	75.4	105.9
Killdeer	36.0	102.5	112.5	34.1	48.6	102.5	40.6	93.8	107.4	45.3	74.8	115.9	39.0	79.9	109.6
Leggett	37.9	88.5	93.9	33.0	49.9	103.4	42.9	84.9	116.4	44.5	63.9	112.5	39.6	71.8	106.6
ND Heart	33.8	93.0	98.4	34.0	42.9	99.4	41.5	94.6	112.7	44.4	58.5	89.9	38.4	72.2	100.1
Newburg	37.4	101.3	97.0	32.8	40.5	98.4	41.2	88.6	99.3	45.5	70.0	101.1	39.2	75.1	98.9
Otana	37.9	94.5	100.1	36.0	42.9	99.8	41.3	107.5	106.9	44.3	65.8	105.6	39.9	77.7	103.1
Paul[1]	43.8	62.3	77.3	43.0	32.9	70.4	45.7	77.1	87.6	51.4	41.0	72.1	46.0	53.3	76.9
Rockford	38.2	90.5	104.3	36.5	55.9	112.0	41.2	106.6	120.2	45.5	68.5	108.2	40.4	80.4	111.2
Souris	36.9	103.2	102.9	35.1	46.4	100.8	40.8	91.7	102.3	46.1	63.3	99.4	39.7	76.2	101.3
Stallion	38.7	94.6	104.0	36.4	33.8	91.7	41.5	103.1	119.9	45.3	66.7	102.4	40.5	74.5	104.5
Warrior	36.8	91.6	--	33.3	47.4	--	40.4	99.0	--	44.6	62.0	--	38.8	75.0	--
Mean	37.8	91.3	101.2	34.9	46.8	104.8	41.7	98.1	112.1	45.7	64.1	102.0	39.8	74.4	103.9
CV %	2.6	7.9	--	2.3	7.5	--	2.0	6.8	--	1.3	8.6	--	--	--	--
LSD 0.05	1.4	10.1	--	1.1	4.9	--	1.4	10.8	--	1.0	9.0	--	1.4	8.5	8.9
LSD 0.10	1.2	8.4	--	0.9	4.1	--	1.1	9.0	--	0.8	7.5	--	1.2	7.1	7.5

[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% of the weight).

Table 9. 2020 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.	Fair
Danko	Poland	1976	36	Good	150	Green	Large	Poor
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.
[2] NA = not available.
[3] Hybrid.
[4] Varieties with fair or poor 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, 2018-2020.

	Carrington			Carrington (organic)			Hettinger			Langdon		
	Test	Seed Yield		Test	Seed Yield		Test	Seed Yield		Test	Seed Yield	
Variety	Wt.	2020	3-yr.	Wt.	2020	3-yr.	Wt.	2020	3-Yr.	Wt.	2020	3-Yr.
	(lb/bu)	---(bu/a)---		(lb/bu)	---(bu/a)---		(lb/bu)	---(bu/a)---		(lb/bu)	---(bu/a)---	
AC Hazlet	52.9	56.3	54.8	53.8	41.5	62.0	53.6	50.1	53.0	53.4	54.9	--
Aroostok	51.5	43.4	34.9	53.4	34.0	45.0	50.4	36.6	39.4	52.0	38.9	47.3
Bono	52.8	69.5	--	54.1	55.5	--	54.4	68.9	--	53.0	51.8	--
Brasetto	51.9	64.0	56.4	53.3	58.3	68.5	53.6	64.3	70.9	51.4	68.3	79.9
Dacold	52.1	46.3	47.7	52.6	30.5	54.8	51.1	38.4	39.9	51.9	31.4	51.7
Danko	52.3	43.9	--	53.8	41.5	--	54.0	45.5	--	52.0	27.7	--
ND Dylan	51.8	50.8	52.2	53.3	42.1	60.9	52.1	50.5	47.2	53.2	59.5	67.3
ND Gardner	51.8	51.8	47.0	53.1	39.7	53.5	51.1	38.3	42.9	52.6	49.0	53.6
Rymin	51.5	44.9	51.7	52.7	39.1	60.9	52.9	44.6	49.7	53.1	54.4	54.4
Spooner	52.6	50.7	43.9	53.7	35.7	50.6	52.3	42.2	46.0	52.4	44.7	53.4
Mean	52.1	52.2	48.6	53.4	41.8	57.0	52.5	47.9	48.6	52.7	49.7	58.2
CV %	0.6	11.3	--	0.8	8.1	--	1.8	15.0	--	1.0	17.9	--
LSD 0.05	0.5	8.5	--	0.7	4.9	--	1.4	10.5	--	0.7	12.8	--
LSD 0.10	0.4	7.1	--	0.5	4.1	--	1.1	8.7	--	0.6	10.6	--

Minot			Average		
Test	Seed Yield		Test	Seed Yield	
Wt.	2020	3-yr.	Wt.	2020	3-yr.
(lb/bu)	---(bu/a)---		(lb/bu)	---(bu/a)---	
53.4	105.1	79.1	53.4	61.6	--
53.8	75.1	54.0	52.2	45.6	44.1
54.3	132.8	--	53.7	75.7	--
52.3	130.2	96.9	52.5	77.0	74.5
51.4	93.3	70.9	51.8	48.0	53.0
53.3	86.4	--	53.1	49.0	--
53.1	98.9	73.9	52.7	60.4	60.3
53.2	79.0	61.3	52.4	51.6	51.7
53.9	78.1	69.8	52.8	52.2	57.3
53.2	79.9	58.7	52.8	50.6	50.5
53.2	95.9	70.6	52.7	57.2	55.9
1.8	6.5	--	--	--	--
1.7	10.8	--	0.9	10.0	4.7
1.4	8.9	--	0.7	8.3	3.9

Marshall, Polk, Pennington – Red Lake County Soybean / Corn Growers 2020 Variety Trial Results

Dear Soybean/Corn Grower Member,

Enclosed are the 2020 Soybean Varietal Trial results. This information is brought to you on behalf of the Marshall, Pennington / Red Lake, and Polk County Soybean / Corn Growers Associations. Our trials are funded by seed company entry fees. We would like to thank each seed company for participating in our varietal trials this year. I ask you to relay your appreciation to your seed dealer if you find this project and information worthwhile. Thank you!

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Plot Coordinator,
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Medium Maturity

Brand	Variety	Trait	RM	Marshall	Penn/RL	Polk	Combined
Golden Harvest	0390RR	RR	0.3	70.1	66.2	58.6	65
Legacy Seeds	LS-0239N RR2X	RR2X	0.2	60.8	61.6	57.4	59.9
Legacy Seeds	LS-0320N	Enlist E3	0.3	61.7	57.5	58.2	59.1
Pioneer	P03A17X	Xtend	0.2	58.2	59.2	57	58.1
Pioneer	P03A26X	Xtend	03	58.1	61.5	54.1	57.9
Integra Seed	50309N	Xtend	0.3	52.6	63.9	55.7	57.4
Dyna-Gro	S02EN71	Enlist E3	0.2	55.4	49.4	64.5	56.5
Stine Seed	03EB02	Enlist	03	54.9	52.8	55.5	54.4
LG Seed	LGS 0111 RX	Xtend	0.1	55.2	56.2	51.6	54.3
Pioneer	P01A84X	Xtend	01	55.4	55.4	50.7	53.8
Thunder Seed	SB8903N	Xtend	0.3	57.2	55	48.2	53.5
Stine Seed	01EA63	Enlist	00/01	51.6	54.3	54.3	53.4
Peterson Farm Seeds	2002E	Enlist E3	0.2	54.6	50.1	55	53.2
Thunder Seed	TE7003N	Enlist	0.3	54.3	52.5	52	52.9
Golden Harvest	0145X	Xtend	0.1	53	52.7	52.3	52.7
Dyna-Gro	S03XT29	Xtend	0.3	51.7	50.4	51.1	51.1
Thunder Seed	SB8001	Xtend	0.1	55.7	42.9	53.1	50.6
Integra Seed	40201N	Enlist	0.2	50.1	40.6	54	48.2
Proseed	XT80-20N	Xtend	.2	45	51.8	47.3	48.1
			Mean	**55.6**	**54.4**	**54.2**	**54.7**
			CV	8.3%	11.8%	9.2%	9.9%
			LSD (0.10)	6.3	8.9	6.9	5.6
			LSD (0.20)	4.9	6.9	5.3	4.3
			Top 1/3	70.1 - 61.8	66.2 - 57.7	64.5 - 58.8	65 - 59.3
			Mid 1/3	61.7 - 53.4	57.6 - 49.1	58.7 - 53	59.2 - 53.7
			Bottom 1/3	53.3 - 45	49 - 40.6	52.9 - 47.3	53.6 - 48.1

NW MN Soybean Varietal Trial Results 2020

Planting Date: 5/19/2020 Harvest Date: 9/29/2020

Early Maturity

Brand	**Variety**	**Trait**	**RM**	**Marshall**	**Penn/RL**	**Polk**	**Combined**
Dyna-Gro	S009XT49	Xtend	0.09	55.3	59.8	53.8	56.3
Legacy Seeds	LS-00639N	RR2X	0.06	50.3	61.2	54.5	55.3
Dyna-Gro	S009XT68	Xtend	0.09	54.9	53.1	57.4	55.2
Peterson Farm Seeds	21X007	Xtend	00.7	54.1	56	52.4	54.2
LG Seed	LGS 00899 RX	Xtend	0.08	47.7	57.4	57	54
Proseed	XT70-09N	Xtend	0.09	55.1	52.2	52.5	53.2
Integra Seed	40089N	Enlist	0.08	46.3	56.1	54.4	52.3
Proseed	XT20-07	Xtend	0.07	48.8	44.8	57.3	50.3
Peterson Farm Seeds	19EN008	Enlist E3	00.8	42	51.6	56	49.9
Legacy Seeds	LS-00930 RR2X	RR2X	00.9	49.6	44.5	52.2	48.8
LG Seed	LGS00713E3	Enlist E3	0.07	43	46	54.9	47.9
Proseed	EL80-093	Enlist	0.09	40.4	46.5	53.4	46.8
			Mean	**49.0**	**52.4**	**54.7**	**52.0**
			CV	5.3%	11.3%	7.4%	8.5%
			LSD (0.10)	3.7	8.3	NS	5.9
			LSD (0.20)	2.8	6.4	NS	4.6
			Top 1/3	55.3 - 50.3	61.2 - 55.6	57.4 - 55.7	56.3 - 53.1
			Mid 1/3	50.2 - 45.4	55.5 - 50.1	55.6 - 54	53 - 50
			Bottom 1/3	45.3 - 40.4	50 - 44.5	53.9 - 52.2	49.9 - 46.8

Late Maturity

Brand	**Variety**	**Trait**	**RM**	**Marshall**	**Penn/RL**	**Polk**	**Combined**
Golden Harvest	0443X	Xtend	0.4	56	62.7	61.8	60.2
Golden Harvest	0543X	Xtend	0.5	57	42.3	64.3	54.5
Integra Seed	50510N	Xtend	0.5	53.5	44.3	59.5	52.4
Dyna-Gro	S04XT91	Xtend	0.4	53.8	42.7	59.8	52.1
LG Seed	LGS 0400 RX	Xtend	0.4	52.9	41.1	56.1	50
Legacy Seeds	LS-0438 RR2X	RR2X	0.4	45.3	37.1	64.4	48.9
Golden Harvest	0749X	Xtend	0.7	57.1	21.3	57.8	45.4
			Mean	**53.7**	**41.6**	**60.5**	**51.9**
			CV	10.6%	25.6%	9.4%	15.9%
			LSD (0.10)	NS	16.3	NS	NS
			LSD (0.20)	NS	12.5	NS	NS
			Top 1/3	57.1 - 53.2	62.7 - 48.9	64.4 - 61.6	60.2 - 55.2
			Mid 1/3	53.1 - 49.2	48.8 - 35.1	61.5 - 58.8	55.1 - 50.3
			Bottom 1/3	49.1 - 45.3	35.0 - 21.3	58.7 - 56.1	50.2 - 45.4

Thank you to our 2020 plot cooperators:
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