MINNESOTA WHEAT & SOYBEAN RESEARCH REVIEW

2025

MINNESOTA WHEAT
RESEARCH & PROMOTION COUNCIL

Wheat Research Reports: Funded in Part by the Minnesota Wheat Checkoff

Soybean Research Reports: Funded in Part by the Minnesota Soybean Checkoff

North Dakota State University Variety Trials

2025 Wheat Research Review

In 2025, the Minnesota Wheat Research & Promotion Council allocated about $549,840 of the total $1,523,377 in estimated checkoff income to wheat-related university research and education projects. The 2025 reports from these projects are printed in this book.

Wheat Research Project Funding Process:
Every September, the Minnesota Wheat Research & Promotion Council requests wheat research proposals from researchers in Minnesota, North Dakota and South Dakota. The Minnesota Wheat Research Committee previews and notifies researchers by the end of November if their proposals were selected for review at the Proposal Review Meeting during the Prairie Grains Conference in December. During the meeting, researchers give a presentation in person or via Zoom. Following the presentations, the Research Committee evaluates each proposal and makes their recommendations to the Council in early January.

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 vs. benefit?

In addition to the project reports printed and distributed in this booklet, some of the project researchers deliver oral presentations at the Prairie Grains Conference, Best of the Best workshops and Small Grains Updates. Also, some of the projects are reported in the Prairie Grains Magazine. The Minnesota Wheat Research Committee comprises wheat growers, agronomists, unbiased 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.

UNIVERSITY OF MINNESOTA
EXTENSION

University of Minnesota Wheat Breeding Program

James A. Anderson & Jochum Wiersma

Research Question/Objectives:
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:
The 2025 State Variety Trial, which contained 51 released varieties, 18 University of Minnesota experimental lines, and 3 long term checks was evaluated at 14 locations. Another 175 advanced experimental lines were evaluated in yield trials at 8-9 locations. A total of 392 lines were evaluated in preliminary yield trials: 360 at 3 locations and the remaining 32 lines at one location. A total of 7,031 yield plots were harvested in 2025. Fusarium-inoculated, misted nurseries were established at Crookston and St. Paul. An inoculated leaf and stem rust nursery was also conducted at St. Paul. DNA sequence information was obtained from 2,352 pre-yield trial lines and their FHB resistance, dough mixing properties, and pre-harvest sprouting response were predicted based on a training set of 210 lines and their 53 parents. These predictions were used to help select the 392 preliminary yield trial lines from the 2,352 candidate lines, therefore avoiding more expensive and time-consuming field-based evaluations on more than 1,900 lines with lower genetic potential. Data from the yield and disease nurseries are summarized and published in Prairie Grains and the MAES's 2025 Minnesota Field Crop Variety Trials (https://varietytrials.umn.edu). Table 1 has comparative data of the seven most popular varieties in Minnesota, based on the 2025 variety survey results provided by the MN Association of Wheat Growers.

MN21089-4
Experimental line MN21089-4 (MN14223-5/MN-Rothsay) is undergoing seed increase in Arizona this winter in anticipation of possible release in 2027. MN21089-4 had very high yields in multi-location performance trials from 2022-2024 but was average yielding in 2025. MN21089-4's test weight per bushel is higher than any variety tested in recent years, including the high-quality check variety 'Glenn.' Protein is also relatively high for this yield level, higher than MN-Rothsay, MN-Torgy, and ND Stampede. Straw strength is a '3,' similar to MN-Rothsay. Other traits are acceptable and FHB resistance is comparable to or slightly better than MN-Rothsay.

Table 1. Comparison of experimental hard red spring wheat line MN21089-4 and the seven most popular spring wheat varieties grown in Minnesota in 2025. Entries are sorted based on grain yield (bu/A) over 22 location-years in northern MN since 2023. For traits scored on a 1-9 scale, 1 is best and 9 is worst.

			Grain Yield					Straw	TWT	Prot.	Bake			
	Release	% MN	North, bu/A			HD	HT	Str.	lbs/bu	(%)	Qual.	PHS	BLS	FHB
Variety	Yr.	Acres	2025	2 Yr	3 Yr	d	in.	1-9	2 yr	2 yr	1-9	1-9	1-9	1-9
MN-Rothsay	2022	28.3	109	104	102	64.5	29.8	3	58.5	14.2	5	2	4	4
MN21089-4	2027?	–	104	104	–	61.3	31.6	3	60.3	14.5	–	2	3	3.5
SY Valda	2015	6.8	106	103	102	61.1	31.5	5	58.9	13.8	6	2	4	4
TCG-Zelda	2023	4.6	104	103	–	60.2	30.2	4	58.6	14.3	–	3	6	4
AP Elevate	2024	3.1	104	101	–	62.3	31.0	4	58.7	14.3	–	3	4	4
MN-Torgy	2020	10.4	102	100	98	60.8	31.9	4	59.1	14.5	4	1	3	4
WB9590	2017	19.4	100	98	97	58.3	28.6	3	58.0	14.6	4	2	6	7
WB9479	2017	4.4	98	97	94	58.6	29.7	3	58.4	15.1	1	2	6	7

Application/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 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 8-9 locations. All yield nurseries are grown as 42-70 sq. ft. plots. Misted, inoculated Fusarium head blight and bacterial leaf streak nurseries are grown at Crookston and St. Paul and an inoculated leaf and stem rust nursery is grown 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. Pre-harvest sprouting resistance is assessed on named varieties and advanced lines. 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 5% higher will produce 4 extra bushels/acre in a field that averages 80 bu/A. At $6.00/bushel that equates to more than $12,000 in additional 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 2025 came from the MN Small Grains Initiative via the Minnesota Agricultural Experiment Station (MAES), the U.S. Wheat and Barley Scab Initiative via USDA-ARS, and the MAES's Variety Development Fund.

Recommended Future Research:

We continue to explore adding additional traits to our genomic selection models. Current traits include FHB, BLS, seed size, gluten strength, water absorption, and heading date. Drone images were captured on a weekly basis at out St. Paul location and we are assessing the usefulness of this data and will considering expanding our use of drone imagery in 2026.

Publications:

Gill, H.S., E. Conley, C. Brault, L. Dykes, J.J. Wiersma, K. Frels, and J.A. Anderson. 2024. Association mapping and genomic prediction for processing and end-use quality traits in wheat (Triticum aestivum L.) Plant Genome DOI: 10.1002/tpg2.20529.

Dvorak, J., K.R. Deal, P.E. McGuire, E.J. Conley, J.A. Anderson, G. Fedak, J. Malvick, H. Chen, and H.G. Mueller. 2025. High levels of type II fusarium head blight resistance in wheat conferred by combined expression of wheat gene Fhb1 and Lophopyrum elongatum gene Fhb7The2. Czech Journal of Genetics and Plant Breeding. 61:31-42 DOI:10.17221/104/2024-CJGPB

Brault, C. E.J. Conley, A.J. Green, K.D. Glover, J.P. Cook, H.S. Gill, JD. Fiedler, and J.A. Anderson. 2025. Leveraging historical trials to predict Fusarium head blight resistance in spring wheat breeding programs. Plant Genome, https://doi.org/10.1002/tpg2.20559

Brault, C., E.J. Conley, A.C. Read, A.J. Green, K.D. Glover, J.P. Cook, H.S. Gill, J.D. Fiedler, J.A. Anderson. 2025. Improving genomic prediction for plant disease using environmental covariates. Plant Methods, https://doi.org/10.1186/s13007-025-01418-0.

Gill, H.S., S. Blecha, C. Brault, K. Glover, A. Green, J. Cook, A. Lorenz, A. Read, and J.A. Anderson. 2025. Genetic gains from 60 years of spring wheat breeding in the Northern Plains of the United States. Crop Science, 65(4). https://doi.org/10.1002/csc2.70106

UNIVERSITY OF MINNESOTA
EXTENSION

Minnesota Small Grains Pest Survey 2025

Dr. Anthony Hanson, Dr. Angie Peltier, & Dr. Jochum Wiersma

Research Question/Objectives:
The goals of this pest survey were to produce timely alerts for small grains producers throughout the growing season so that sound economic control options can be implemented. We integrated this survey with the ongoing efforts in North Dakota that are coordinated by NDSU's IPM Survey to improve efficiency and impact of this program across Minnesota and North Dakota. Specific project objectives included:

1) Survey small grain fields each week from mid-May through July in western and northwestern Minnesota small grain production areas monitoring for agronomic, insect and disease issues.

2) Generate survey maps along with NDSU Extension cooperators regarding scout findings.

3) Provide timely alerts about pest and disease issues in small grains so that producers can implement sound economic control options.

4) Estimate the area in which wheat stem sawfly has established successfully as an economic pest in spring wheat in Minnesota

Results:
The 2025 small grain scouting program had 298 unique field visits of 92 fields during the small grain scouting season. These fields were volunteered by producers in early spring and scouted throughout spring and early summer by three survey scouts. Scouts were hired this year based out of Crookston, Moorhead, and Morris. Areas scouted primarily focused on northwestern Minnesota and then south and east to approximately Fergus Falls and Elbow Lake with additional southern sites near Marshall. Scouting started May 28 and continued through the first week of July. A final check for crop status and head disease incidence at most fields was performed between late July and early August.

Data was collected on severity and incidence of the major cereal diseases in Minnesota and some of the important insect pests. Data was submitted each week to the NDSU IPM team that then generated distribution maps for the region (See Appendix). Archived distribution data can be found at: https://www.ag.ndsu.edu/ndipm for various crops. Postings were also made to the Minnesota Crop News Blog at https://blog-crop-news.extension.umn.edu/ for commentary on disease development. There were a total of 13 pest or scout timing related updates posted to the Minnesota Crop News Blog with a total of more than 4,782 views, averaging 435 views per post. One webinar was also held through the growing season Strategic Farming: Field Notes program that focused in part on wheat issues as well as a podcast episode featuring Dr. Jochum Wiersma on challenges with winter cereals in MN through the UMN MN CropCast.

Timely (or excessive) rains appeared to drive most of the pest populations in 2025. However, while some diseases and insects were widespread across the state, their populations or overall severity were generally low this year. Especially with the wet conditions, there were occasional individual reports of more severe disease issues, but in the survey, symptoms were not widespread in most fields. Ergot and loose smut were some of the most commonly found diseases, especially in west-central counties up to Clay and Becker counties, though the percent of infected plants rarely exceed 15%. Fusarium head blight followed a similar trend. Tan spot finds were mostly centered around Wilkin and surrounding counties this year, though severity was extremely low in these fields.

Later in the season, true armyworm became a major issue for growers just prior to harvest (Fig. 1). Adult moths are attracted to grasses for egg-laying sites, and unfortunately the timing of flights often spurred by southerly fronts led to outbreaks across western and central Minnesota in July. True armyworm larvae defoliate plants, but more problematic for maturing wheat is when these larvae start clipping heads to cause major yield loss. Scouts and growers who volunteered fields noticed these outbreaks just as we were conducting end-of-season scouting, and an alert was sent out through MN Crop News (Heavy late-season true armyworm infestations in wheat, July 25, 2025). Insecticide options were very limited due to harvest timing and pre-harvest interval limitations on most insecticides.

Figure 1. True armyworm larvae feeding on wheat heads and leaves in a Becker County, MN field in late July. Photo: Jordan Hunnicutt - 2025 IPM scout.

Cereal leaf beetle (CLB) was another insect concern, though populations appeared to decrease this year. CLB is native to Europe and was first detected in the U.S in Michigan in the early 1960's. Since then, the insect has spread through the eastern states, west to Montana, south to Missouri and east to Virginia. It had been reported previously in southern Minnesota, primarily east of the Minnesota River Valley. Economically damaging infestations haven't been widely reported in Minnesota prior to 2023. More than 3 larvae per flag leaf can cause significant impact on plant growth and vigor, resulting in decreased yield and grain quality. After the boot stage, the threshold lowers to one larva per flag leaf.

Prior to 2023, this insect pest had not been found in northwestern Minnesota, but was found in Clay, Pennington, Red Lake, Norman, Mahnomen, Becker, and Clay, Otter Tail, and Grant counties during our 2023-24 surveys, sometimes at economically damaging levels (Fig. 2). There were no new counties added to this list in the 2025 survey, though CLB was found again in Pennington, Mahnomen, Norman, and Becker counties at much lower population densities than previous years. Of the five fields in 2025 where CLB was found, most had very mild infestations with 2-4% of stems infested. During the 2023 survey, the largest infestation was a Mahnomen field with 30% of stems infested. Since year-to-year insect populations can fluctuate, growers should be actively scouting during the 2026 growing season for cereal leaf beetle in case it has a resurgence year.

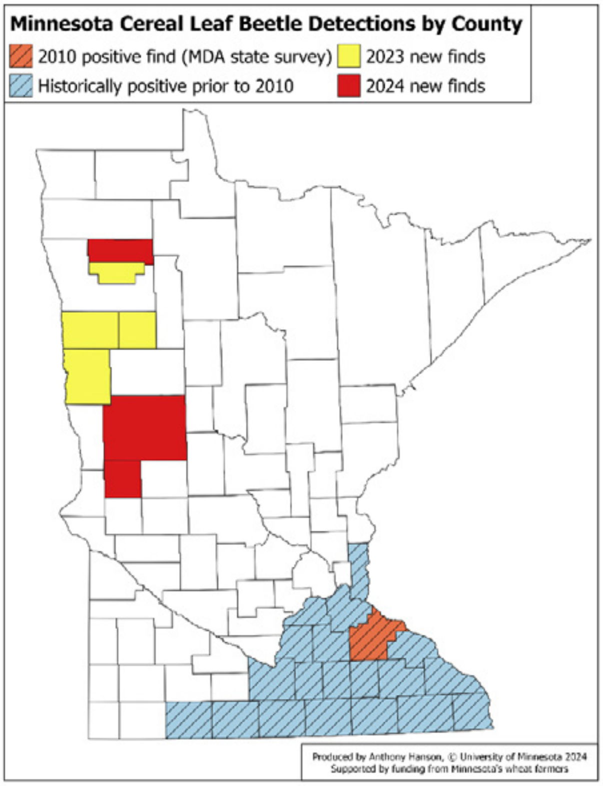


Figure 2. Counties in which cereal leaf beetle has been found since 2023. There were no new finds in 2025 to add to the map, though the insect was found in Pennington, Mahnomen, Norman, and Becker counties that year.

Wheat stem maggot was found primarily in west-central counties again this year, though at lower densities than 2024. Cereal aphid reports were found in nearly every field surveyed this year, but not exceed 1-4 aphids per plant in the state. Barley yellow dwarf virus, a virus vectored by cereal aphids, was found at low levels (1-15%) in west-central counties. Wheat stem sawfly was found Kittson County this year, though it has been found more widespread and at higher population densities in the past. Wheat stem sawfly has been occasionally found in the Crookston area in previous surveys.

Grasshoppers were often found in the sweep net samples though both adults and nymphs were at low population densities throughout the year. Cool, wet weather helped fungi that control grasshopper populations before they became a major risk by increasing egg and nymph mortality. Timely rains during the 2025 growing season may have helped suppress grasshopper populations.

The Season Summary maps by disease or insect are provided in an appendix at the end of the report (Appendix 1).

Application/Use:
Results from this scouting project are used widely by farmers, crop consultants, and Extension educators throughout Minnesota. The in-season commentary published online in Minnesota Crop News blog and distributed to subscribers via email provides Minnesota farmers with real-time pest reports and recommendations to make informed pest management decisions. These results were also used to give updates during summer webinars, such as Strategic Farming: Field Notes. The findings were also included at in-person events such as Farmfest by Hanson and will be included in 2025 winter research updates as well as 2026 pesticide recertification workshops. Wiersma provided information in-person through the Small Grains Summer Plot Tours at cooperator field locations in Rochester (June 10), Le Center (June 11), Benson (June 12), Fergus Fall (June 23), Oklee (June 24), Humbolt (June 24), and Strathcona (June 263). This was the second year of a major new reporting component of the project was to provide any growers who volunteered fields for sampling a link to weekly field status reports. Growers were also directly notified if scouts noticed problems requiring further attention (e.g., true armyworm).

Materials and Methods:
Three scouts operating throughout western Minnesota scouted approximately 20-30 small grains fields per week during the small grains growing season. Scouts underwent training at the beginning of the season to learn how to identify and score pest incidence and severity and how to record the data collected. The MN survey was conducted according to the same protocol followed by the NDSU IPM survey so that the output could be merged and reflect regional trends. The only difference from the North Dakota survey is fields in Minnesota are volunteered each spring to ensure we have permission to scout various fields in addition to variety trial locations. Scouts collected GPS data to aid the construction of distribution maps for each week of data collected for each disease or insect pest. Fields were scouted by walking out past the headland in each field and walking in a "w" pattern, collecting observations on 10 plants at each point of the "w". Sweep nets were used to monitor the number of grasshoppers per four sweeps in field margins and ditches. Incidence and severity data were collected for leaf rust, tan spot, Septoria spot blotch, and Fusarium head blight (FHB). Incidence only data was collected for bacterial leaf streak, Barley yellow dwarf virus, Wheat streak mosaic virus, stem rust, stripe rust, powdery mildew and loose smut. For FHB, scab index was calculated by combining the severity and incidence data. The weekly scouting data was combined and sent to the NDSU IPM team who then used this data to construct both weekly distribution maps, as well as end of season maps. Data was interpreted and distributed weekly as commentaries posted to the Minnesota Crop News blog.

Economic Benefit to a Typical 500 Acre Wheat Enterprise:
A follow-up survey to the users of the Minnesota Crop News blog is necessary to fully assess whether the timely disease and pest updates and commentary altered producer decisions for their disease and pest management in 2024. Each update posted to the Minnesota Crop News Blog had an average of 435 page visits (approximately double the readership of similar articles from 2023 and similar to 2024), indicating a large potential impact with this scouting program as most Minnesota Crop News blog subscribers are farmers or crop consultants. Even small impacts on a typical wheat enterprise have the potential for large economic benefits, as informed pest management decisions can easily provide impacts of more than $10 per acre, with drastically greater impacts in some situations. Even at these conservative levels a 500-acre wheat enterprise could increase gross returns by $5,000 in a given year with timely alerts. This year, the overall lack of some major pest issues in the surveys would reassure growers that risk of economic loss was low, and that extra costs for pest management largely were not needed. This survey also informed growers of new pests, such as cereal leaf beetle, that may lead to additional expense through yield loss or insecticide costs that they may have to prepare for. If cereal leaf beetle becomes a more widespread issue, this survey will help to avoid growers being caught unaware.

Related Research:
This project directly ties in with the North Dakota State University Integrated Pest Management scouting program in North Dakota as reflected by the regional scouting maps produced between the two programs. This project also ties in with the Wheat Stem Sawfly screening program in an effort to identify the geographic area affected by wheat stem sawfly. This project also collaborates with the Minnesota Soybean Scouting project funded by the Minnesota Soybean Research and Promotion Council, as these programs complement each other by providing a full summer scouting experience for scouts, who are able to scout small grains in the spring and early summer, shifting to soybeans mid-summer. We would also like to thank our 2025 IPM scouts who gathered survey data: Stephen McFadzen, Elizabeth Dulmage, Jordan Hunnicutt, and Zoe Hoaglund.

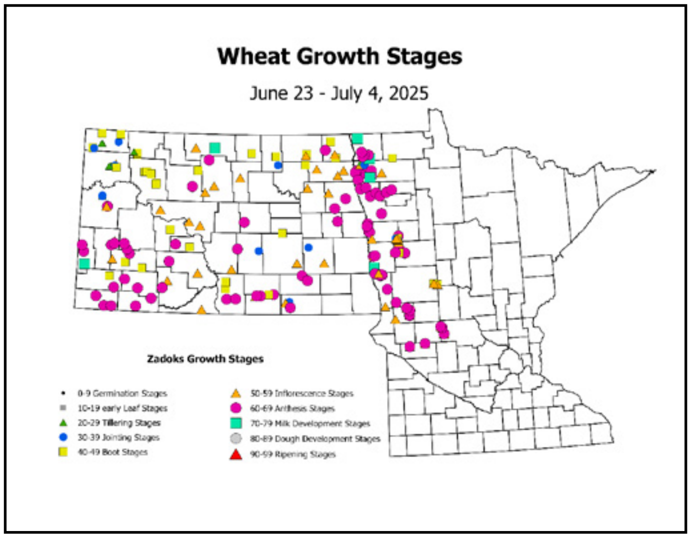
Recommended Future Research:
The PIs would like to continue the small grains pest survey across the state to continue monitoring pest levels in the state and to continue providing well-informed commentaries for Minnesota small grain producers into the future. The hope is to continue the scouting program to include three locations in the state again to obtain better coverage of fields in the western half of the state. In terms of the number of volunteered fields, the northwestern portion of the state is well-represented, though additional effort may be needed to recruit cooperating farmers in west-central Minnesota.

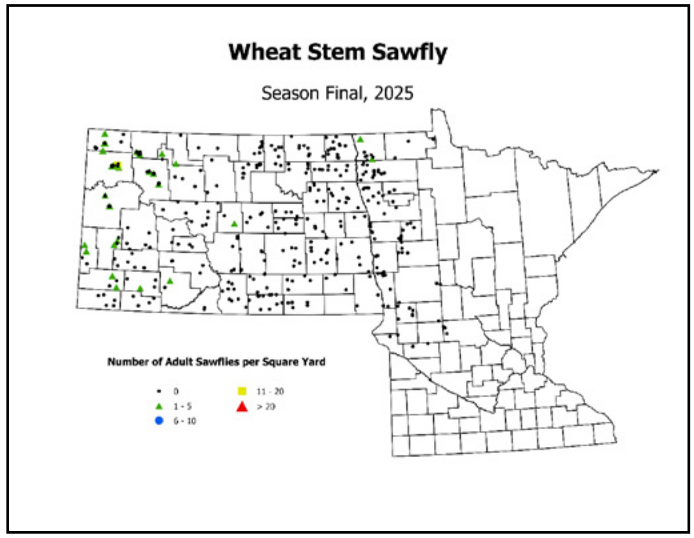
Continuing the survey in future years will also benefit small grains growers by helping to better target education efforts to fit the geographic region occupied by emerging pests, such as cereal leaf beetle.

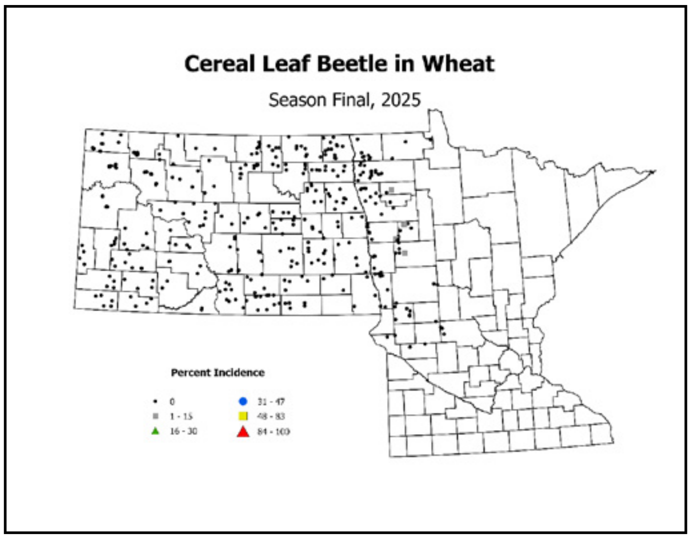
Publications:
Minnesota Crop News (https://blog-crop-news.extension.umn.edu/)

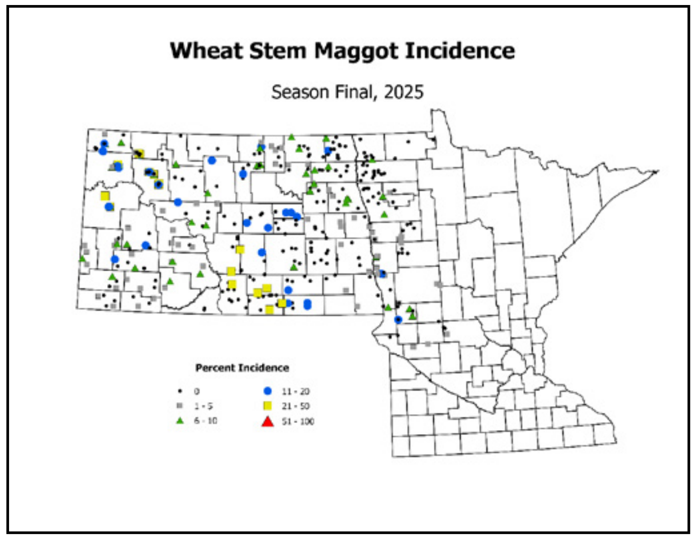
Wheat fields needed for 2025 western summer pest surveys and invasive insect updates. A. Hanson, J. Wiersma, & A. Peltier. April 08, 2025. 521 views.
MN CropCast: Dr. Wiersma on winter cereals - A great idea but will they work in Minnesota? May 29, 2025. 440 views.
Spray Early and Often....Is That Really True? . J. Wiersma. 384 views.
Strategic Farming: Field Notes discusses sidedress N and small grain pests
Small Grains Disease and Pest Update. L. Stahl, J. Wiersma, & F. Fernandez. June 05, 2025. 547 views.
Small Grains Disease and Pest Update 06/10/25. J. Wiersma. 347 views.
How Do Disease Management Decision Support Systems Work? J. Wiersma. June 10, 2025. 317 views.
Small Grains Disease and Pest Update 06/17/25. J. Wiersma. 311 views.
Small Grains Disease and Pest Update 06/24/25. J. Wiersma. 402 views.
Small Grains Disease and Pest Update 06/30/25. J. Wiersma. 416 views.
Small Grains Disease and Pest Update 07/07/25. J. Wiersma. 217 views.
Physiological Maturity in Wheat, Barley, and Oat. J. Wiersma. July 11, 2025. 880 views.
Heavy late-season true armyworm infestations in wheat. A. Hanson, J. Wiersma, & A. Peltier. July 25, 2025. 830 views.

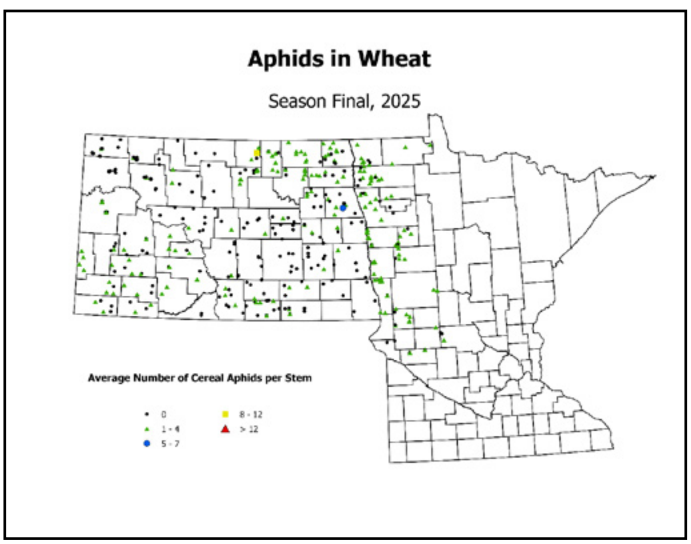
Strategic Farming: Field Notes webinar and podcast (https://share.transistor.fm/s/be3087cf)
June 4, 2025. Nutrient management and sidedress considerations and small grains updates.

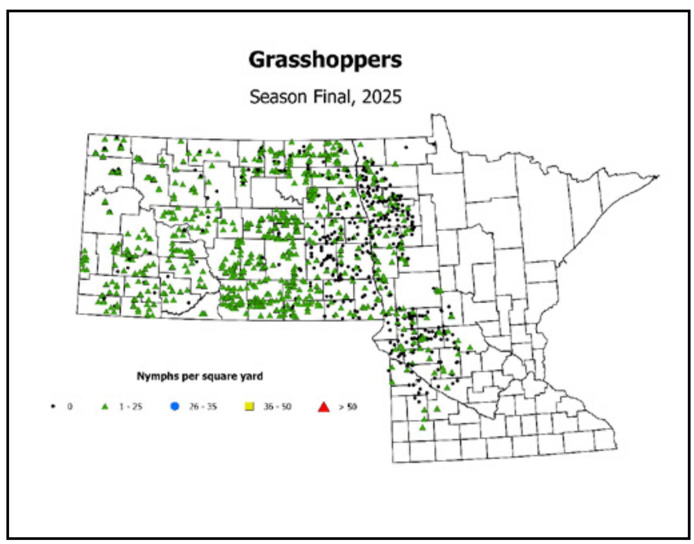

Wheat Growth Stages
June 23 - July 4, 2025
Zadoks Growth Stages
0-9 Germination Stages
10-19 early Leaf Stages
20-29 Tillering Stages
30-39 Jointing Stages
40-49 Boot Stages
50-59 Inflorescence Stages
60-69 Anthesis Stages
70-79 Milk Development Stages
80-89 Dough Development Stages
90-99 Ripening Stages


Wheat Stem Sawfly
Season Final, 2025
Number of Adult Sawflies per Square Yard
0
1 - 5
6 - 10
11 - 20
> 20


Cereal Leaf Beetle in Wheat
Season Final, 2025
Percent Incidence
0
1 - 15
16 - 30
31 - 47
48 - 83
84 - 100

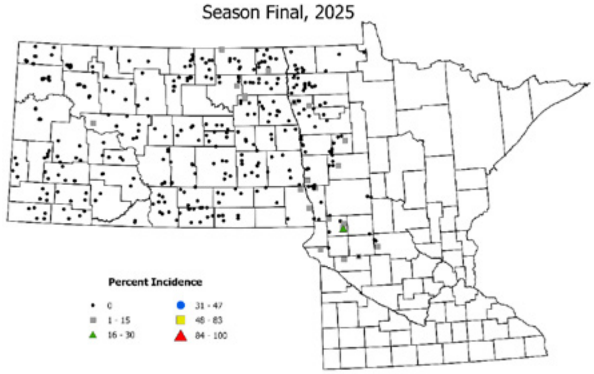

Wheat Stem Maggot Incidence
Season Final, 2025
Percent Incidence
0
1 - 5
6 - 10
11 - 20
21 - 50
51 - 100


Aphids in Wheat
Season Final, 2025
Average Number of Cereal Aphids per Stem
0
1 - 4
5 - 7
8 - 12
> 12


Grasshoppers
Season Final, 2025
Nymphs per square yard
0
1 - 25
26 - 35
36 - 50
> 50

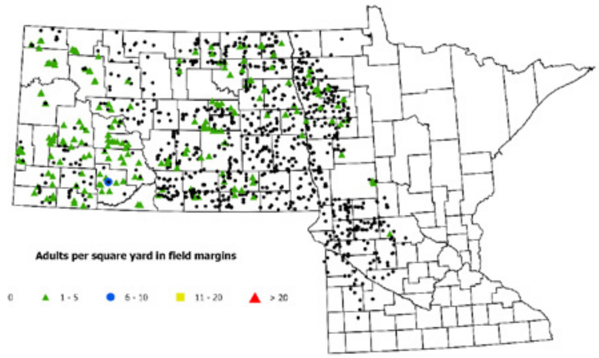
Wheat Ergot Incidence

Season Final, 2025



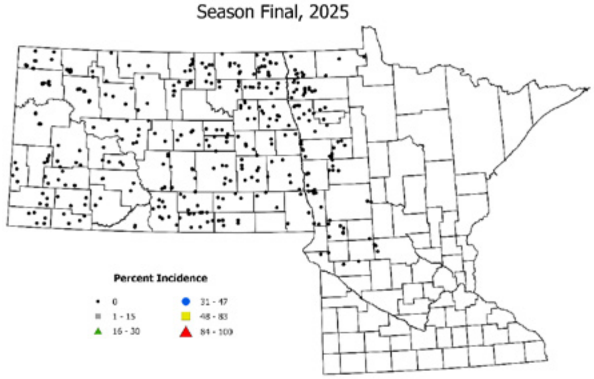
Grasshoppers

Season Final, 2025



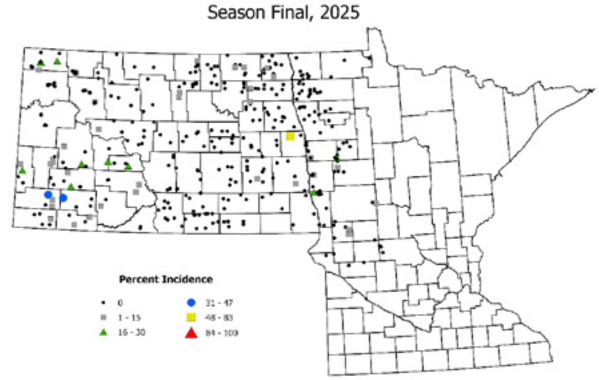
Wheat Flag Smut Incidence

Season Final, 2025



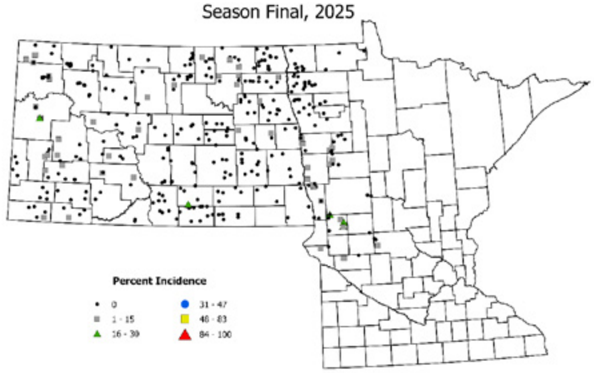
Wheat Bacterial Leaf Streak Incidence

Season Final, 2025



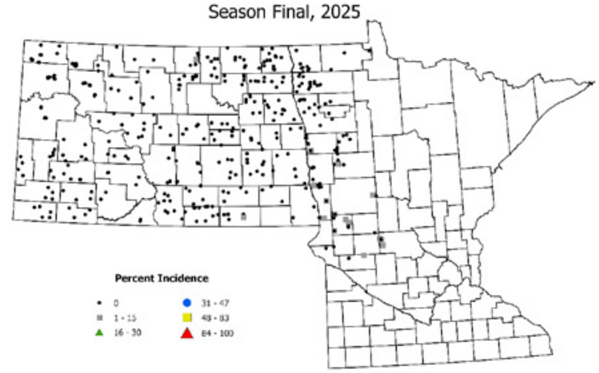
Wheat Loose Smut Incidence

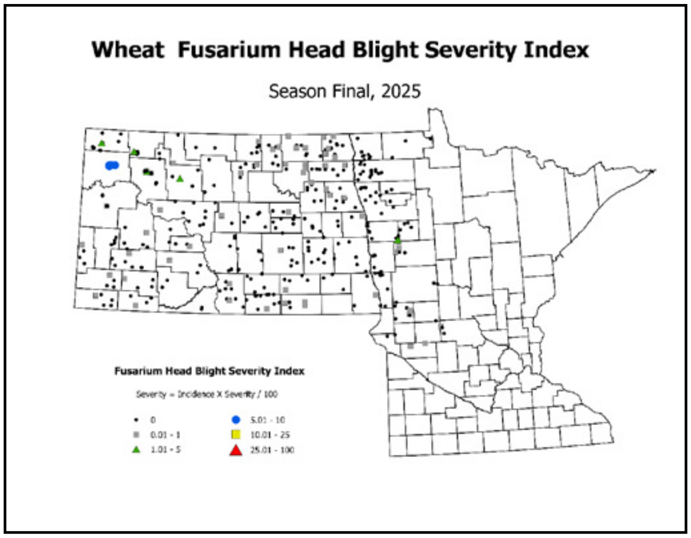
Season Final, 2025

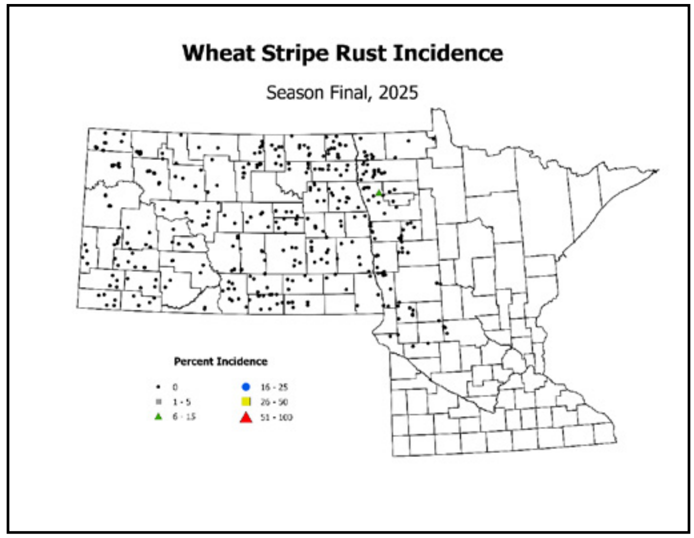


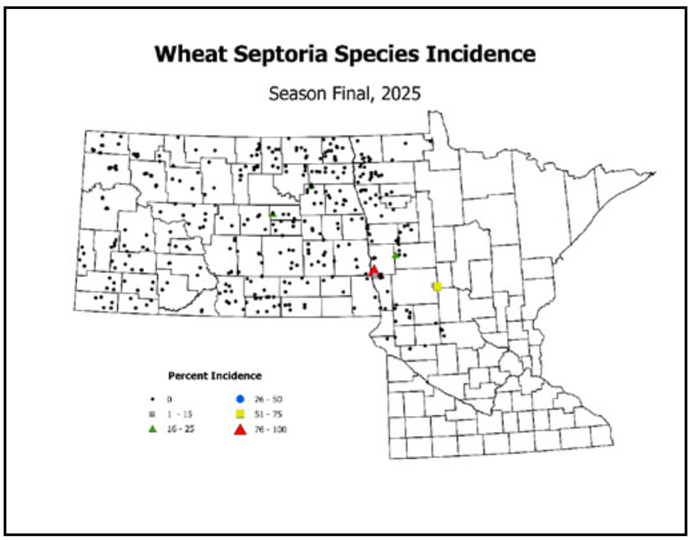
Wheat Barley Yellow Dwarf Virus Incidence

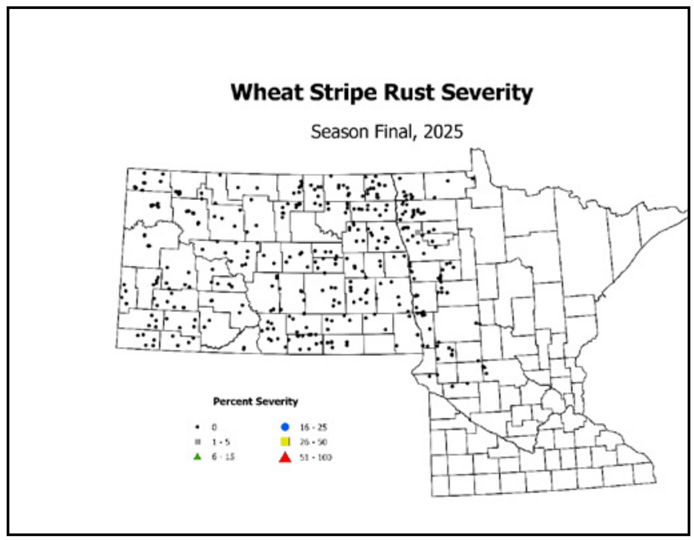
Season Final, 2025

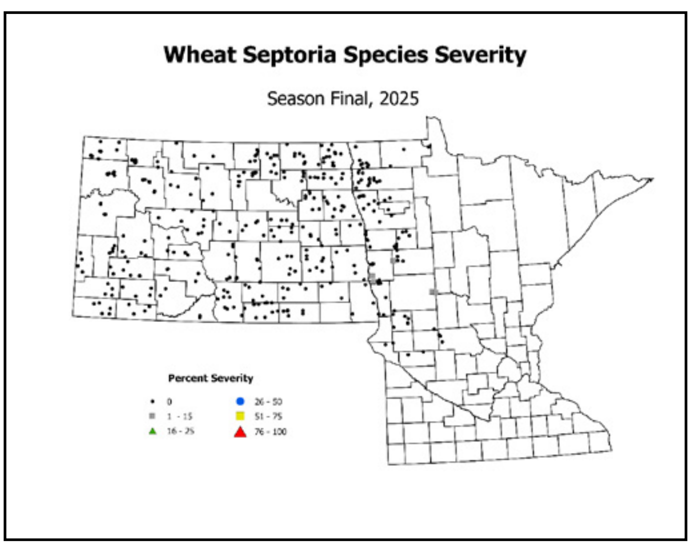


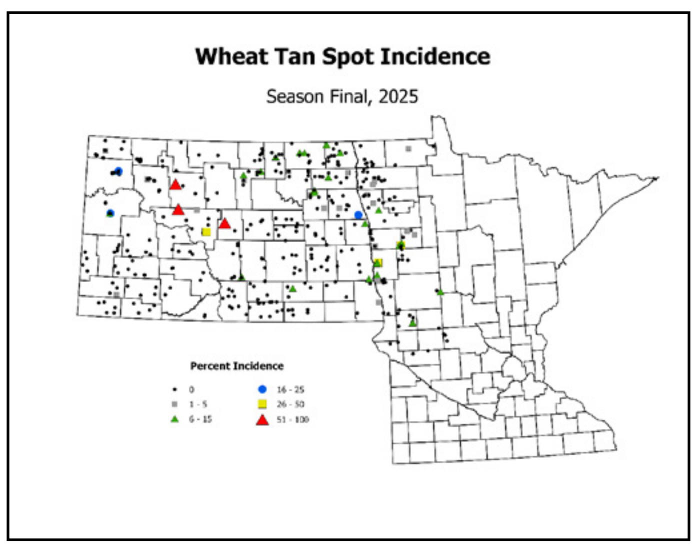

Wheat Fusarium Head Blight Severity Index
Season Final, 2025
Fusarium Head Blight Severity Index
Severity = Incidence X Severity / 100
0
0.01 - 1
1.01 - 5
5.01 - 10
10.01 - 25
25.01 - 100

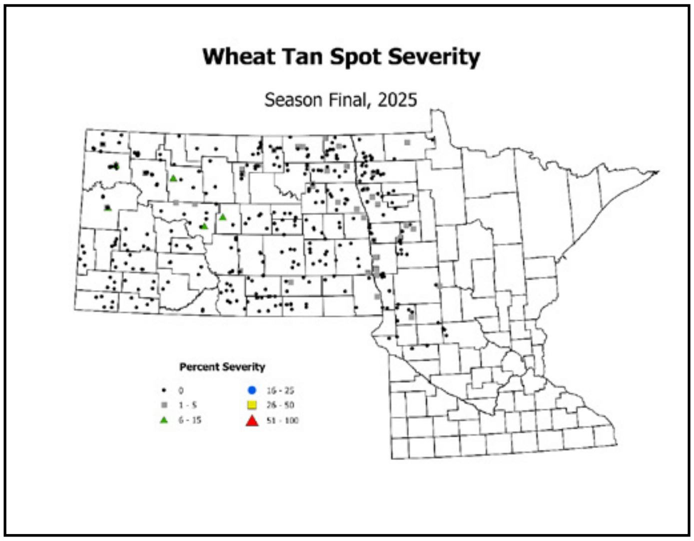

Wheat Stripe Rust Incidence
Season Final, 2025
Percent Incidence
0
1 - 5
6 - 15
16 - 25
26 - 50
51 - 100

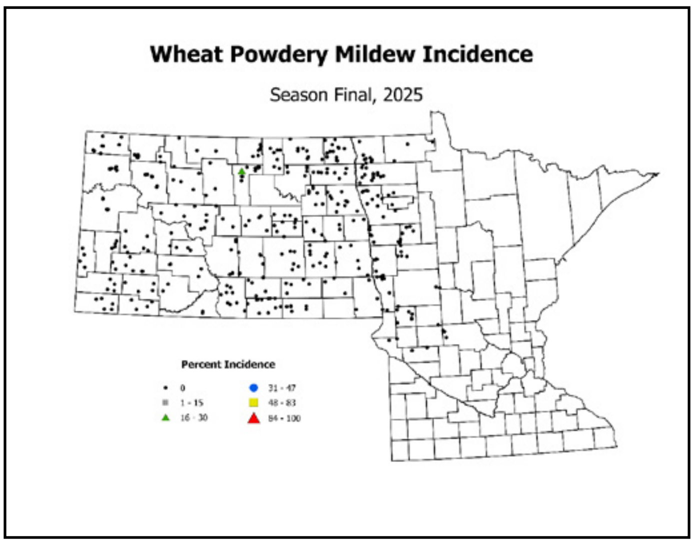

Wheat Septoria Species Incidence
Season Final, 2025
Percent Incidence
0
1 - 15
16 - 25
26 - 50
51 - 75
76 - 100


Wheat Stripe Rust Severity
Season Final, 2025
Percent Severity
0
1 - 5
6 - 15
16 - 25
26 - 50
51 - 100


Wheat Septoria Species Severity
Season Final, 2025
Percent Severity
0
1 - 15
16 - 25
26 - 50
51 - 75
76 - 100


Wheat Tan Spot Incidence
Season Final, 2025
Percent Incidence
0
1 - 5
6 - 15
16 - 25
26 - 50
51 - 100


Wheat Tan Spot Severity
Season Final, 2025
Percent Severity
0
1 - 5
6 - 15
16 - 25
26 - 50
51 - 100


Wheat Powdery Mildew Incidence
Season Final, 2025
Percent Incidence
0
1 - 15
16 - 30
31 - 47
48 - 83
84 - 100

Accelerated Breeding for Resistance to Fusarium Head Blight

Karl D. Glover

Research Question/Objectives:
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 2025 AYT are presented in Table 1. Thirty-six experimental breeding lines were tested along with twelve check cultivars during the 2025 growing season. Of the thirty-six experimental lines, eleven had FHB disease index (DIS) values that were equal to or lower than the test average. Among these entries, six produced more grain than average. Among the six, test weight of four was higher than average. Of these four entries, only SD5175 had a higher protein content than average. Although their protein content was slightly lower than average, both SD5180 and SD5231 are of most interest for potential release as varieties. An initial round of seed increase for SD5180 will take place this winter near Yuma, Arizona. SD5231 may be increased next winter. Sufficient seed quantities of SD5180 should be produced this winter and next summer so that release consideration could be as soon as fall 2026. Each of these lines are more resistant to FHB than average and have been among the most productive AYT entries over the past two growing seasons.

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

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;

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 nine environments in 2025.

ENTRY	DIS INDEX	YIELD (BU/AC)	TW (LB/BU)	PROTEIN (%)	HEADING (D > 6/1)	HEIGHT (INCHES)
BRICK	12	48.3	59.7	15.5	14.7	32.4
SD5256	19.1	48.3	58.9	16	17.3	32.1
SD5175	19.5	52.9	60.4	16.3	16.6	31.5
SD5050	19.5	54.7	60	15.3	17.2	30.2
SD5196	19.6	55.6	59.4	15.6	18.8	30.7
SD5155	19.6	51.8	59.7	15.9	18.8	31.8
SD5231	19.7	59	60.5	15.5	20.9	33.8
SD5278	19.7	47.6	59	16.5	22	32.8
SURPASS	20	49.6	58.5	15.9	15.7	31
FOREFRONT	20	47	59.2	15.7	15.3	35
SD5180	20.4	58.8	60.3	15.4	22.7	32.7
SD5181	20.4	57.5	59.6	15.3	23.2	31.6
SD5241	20.4	50.3	60.6	16.4	15.8	30.4
SD5238	20.4	47	59.5	16.5	21.2	35.9
ASCEND-SD	20.6	55.8	59.5	16	20.9	34.1
SD5277	20.7	47.1	58.3	17	19.8	32.1
ENHANCE-SD	21	56	58.5	16.1	17.3	32.2
SD5235	21.1	50.9	58.5	16.3	23.3	33.2
SD5296	21.1	51.9	59.5	15.6	16.5	31.7
BRAWN-SD	21.2	50.9	59.7	14.9	18.8	31.6
SD5197	21.4	53.6	59.1	15.5	18.9	29.7
SD5247	21.4	55.1	60.4	15.8	18.7	32.9
SD5158	21.5	54.9	61.3	15.3	14.7	31.9
DRIVER	21.7	53.1	60.1	15.6	20.8	32.5
SD5295	22.2	50	59.8	15.9	16.3	31.5
SD5257	22.4	51.6	59.3	16.1	16.4	32.8
SD5262	22.7	47.5	60.3	16.7	17.2	33.1
SD5236	22.8	51.7	59.4	15.9	19.5	32.7
SD5281	22.8	54.1	59.7	15.4	18.8	32.8
SD5287	22.9	50.9	58	15.8	20.1	30.8
SY-VALDA	22.9	52.7	59	15.2	18.8	29.8
SD5138	23.1	52.7	59.7	15.7	15.8	31.2
SD5266	23.1	52	60.6	16	19.1	31.9
PREVAIL	23.3	51.2	58.8	15	17.3	31.7
SD5213	23.4	53.5	59.9	15.9	21.2	30.7
SD5090	23.7	50.8	60.2	15.9	19.2	31.1
SD5189	23.9	54.9	59.1	15.7	21.6	33.4
SD5187	24.5	52.8	58.7	15.9	21.9	33.7
SD5273	24.7	53.6	58.8	16.2	20.8	30.5
SD5103	25	52.5	59.5	15.8	20.9	31.9
SD5243	25	53.7	59.3	16.3	18.8	34
SD5119	25.1	55.9	61	15.3	19.8	27.6
SD5279	26.3	50.5	59.7	15.8	18	33.1
BOOST	26.4	47.7	58.2	15.6	21.1	32.8
SD5096	26.5	57	59.6	15.9	19	30.2
LCS-TRIGGER	27.6	58.1	59.9	13.7	23.7	33.1
SD5134	29.3	50.1	59.1	16.6	19.9	32.4
TRAVERSE	31.7	51.7	56.7	15	16.9	33.5
mean	22.4	52.4	59.5	15.8	19	32.1
lsd	5.1	2.1	0.4	0.2	0.7	0.6
cv	20.2	7.4	1.2	2.8	5.8	3.1

Year 1	Field	Space-planted F2 populations
Year 1	Fall greenhouse	F2:3 hills
Year 1	Spring greenhouse	F3:4 hills
Year 2	Field	F4:5 progeny rows
Year 2	Off-season Nursery	F5:6 progeny rows
Year 3	Field	F5:7 Yield Trials (1 replication, 2 locations)
Year 4	Field	F5:8 Yield Trials (2 replications, 5 locations)
Year 5	Field	Advanced Yield Trials (3 reps, 10 locations)

F2 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 F2:3 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 F3:4 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 F4:5 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 F5:6 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 F5:6 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 2025 AYT are presented in Table 1.

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.

Publications:
Ahmed, Muhammad, Jose L Gonzalez-Hernandez, Shyam Solanki, Karl David Glover, and Gazala Ameen. 2025. First Report of Xanthomonas prunicola causing Leaf Streak Disease on Wheat (Triticum aestivum) in the United States. Plant Disease. https://doi.org/10.1094/PDIS-06-25-1194-PDN

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Brault, Charlotte, Emily J Conley, Andrew C Read, Andrew J Green, Karl D Glover, Jason P Cook, Harsimardeep S Gill, Jason D Fiedler, and James A Anderson. 2025. Improving genomic prediction for plant disease using environmental covariates. Plant Methods 21, 114 (2025). https://doi.org/10.1186/s13007-025-01418-0

Brault, C., Conley, E. J., Green, A. J., Glover, K. D., Cook, J. P., Gill, H. S., Read, A. C., Fiedler, J. D., and Anderson, J. A. 2025. Leveraging historical trials to predict Fusarium head blight resistance in spring wheat breeding programs. The Plant Genome. 18, e20559. https://doi.org/10.1002/tpg2.20559

Kumar Saini, Dinesh, Anshul Rana, Jyotirmoy Halder, Mohammad Maruf Billah, Harsimardeep S Gill, Jinfeng Zhang, Subash Thapa, Shaukat Ali, Brent Turnipseed, Karl Glover, Maitiniyazi Maimaitijiang, Sunish K Sehgal. 2024. Rapid estimation of DON content in wheat flour using close-range hyperspectral imaging and machine learning. The Plant Phenome Journal. https://doi.org/10.1002/ppj2.70001

NDSU EXTENSION

2025 Hard Red Spring Wheat Regional Quality Survey

Dr. Shahidul Islam

Research Question/Objectives:

Annual Survey of Hard Red Spring wheat grown in Minnesota as Part of the Northern Great Plains States.
This report details the survey of hard red spring wheat cultivated in Minnesota in 2025, as a key component of the Northern Great Plains states' wheat production. The survey includes the collection, analysis, and reporting of significant wheat quality attributes that are critical for marketing the crop. Due to a diversity of environmental conditions, cultivars, and agronomic practices across the region, a variety of quality attributes emerge. This survey assesses these important marketing attributes as the wheat enters commercial market channels.

Results:

This year a total of 118 samples of hard red spring wheat were collected from Minnesota, distributed across two regional crop reporting areas, designated as A and B. The sample size from each county was determined by its wheat production volume; counties with higher production yielded more samples. Specifically, in counties with lower production, a minimum of two samples were collected, whereas in high-producing counties, up to fifteen samples were gathered. Efforts were concentrated on obtaining samples that accurately represent the condition of the grain available to the commercial market within each area. The collection of these samples was facilitated under a contract with the USDA-National Agricultural Statistics Service, based in Fargo, ND.

Table 1: list of the collected samples

County	Samples collected
Region A	
Kittson	14
Roseau	13
Marshall	15
Polk	17
Pennington	11
Red Lake	7
Norman	12
Mahnomen	4
Lake of the Woods	2
Region B	
Clay	7
Becker	3
Wilkin	7
Otter Tail	2
Traverse	2
Grant	2

Approximately 60% of the HRS wheat samples collected were graded by a federally licensed grain inspector. These samples were also analyzed for protein content, falling number, test weight, and thousand-kernel weight, providing a basis for estimating assay distributions within the crop. To represent each of the two HRS wheat crop reporting areas (CRAs) in Minnesota, composite samples were prepared by combining equal portions of individual samples.
Comprehensive analyses on these composite samples were conducted to assess quality. Assays included measurements of test weight, falling number, size distribution, protein, ash, 1000-kernel weight, grade, wet gluten, solvent retention capacity (SRC), among others. Milling yields and flour quality traits such as ash and protein content were determined. Dough testing utilized instruments like the Farinograph, Alveograph, and Extensograph. The end-product performance model was based on bread (100 g pup loaves), evaluating baking absorption, bread loaf volume, crumb and crust color, symmetry, grain, and texture properties.

The results were detailed in multiple tables within a published bulletin, and further elaborations are presented in the following pages. Bulletins summarizing findings across HRS-growing states were published and distributed mainly by the sponsoring agencies, with approximately 4,100 copies printed. Additionally, the data are available electronically on the North Dakota Wheat Commission website.

Furthermore, wheat samples representing protein ranges of less than 13.5%, 13.5% to 14.5%, and greater than 14.5% protein (12% moisture basis) were selected from the sample population for detailed analysis. Complete assessments of wheat, flour, and bread baking properties were performed on these categorized samples. Reports on these findings were submitted to U.S. Wheat Associates to aid in their international wheat marketing efforts.

Table 2: Wheat grading data

Crop Growing Area	Test Weight (lb/bu)	Test Weight (KG/HL)	Damaged Kernel (%)	Foreign Materials (%)	Shrunken/Broken kernel (%)	Total Defects (%)	Wheat of Contrast Classes (%)	Grade	Vitreous Kernel (%)
MN A	62.1	81.7	0.3	0.0	0.3	0.6	0.0	1 NS	59
MN B	60.5	79.6	0.7	0.0	0.6	1.3	0.0	1 NS	59
2025 Avg	**61.8**	**81.2**	**0.4**	**0.0**	**0.4**	**0.8**	**0.0**	**1 NS**	**59**
2024 Avg	**61.4**	**80.7**	**1.1**	**0.0**	**0.4**	**1.5**	**0.0**	**1 NS**	**45**

Table 3: Kernel quality data

Crop Growing Area	Dockage (%)	Moisture (%)	1000 Kernel Weight (g)	Kernel Size Distribution medium (%)	Kernel Size Distribution large (%)	Protein Content (%) [Dry basis]	Protein Content (%) [12% moisture basis]	DON (ppm)	Wheat Ash (%)	Wheat Falling Number (sec)	Zeleny Sedimentation (cc)
MN A	0.4	12.9	36.0	35	64	15.9	14.0	0.3	1.45	414	65
MN B	0.4	12.8	29.9	54	43	15.3	13.5	0.7	1.58	399	55
2025 Avg	**0.4**	**12.9**	**34.8**	**39**	**60**	**15.8**	**13.9**	**0.4**	**1.48**	**411**	**63**
2024 Avg	**0.4**	**13.0**	**35.2**	**33**	**66**	**15.2**	**13.4**	**0.9**	**1.52**	**336**	**64**

Table 4: Flour quality data

Crop Growing Area	Extraction (%)	Flour Ash (%)	Flour Protein (%)	Starch Damage (%)	Wet gluten (%)	Gluten Index	Falling Number (sec)	Peak 65G FL	SRC: GPI	SRC: Water	SRC: 50% Sucrose	SRC: 5% Lactic Acid	SRC: 5% Sodium Carbonate
MN A	69.2	0.56	13.3	6.8	34.8	97	406	511	0.67	72	117	144	97
MN B	68.1	0.60	12.3	7.0	32.0	95	412	498	0.63	69	117	135	96
2025 Avg	**69.0**	**0.57**	**13.1**	**6.8**	**34.2**	**97**	**407**	**508**	**0.66**	**71**	**117**	**142**	**97**
2024 Avg	**69.4**	**0.46**	**12.1**	**6.5**	**31.8**	**91**	**357**	**358**	**0.75**	**66**	**105**	**145**	**87**

Table 5: Dough physical properties data (Farinograph)

Crop Growing Area	Absorption (%)	Peak Time min	Stability min	MTI BU	Quality Number mm
MN A	62.7	8.0	13.1	26	151
MN B	61.9	5.6	9.7	25	119
2025 Avg	**62.5**	**7.5**	**12.4**	**26**	**145**
2024 Avg	**60.0**	**6.0**	**11.3**	**27**	**133**

Table 6: Dough physical properties data (Extensograph and Alveograph)

Crop Growing Area	Extensograph						Alveograph			
	Extensibility 45 min	Resistance 45 min	Area cm	Extensibility 135 min	Resistance 135 min	Area cm	P mm	L mm	P/L ratio	W JOULES X 104
MN A	16.7	638	133	16.1	1004	197	94	131	0.72	420
MN B	15.3	552	106	16.0	739	148	83	128	0.65	331
2025 Avg	**16.4**	**621**	**128**	**16.1**	**951**	**187**	**92**	**130**	**0.70**	**402**
2024 Avg	**18.3**	**534**	**118**	**15.3**	**890**	**161**	**81**	**129**	**0.63**	**375**

Table 7: Baking data

Crop Growing Area	Absorption (%)	Dough Handling*	Loaf Volume cc	Grain & Texture*	Crumb Color*	Crust Color*	Symmetry*
MN A	64.9	10.0	900	7.0	7.5	10.0	7.0
MN B	61.8	9.0	955	8.0	7.0	10.0	8.0
2025 Avg	**64.3**	**9.8**	**911**	**7.2**	**7.4**	**10.0**	**7.2**
2024 Avg	**62.8**	**8.9**	**942**	**7.1**	**7.1**	**9.9**	**8.0**

*Dough handling, grain and texture, crumb color, crust color, symmetry all have a scale of 1-10. The highest rating is 10.

Application/Use:

This project stands as one of the most effective strategies for marketing Minnesota-grown HRS wheat, contributing significantly to the enhancement and sustenance of HRS wheat sales both domestically and internationally. Quality analysis results are promptly published in the HRS Regional Quality Report and the US Wheat Associates Crop Quality Report, which serve as key marketing tools for US wheat.

Furthermore, the project's principal investigator, Dr. Shahidul Islam, has presented these quality analysis results to numerous international trade teams and milling companies worldwide, major importers of U.S. hard red spring wheat. Additionally, representatives from U.S. Wheat Associates have also presented these findings to national and international buyers, further bolstering the visibility and marketability of this crop.

Materials and Methods:

SAMPLE COLLECTION – Each sample contained approximately 2 to 3 pounds of wheat, stored in sealed, moisture-proof plastic bags.

MOISTURE – Official USDA procedure using Dickey-John Moisture Meter.

GRADE – Official United States Standards for Grain, as determined by a licensed grain inspector. North Dakota Grain Inspection Service, Fargo, ND, provided grades for composite wheat samples representing each crop reporting area.

VITREOUS KERNELS – Approximate percentage of kernels having vitreous endosperm.

DOCKAGE – Official USDA procedure. All matter other than wheat which can be removed readily from a test portion of the original sample by use of an approved device (Carter Dockage Tester). Dockage may also include underdeveloped, shriveled and small pieces 0f wheat kernels removed in properly separating the material other than wheat and which cannot be recovered by properly rescreening or recleaning.

TEST WEIGHT – American Association of Cereal Chemists International (AACCI) Method 55-10. Measured as pounds per bushel (lb/bu), kilograms per hectoliter (kg/hl) = (lbs/bu X 1.292) + 1.419. *Approved Methods of the AACCI Approved Methods (11th Edition), St. Paul, MN.

THOUSAND KERNEL WEIGHT – Based on 10 gram sample of cleaned wheat (free of foreign material and broken kernels) counted by electronic seed counter.

KERNEL SIZE DISTRIBUTION – Percentages of the size of kernels (large, medium, small) were determined using a wheat sizer equipped with the following sieve openings:
•top sieve—Tyler #7 with 2.92 mm opening;
•middle sieve—Tyler #9 with 2.24 mm opening; and
•bottom sieve—Tyler #12 with 1.65 mm opening.

PROTEIN – AACCI (NIR) Method: 39.10.01 expressed on dry basis and 12 percent moisture basis.

ASH – AACCI Method 08.01, expressed on a 14 percent moisture basis.

DON – Analysis was done on ground wheat using a gas chromatograph with an electron capture detector as described in J. Assoc. Official Anal. Chem 79,472 (1996)

FALLING NUMBER – AACCI Method 56.81.04; units of seconds (14 percent moisture basis).

SEDIMENTATION – AACCI Method 56.61.01, expressed in centimeters.

FLOUR EXTRACTION – Samples are cleaned and tempered according to AACCI 26-01.02. The milling laboratory is controlled at 68 percent relative humidity and 72°F to 74°F. Milling is performed on a Buhler laboratory mill (Type MLU-202). Straight grade flour (of all six flour streams) is blended and reported as "flour extraction."The blended flour is rebolted through an 84 SS sieve. All mill settings are optimized to achieve maximum laboratory mill flour extraction with standardized ash content.

ASH – AACCI Method 08.01, expressed on a 14 percent moisture basis.

PROTEIN – AACCI Method 39.10.01 (NIR Method), expressed on a 14 percent moisture basis.

WET GLUTEN – AACCI Method 38.12.02, expressed on a 14 percent moisture basis determined with the glutomatic instrument.

GLUTEN INDEX – AACCI Method 38.12.02, determined with the glutomatic instrument as an indication of gluten strength.

FLOUR FALLING NUMBER – AACCI Method 56.81.03, units of seconds. Determination is performed on 7.0 g of Buhler milled flour (14 percent moisture basis).

AMYLOGRAM – (65 g) AACCI Method 22.10.01, modified as follows: 65 g of flour (14 percent moisture basis) are slurried in 450 ml distilled water, paddle stirrers are used with the Brabender Amylograph. Peak viscosity reported in Brabender units (B.U.), on a 14 percent moisture basis.

STARCH DAMAGE – AACCI Method 76.31.01. Spectrophotometric method (Megazyme).

SOLVENT RETENTION CAPACITY (SRC) – AACCI 56-11.02, expressed on a 14 percent moisture basis. SRC is used to predict commercial baking performance. Flour is shaken with excess of four types of solvent, to determine the amount of solvent held by the flour. The four solvents used relate to the functionality to flour components as follows: Water – Water absorption; Sucrose – Non-starch polysaccharides; Lactic Acid – Glutenins; Sodium Carbonate – Damaged Starch; Gluten Performance Index (GPI) – is a ratio of the solvents and used as an overall performance of flour glutenins especially in relation to bread wheat flour.

PHYSICAL DOUGH PROPERTIES FARINOGRAM – AACCI Method 54-21.02; constant flour weight method, small (50 g) mixing bowl. (Flour weight 14 percent moisture basis). Farionograph-E.

ABSORPTION – Amount of water required to center curve peak on the 500 Brabender unit line, expressed on 14 percent moisture basis.

PEAK TIME – The interval, to the nearest 0.5 min, from the first addition of water to the maximum consistency immediately prior to the first indication of weakening. Also known as dough development time.

STABILITY – The time interval, to the nearest 0.5 min, between the point where the top of the curve that first intersects the 500-BU line and the point where the top of the curve departs the 500-BU line.

MIXING TOLERANCE INDEX – The difference, in Brabender units, from the top of the curve at the peak to the top of the curve measured five minutes after the peak.

QUALITY NUMBER – AACCI Method 115. The length, expressed in mm, along the time axis, between the point of water addition and the point where the height in the center of the curve decreased by 30 BU compared to the height of the center of the curve at development time. Stronger flours have a higher quality number.

EXTENSOGRAM – AACCI Method 54-10.01; modified as follows: (a) 100 grams of flour (14 percent moisture basis), 2.0 percent sodium chloride (U.S.P.) and water (equal to farinograph absorption minus 2 percent) are mixed to optimum development in a National pin dough mixer; (b) doughs are scaled to 150 grams, rounded, moulded, placed in extensigram holders, and rested for 45 minutes and 135 minutes, respectively, at 30°C and 78 percent relative humidity. The dough is then stretched as described in the procedure referenced above. For conversion purposes, 500 grams equals 400 B.U.

EXTENSIBILITY – Total length of the curve at the base line in centimeters.

RESISTANCE – Maximum curve height, reported in Brabender units (B.U.).

AREA – The area under the curve is measured and reported in square centimeters.

ALVEOGRAPH – AACCI Method 54.30.02. Alveolab is used to measure dough extensibility and resistance to extension.
"P" – Maximal overpressure; related to dough's resistance to deformation.
"L" – Dough extensibility.
"W" – The "work" associated with dough deformation.

BAKING PROCEDURE – AACCI Method 10-09.01, modified as follows: (a) fungal amylase (SKB 15) replacing malt dry powder, (b) Instant dry yeast (1 percent) in lieu of compressed yeast, (c) 5 to 10 ppm ammonium phosphate, where added oxidants are required, (d) 2 percent shortening added. Doughs are mechanically punched using 6-inch rolls, and mechanically moulded using a National Laboratory Test moulder. Baking is accomplished in "Shogren-type" pans.
BAKING ABSORPTION – Water required for optimum dough baking performance, expressed as a percent of flour weight on a 14 percent moisturebasis.

DOUGH CHARACTER – Handling conversion assessed at panning on a scale of 1 to 10 with higher scores preferred.

LOAF VOLUME – Rapeseed displacement measurement made 30 minutes after bread is removed from the oven.

CRUMB GRAIN AND TEXTURE –Visual comparison to standard using a constant illumination source. Scale of 1 to 10, the higher scores preferred.

CRUMB COLOR – Visual comparison with a standard using a constant illumination source on a scale of 1 to 10, the higher scores preferred.

CRUST COLOR –Visual comparison with a standard using a constant illumination source on a scale of 1 to 10, the higher scores preferred.

SYMMETRY –Visual comparison with a standard using a constant illumination source on a scale of 1 to 10, the higher scores preferred.

Economic Benefit to a Typical 500 Acre Wheat Enterprise:
This project has markedly enhanced the market presence of Hard Red Spring (HRS) wheat grown in Minnesota. Wheat quality is understood as the amalgamation of characteristics that determine the excellence of the final product, which is crucial for maintaining the viability of the HRS wheat market to meet the demands of food manufacturers producing sought-after products. Each milling and baking group possesses distinct expectations, which can differ significantly across global export markets due to local consumer preferences. For example, U.S. millers and bakers often have specifications that diverge from those of their international counterparts. Conversely, farmers assess quality based on traits that provide the greatest economic return, indicating that the concept of quality is inherently variable, dependent on the market context. Ultimately, it is the end user who establishes the value of a specific quality standard. This initiative employs advanced quality assessment techniques to measure wheat quality for a variety of uses in both local and international markets.

Related Research:
Since the early 1960s, the Department of Plant Sciences at North Dakota State University has conducted annual quality assessments of HRS wheat grown in North Dakota. These surveys collect, analyze, and report crucial wheat quality characteristics to support marketing efforts. Recognizing that other states in the Northern Great Plains contribute approximately 40% of the region's HRS yield, the surveys from 1980 onward have included data from the four main plains states, collectively representing 90% of U.S. HRS production. Recently, the scope of the survey has been extended to encompass HRS wheat from the Pacific Northwest (PNW), now accounting for about 95% of total U.S. production.

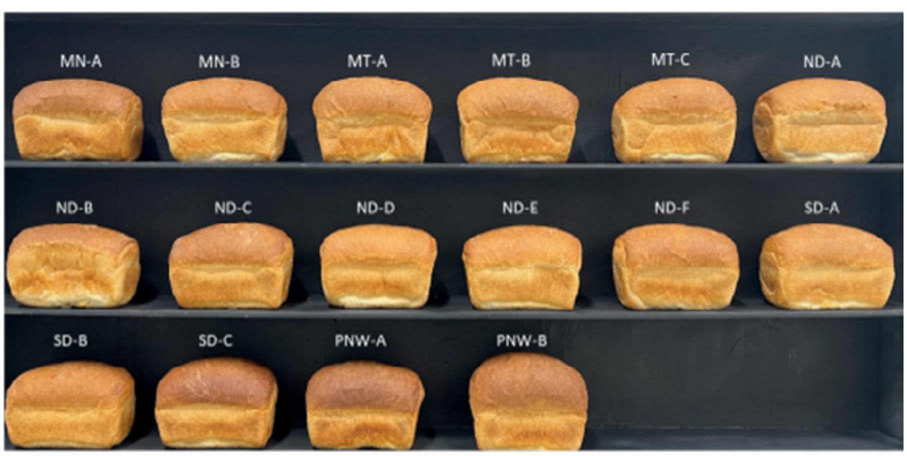
The variation in environmental conditions, crop varieties, and farming practices results in a wide range of quality attributes. By expanding the survey to include the entire Northern Great Plains and the PNW, a comprehensive evaluation of the primary marketing traits of HRS wheat as it enters commercial distribution channels is achieved, enhancing its marketability and industry relevance.

Recommended Future Research:
Wheat quality analysis of every year's production is strongly recommended to be continued as one of the most effective ways of marketing Minnesota grown HRS wheat.

Publications (if any):

- 2024 Regional Quality Report, U.S. HARD RED SPRING WHEAT (https://uswheat.org/wp-content/uploads/2025/10/2025-Hard-Red-Spring-Regional-Report.pdf)

- US Wheat Associates 2025 Crop Quality Report, HARD RED SPRING (https://uswheat.org/wp-content/uploads/2025/10/2025-USW-Crop-Quality-Report-English.pdf)



UNIVERSITY OF MINNESOTA
EXTENSION

Southern Minnesota Small Grains Research & Outreach Project

Dr. Jochum J. Wiersma

Research Question/Objectives:
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, LeCenter, and Rochester.
2. Organize extension programming for small grain production and management in southern Minnesota using summer field days and winter meetings.

Results:
The winter extension programming for small grains production and management in central and southern Minnesota was held in Morris, LeCenter, Rochester, Slayton, and Benson in 2025. Each workshop had a regional focus. Year-over-year attendance held steady with some 150 people in attendance across these five locations. The summer plot tours were held two weeks earlier than usual to (re)educate producers on how to best manage Fusarium head blight. The plot tours were held at the trials near Rochester, Le Center, and Benson. Attendance totaled 50.

A summary of the attained grain yield of the HRSW and HRWW variety trial results can be found in tables 1 and 2. The winter wheat performance trials were located near Lamberton, Le Center, St. Paul, and Becker. The open winter caused more winterkill than most years and the trials near LeCenter and Becker. The average yield across the southern Minnesota locations was 64 bu/acre for HRWW (2 locations) and 74 bu/acre for HRSW (5 locations). 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/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 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 19 and 12 released varieties as entries, respectively. The spring wheat, oats, and barley variety trials had 51, 20, and 14 released varieties amongst the entries, respectively. Trials were organized using a randomized complete block design with either three or four replications. Field preparations and fertility management were completed by plot cooperators and represented typical production practices. 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. This year there was a 19 bu/acre difference between ND-Stampede, the highest-yielding variety across the southern locations, and Linkert, the lowest-yielding HRSW variety across the southern locations. That increases the gross return $95.- per acre when using a cash bid delivery of $ 5.00/bu. That equates to a $47,500 higher gross return for a 500-acre wheat enterprise. All while only changing variety selection. Variety trials are especially valuable in southern Minnesota, where variety trial information is otherwise limited. The ability to recommend varieties adapted to southern Minnesota as well as for farmers to see varieties firsthand before planting them has an invaluable impact on current and future wheat farmers in southern Minnesota. These trials also influence the spring wheat, barley, and oat breeding programs at the University of Minnesota, by allowing on-farm assessments of yield, disease, lodging and other agronomic characteristics that are used to influence future varietal releases and agronomic ratings. These factors further add to the long-term impact that this project has on a typical wheat farm in Minnesota.

Related Research:
This research is integrally linked with the small grain breeding programs at the University of Minnesota. The spring wheat, barley, and oat breeding programs utilize the data generated in these trials as part of their southern small grain variety performance evaluations, which expands the geographical coverage of small grain variety trials as well as provides on-farm credibility to the variety evaluations. Likewise, the winter rye variety trials are co-located at a number of southern locations too.

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 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 Minnesota Field Crop Variety Trials (https://varietytrials.umn.edu/). The 2023 trial results were published in:

1. Anderson J.A. et al. 2024. Hard Red Spring Wheat. In: 2024 Minnesota Field Crop Variety Trials (varietytrials.umn.edu). Minnesota Agricultural Experiment Station. University of Minnesota, St. Paul, MN.
2. Smith, K. et al. 2024. Barley. In: 2024 Minnesota Field Crop Variety Trials (varietytrials.umn.edu). Minnesota Agricultural Experiment Station. University of Minnesota, St. Paul, MN.
3. Smith K. et al. 2024. Oat. In: 2024 Minnesota Field Crop Variety Trials (varietytrials.umn.edu). Minnesota Agricultural Experiment Station. University of Minnesota, St. Paul, MN.
4. Wiersma, J.J. 2024 Winter Rye. In: 2024 Minnesota Field Crop Variety Trials (varietytrials.umn.edu). Minnesota Agricultural Experiment Station. University of Minnesota, St. Paul, MN.
5. Wiersma, J.J. et al. 2024 Winter Wheat. In: 2024 Minnesota Field Crop Variety Trials (varietytrials.umn.edu). Minnesota Agricultural Experiment Station. University of Minnesota, St. Paul, MN.

Entry	Becker	Benson	Lamberton	Le Center	St. Paul	Waseca
	(%)	(%)	(%)	(%)	(%)	(%)
AP Dagr	112	102	94	111	114	107
AP Elevate	104	96	93	104	94	105
AP Iconic	112	108	100	111	97	108
AP Murdock	103	101	104	107	88	107
AP Smith	107	98	94	106	108	95
Ascend-SD	113	98	107	96	103	129
Brawn-SD	105	99	96	99	92	120
CAG Ceres	98	92	103	91	92	98
CAG Recoil	107	103	96	104	106	114
CP3099A	121	106	96	102	81	95
CP3530	102	101	97	103	101	103
CP3555	113	101	98	113	96	93
CP3678	112	96	105	94	102	96
CP3915	91	104	98	99	86	88
Driver	98	88	95	92	96	97
Dyna-Gro 8582	114	109	100	109	117	105
Dyna-Gro Ambush	110	97	90	100	105	104
Dyna-Gro Ballistic	123	104	94	105	103	103
Dyna-Gro Commander	124	110	96	102	103	98
Dyna-Gro Rocker	117	86	103	92	89	95
Enhance-SD	101	106	100	102	114	106
LCS Ascent	107	109	103	101	92	93
LCS Boom	88	98	104	99	87	86
LCS Buster	100	100	110	108	89	104
LCS Cannon	101	102	97	99	86	97
LCS Dual	119	93	100	92	106	97
LCS Hammer AX	98	99	95	102	91	93
LCS Rimfire	114	100	95	97	94	97
LCS Trigger	112	110	98	113	116	115
Linkert	82	87	99	83	86	88
MN-Rothsay	86	101	100	98	107	103
MN-Torgy	90	96	98	95	86	94
MS Charger	90	111	101	109	86	113
MS Cobra	100	96	107	88	76	97
MS Nova	93	97	106	96	93	87
ND Horizon	109	105	104	99	106	104
ND Stampede	122	112	112	113	127	98
ND Thresher	90	98	102	95	84	86
PFS Muffins	109	104	104	106	102	100
PFS Rolls	107	95	101	107	94	105
Shelly	89	101	104	109	109	109
SY 611 CL2	109	97	107	95	89	104
SY Valda	97	101	96	102	100	107
TCG-Arsenal	93	94	99	101	103	114
TCG-Badlands	107	96	109	95	94	97
TCG-Wildcat	99	88	99	91	110	106
TCG-Zelda	119	102	101	102	109	101
TW Olympic	111	97	113	101	100	104
TW Trailfire	105	94	88	94	77	97
WB9479	100	96	104	94	104	87
WB9590	101	106	103	99	99	101
Mean (bu/acre)	58.7	97.8	70.7	91.2	70.4	56.6
LSD (0.10)	17	5	16	10	13	17

Entry	Lamberton	St. Paul
	(bu/acre)	(bu/acre)
AAC Vortex	136	89
AP Bigfoot	84	109
AP Sunbird	86	85
Bickford	84	77
FourOSix	105	85
Jupiter	-	-
LCS Radar	89	111
LCS Steel AX[1]	83	103
LCS Warbird AX[1]	80	107
MT Meadowlark	90	99
ND Allison	140	110
ND Noreen	125	108
SD Andes	134	124
SD Midland	124	120
SD Pheasant	117	104
Viking 211	102	90
WB4422	95	102
WB4540	-	-
Winner	125	117
Mean (bu/acre)	51.1	76
LSD(0.1)	7	8

[1] Variety with tolerance to Agressor AX® herbicide

UNIVERSITY OF MINNESOTA
EXTENSION

Continued Provision of Rapid End-Use Quality Characterization Services to the University of Minnesota Wheat Breeding Program

Dr. George Amponsah Annor, Dr. James Anderson

Research Question/Objectives:

Provide a measure gluten strength and water absorption for University of Minnesota spring wheat lines to improve end-use quality of yield trial lines and variety candidates.

Results:

During this reporting period, we analyzed approximately 650 wheat samples supplied by the University of Minnesota Wheat Breeding Program. We currently have an additional 280 samples recently sent to us by the UMN wheat breeding program and are currently being analyzed. The samples received were evaluated for protein aggregation kinetics using the GlutoPeak Tester (GPT). We recorded peak maximum time, maximum torque, torque before and after the maximum, start-up energy, plateau energy, and aggregation energy. Using regression equations previously developed with support from the MWRPC, we converted the GPT outputs to predicted water absorption values. The resulting water absorption estimates are presented in Figures 1 and 2. For the 2024 F5s, the average water absorption across samples is approximately 54%, with most values clustered between 47–61%. The distribution shows a slight negative skew, indicating a few lower-end values (e.g., around 33–40). For the 2025 PYNZ Remnants, the average water absorption is ~54%, nearly identical to the 2024 F5s.

Figure 1a

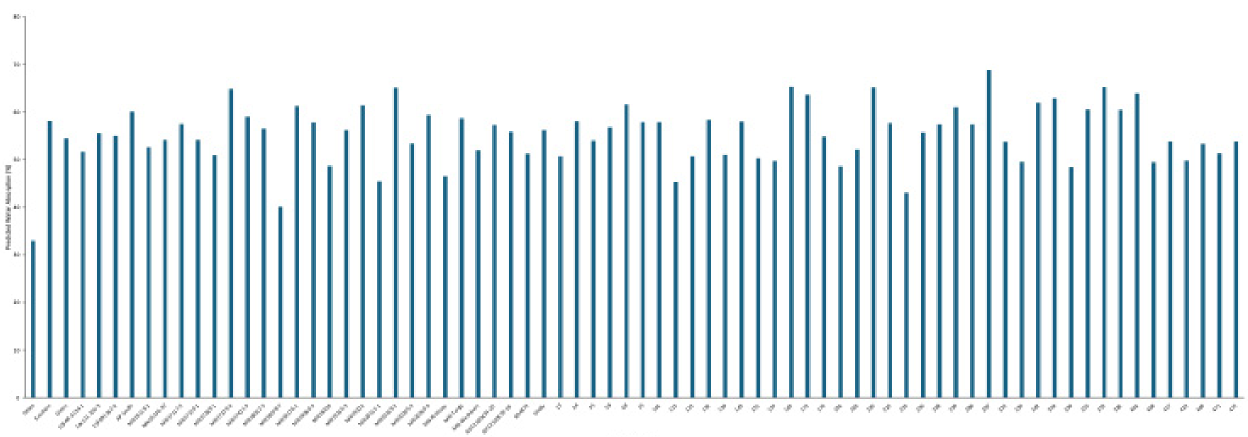


Figure 1b

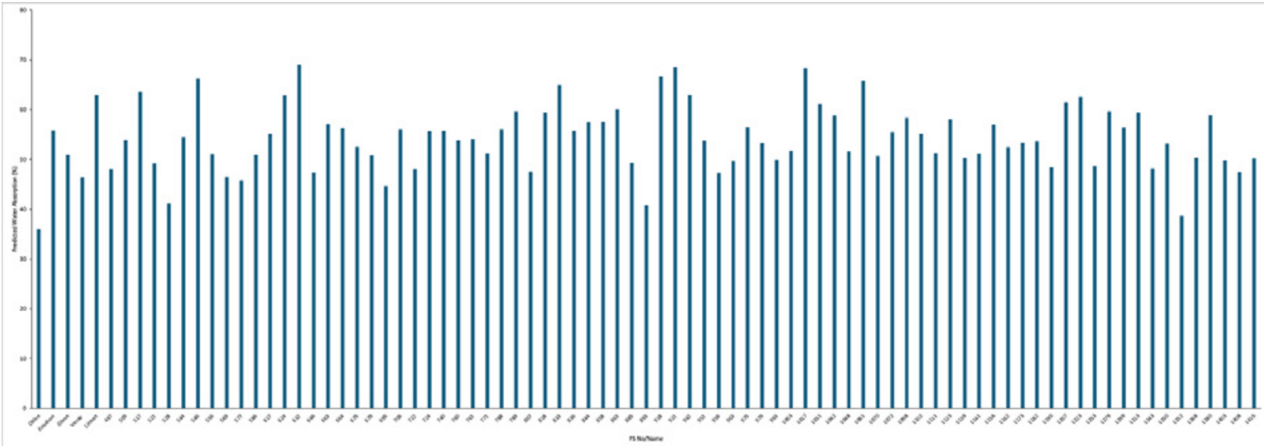


Figure 1c

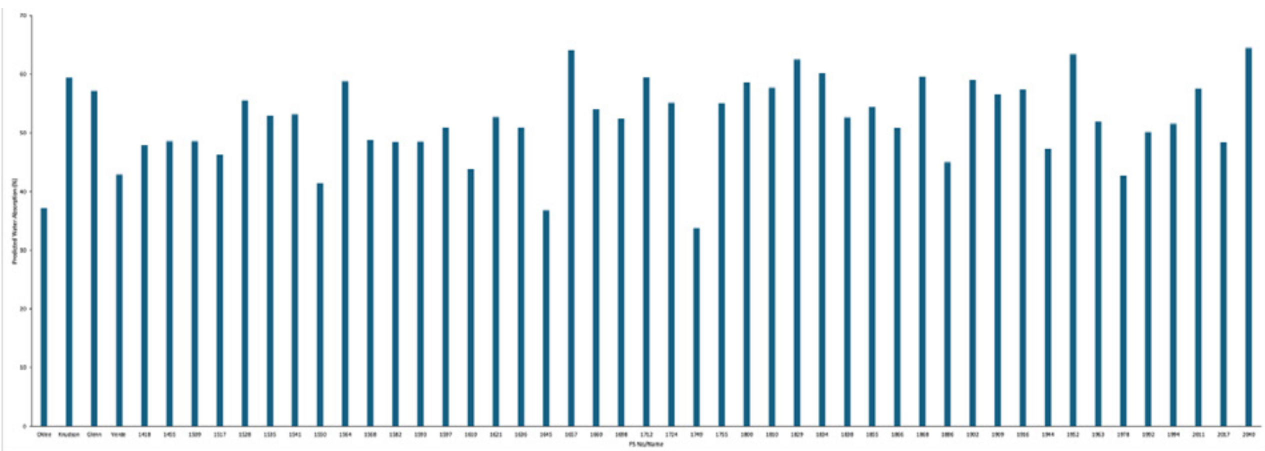


Figure 2a

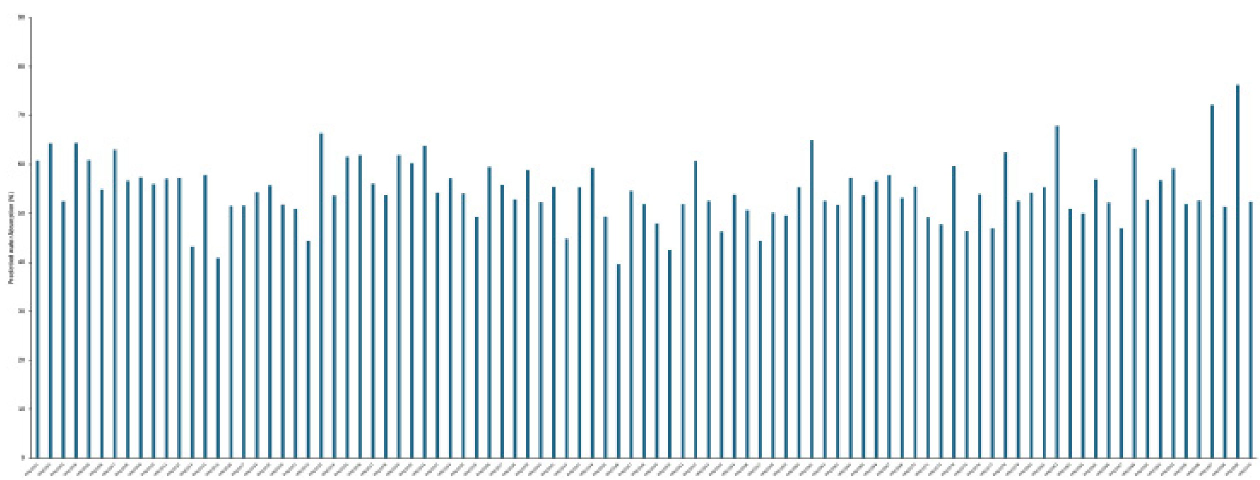


Figure 2b

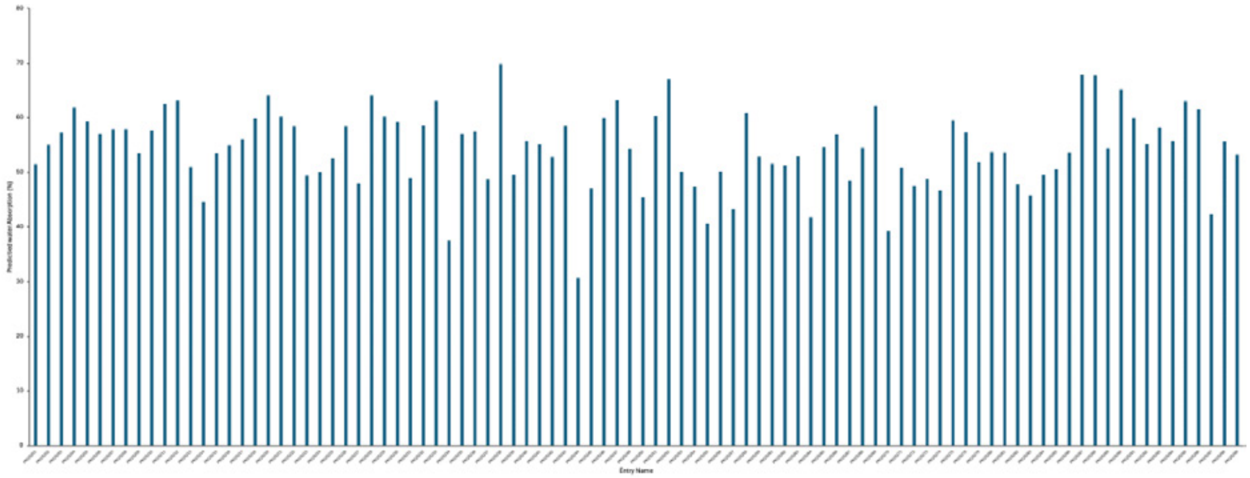
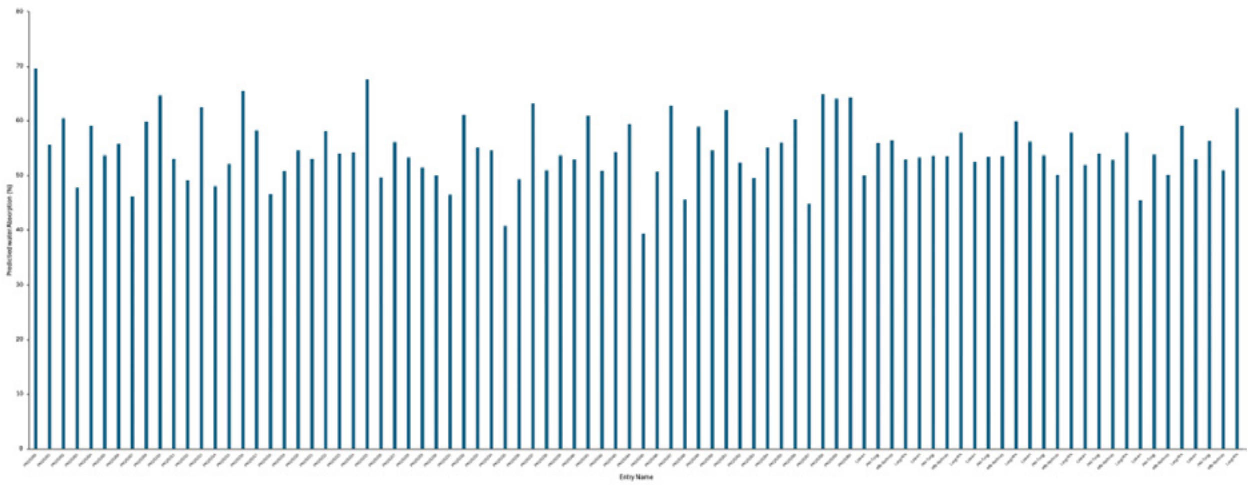


Figure 2c



Application/Use:
The calculated water absorptions, along with grain protein and test weight data are the only end-use quality data the breeding program has available to help decide which of these entries will be advanced for yield trials in 2026.

Materials and Methods:
For this period, we received a total of about 930 samples for analysis. The samples were made up of about 390 wheat samples from the 2025 Preliminary yield (PY) trial remnant seed harvested in New Zealand and 265 samples from the 2024 F5s from Minnesota. The F5 samples are used as a genomic prediction training population and used to develop a predictive model to predict the gluten characteristics of an additional 2,000+ lines. These samples were milled into flour and their protein aggregation kinetics being determined using the Brabender Gluten Peak tester. The samples also included the checks Glenn, Knudson, Linkert, Oklee, and Verde for the F5 samples; and Linkert and MN-Rothsay for the New Zealand samples. We are currently analyzing about 280 samples representing the 2025 F5 cohort.

Economic Benefit to a Typical 500 Acre Wheat Enterprise:
Findings from this study enable the University of Minnesota Wheat Breeding Program to incorporate selection for superior end-use quality at earlier stages of the breeding process, thereby reducing resources spent on advancing poor-quality lines. The results support the development of predictive models for identifying lines and variety candidates with end-use quality traits valued by hard red spring wheat customers. Adoption of such varieties will help sustain the market competitiveness and price premium associated with hard red spring wheat.

NDSU EXTENSION

Organismal Responses During Drought & Recovery in Globally & Regionally Selected Wheat Varieties

Zhikai Liang

Research Question/Objectives:

1. Understanding image-based photosynthetic variations across organs in the single wheat plant resolution under drought stress and recovery conditions;
2. Developing new image-based metrics and statistical models to evaluate drought tolerance and recovery ability in wheats;
3. Quantifying drought tolerance and recovery ability in globally and regionally selected wheat germplasms

Results:

In Year 1, the project focused on installing the PlantExplorer Pro+ system and developing the image-based workflow. In Year 2, we fully implemented this pipeline for high-throughput drought-resilience screening. More than 1,500 individual leaves can be imaged per week using this updated pipeline, yielding >14 quantitative fluorescence-based traits per sample to reflect photosynthesis efficiency over tissue types. Automated analysis in CropReporter™ reduced processing time from several minutes to under two minutes per plant, enabling consistent, repeatable evaluations across large panels. The collaboration with Prof. Marcin Grzybowski (University of Warsaw) expanded our analytical capacity to include NPQ-kinetics modeling, providing dynamic measures of photoprotective efficiency in addition to stable Fv/Fm and NDVI values. The progress in Year 2 demonstrates completion of system optimization and delivery of actionable phenotyping outcomes directly supporting wheat drought-resilience breeding efforts in Minnesota.

Building on the chlorophyll fluorescence imaging results from Year 1, we selected two spring wheat genotypes—CDC Stanley and Rollag—and conducted a high-resolution, time-series water-withdrawal experiment to investigate their physiological responses under progressive drought stress. This high-resolution water withdrawal covered distinct developmental times covering tillering, elongation, heading, flowering and grain filling stages. Our results revealed that water withdrawal occurring between the tillering and elongation stages had the most pronounced impact on overall plant fitness at harvest (Figure 1).

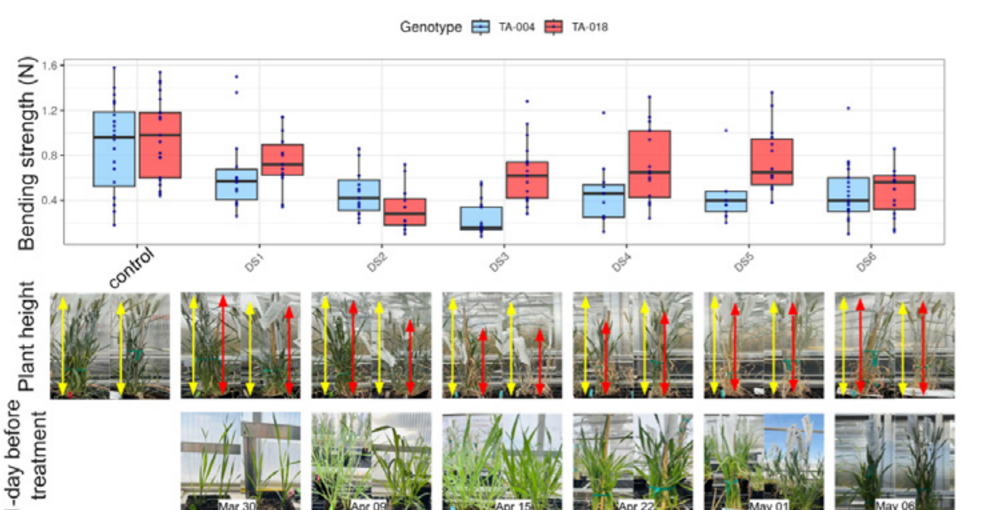


Figure 1. Drought effects at six representative developmental stages on final stem strength and plant height in two wheat genotypes. Stem mechanical strength was measured by peak compression from three-point bending tests. Yellow and red arrows indicate plant height under control and drought conditions, respectively.

Application/Use:

Evaluating crop stress responses is often challenging because plants exhibit a wide range of physiological and morphological reactions that are difficult to quantify precisely. By employing the PlantExplorer Pro+ chlorophyll fluorescence imaging system in this study, we can generate quantitative, image-based metrics—including NPQ, Fv/Fm, and MTR—to objectively assess crop stress responsiveness. The resulting time-series data will allow us to identify developmental stages, particularly tillering and elongation, that are most sensitive to drought stress. Although Northern Minnesota typically receives adequate rainfall, localized drought events can still occur during critical growth periods of spring wheat. Insights from this work will help predict drought-sensitive windows and inform the development of management strategies that minimize yield losses under variable moisture conditions.

Materials and Methods:

In the initial experiment, ten spring wheat varieties were subjected to a two-week drought treatment at the heading stage, while a control group was maintained under regular watering conditions. Soil water content (SWC) was monitored daily using a soil moisture meter to maintain approximately 10% SWC under drought and >30% SWC under well-watered conditions. Each treatment included three biological replicates per variety. After the two-week drought period, all plants were transferred to a dark room for 15 minutes of dark adaptation to allow the photosynthetic machinery to return to a baseline state before imaging. The PlantExplorer Pro+ system was then used to capture side-view chlorophyll fluorescence images following the default protocol, and photosynthetic parameters were extracted using CropReporter™ software. Output data were exported as text files, and t-tests were performed to compare parameter differences between treatments for each variety. For the time-series experiment, two spring wheat genotypes were evaluated across six developmental stages, each with three replicates per stage. Water was withheld for two weeks at each stage, maintaining SWC at approximately 10%. At harvest, each plant was measured for plant height and stem bending strength to assess the physiological impacts of drought across developmental stages.

Economic Benefit to a Typical 500 Acre Wheat Enterprise:

Implementing the PlantExplorer Pro+ system to evaluate and select drought-tolerant wheat varieties offers notable economic benefits for a 500-acre wheat operation. By screening hundreds of candidate germplasms and pinpointing those with superior photosynthetic efficiency and early drought resilience, this technology enables growers to take proactive measures that minimize yield losses under water-limited conditions. The ability to detect early stress responses allows for timely management decisions and the adoption of more resilient varieties. Over time, integrating drought-tolerant varieties identified through advanced phenotyping can improve yield stability and increase overall farm profitability on a per-acre basis.

Related Research:

Photosynthetic parameters such as Fv/Fm and NPQ serve as key indicators of plant health and stress resilience. A decline in Fv/Fm typically reflects reduced photosynthetic efficiency under stress, whereas an increase in NPQ indicates the activation of protective energy-dissipation mechanisms that prevent photodamage. Together, these metrics provide a quantitative framework for assessing how effectively plants respond to and tolerate environmental stress. Although numerous genetic studies have examined photosynthetic responses under stress, most have been limited by the lack of high-throughput tools for quantifying stress-resilience indices. To address this gap, our group is leveraging the PlantExplorer Pro+ system to establish high- and ultra-high-throughput chlorophyll fluorescence imaging pipelines for stress-resilience quantification across multiple crop species.

Recommended Future Research:

In future work, we will focus on this specific developmental stage to better understand how drought events affect the structure and function of key tissues, particularly the stem, which plays a critical role in lodging resistance. By integrating multi-scale phenotyping strategies, we aim to determine how water limitation alters stem integrity and overall plant stability. These insights will help clarify the tissue-specific mechanisms underlying drought-induced yield loss and guide breeding strategies for developing wheat varieties with stronger, more drought-resilient stems.

References:

Sahay, Seema, et al. "Nonphotochemical quenching kinetics GWAS in sorghum identifies genes that may play conserved roles in maize and Arabidopsis thaliana photoprotection." The Plant Journal 119.6 (2024): 3000-3014.

Zivcak, Marek, et al. "Photosynthetic electron transport and specific photoprotective responses in wheat leaves under drought stress." Photosynthesis research 117 (2013): 529-546.

Wang, Huahua, et al. "Involvement of nitric oxide-mediated alternative pathway in tolerance of wheat to drought stress by optimizing photosynthesis." Plant cell reports 35 (2016): 2033-2044.

Gudi, Santosh, et al. "Genome-wide association study unravels genomic regions associated with chlorophyll fluorescence parameters in wheat (Triticum aestivum L.) under different sowing conditions." Plant Cell Reports 42.9 (2023): 1453-1472.

UNIVERSITY OF MINNESOTA
EXTENSION

Optimization of Bacterial Leaf Streak Screening Nurseries for Hard Red Spring Wheat in Minnesota

Rebecca Curland, James Anderson, and Ruth Dill-Macky

Research Question:
Bacterial leaf streak (BLS) continues to be prevalent in Minnesota and poses a significant challenge to wheat production in the Upper Midwest. With no available cultural practices or effective chemical controls for BLS, the most sustainable solution is to develop and deploy BLS-resistant varieties. This project was initiated to ensure our breeding tools are as effective as possible by confirming that our screening techniques are reliable in the face of evolving pathogen populations and variable wheat maturity dates. This project includes two years of field experiments to evaluate the effect of bacterial isolate selection and inoculation timing on BLS symptoms development across 12hard red spring wheat lines.

Objectives:
Isolate screening field nursery: (1) Sequence recent Xanthomonas translucens pv. undulosa isolates (collected 2019-2024) and select two genetically distinct isolates that represent the current pathogen population for field trials. (2) Establish a field trial to evaluate disease response across 12 hard red spring wheat lines when inoculated with the selected isolates.

Inoculation timing field nursery: (1) Established an experiment to identify the best time to apply the BLS pathogen to generate reliable and measurable disease symptoms by assessing the impact of three different inoculation timings (jointing, flag leaf, and anthesis) across 12 hard red spring wheat genotypes on disease severity to ensure that the responses of late-heading varieties to BLS are accurately rated.

Results:
Isolate screening field nursery: We selected two genetically distinct Xanthomonas translucens pv. undulosa strains from a group of ten that were sequenced by collaborators at USDA-ARS (Andrew Read). The ten sequenced strains were isolated from recent BLS outbreaks in Minnesota and included strains representative of the two major phylogenetic clades. These two strains selected (CIX597 and CIX655), plus a 1:1 mixture of these strains, were used in the trial. In the field trials, we observed a range of disease severities, confirming that some lines (e.g. Blade, Boost, and Breaker) maintain stronger resistance, while others (e.g. AP Gunsmoke, Samson, and Select) are highly susceptible (Figure 1). Notably, the wheat lines reacted very similarly whether they were exposed to CIX597 and CIX655 yet showed stronger disease symptoms when inoculated with the mixture.

Inoculation timing field nursery: The earlier inoculation timings, at the jointing stage or the flag leaf stage, gave the most consistent and usable disease ratings (Figure 2). However, when inoculated at the jointing stage, the infection resulting from the inoculation did not move up the plants as they matured resulting in overall lower disease ratings and a narrow range of disease severity ratings. When inoculated at anthesis, plots frequently did not have enough visible disease to accurately score them, because the foliar damage accelerated the senescence of the plant tissue. Inoculation at flag leaf resulted in the development of distinct disease symptoms with a wider range of disease severities across the wheat lines tested, enabling the discernment of resistant-susceptible responses.

Application/Use: The results of the isolate screening study suggest that the moderate resistance previously identified in our panel of wheat lines is effective against the current BLS pathogen population. Additionally, our results ensure that we are using bacterial strains in our screening nurseries that generate appropriate levels of disease to challenge the materials that we are testing. The inoculation timing study indicates that flag leaf may be the optimal time for inoculating field disease screening nurseries. Currently, our nurseries are inoculated within the tillering stages. Consequently, we will adjust our inoculation protocols to target the flag leaf stage.

Materials and Methods:
Isolate screening field nursery: A panel of 12 hard red spring wheat lines was chosen for genetic diversity, differences in heading date, and varying susceptibility to BLS. Varieties were planted in two-row plots with four replications per treatment, arranged in blocks with buffer rows between treatment (isolate) blocks. Plots were inoculated with a bacterial suspension for each treatment (CIX597, CIX655,1:1 mixture of both) at the flag leaf stage using a gas-powered backpack sprayer. Disease severity was assessed visually on a per-plot basis at two- and three-weeks post-inoculation.

Inoculation timing field nursery: In this trial, we utilized the same 12 wheat varieties planted in two-row plots with four replications per treatment, with buffer rows separating the treatment (inoculation timing) blocks. The trial was planted twice in the 2025 season (one early and one later planting date, spaced three weeks apart). Plots were inoculated using a gas-powered backpack sprayer containing a bacterial suspension (strain CIX40, which is currently used in our annual disease nurseries) with each block of plots inoculated at the time point specific to its assigned growth stage (jointing, flag leaf, anthesis). As there was variation of plant maturity within the lines included in this study, inoculation timing was determined by the date when the majority (>75% of plants) had reached the selected growth stage. Disease severity (1-9 scale) was assessed visually on a per-plot basis at two- and three-weeks post-inoculation for each timing treatment.

Economic Benefit to a Typical 500 Acre Wheat Enterprise: The development of BLS-resistant varieties, facilitated by the optimized screening methods from this project, will provide direct benefits to Minnesota growers. As no chemical or cultural practices have currently been identified to reduce the impact of BLS, current management efforts rely on identifying and integrating resistant germplasm into wheat breeding pipelines. The project helps to ensure that future breeding efforts are more efficient, leading to faster development and release of resilient wheat varieties.

Related Research: In collaboration with Andrew Read (USDA-ARS), we sequenced and analyzed ten Xanthomonas translucens pv. undulosa isolates that were collected in Minnesota within the last five years. The results of this genomic analysis informed the selection of the isolates used in this study.

Recommended Future Research: In Year 2 of this project, we will repeat both 2025 field experiments to validate the isolate and timing results across a second growing season and diverse environmental conditions. Following analysis of our combined years of data, we will integrate the optimal timing and isolate selection into the cooperative BLS screening nursery to improve the quality of data collected for all breeding programs. Upon completion of the biennial project, we plan to submit a manuscript detailing the optimized screening protocol and its impact on disease phenotyping to a peer-reviewed journal.

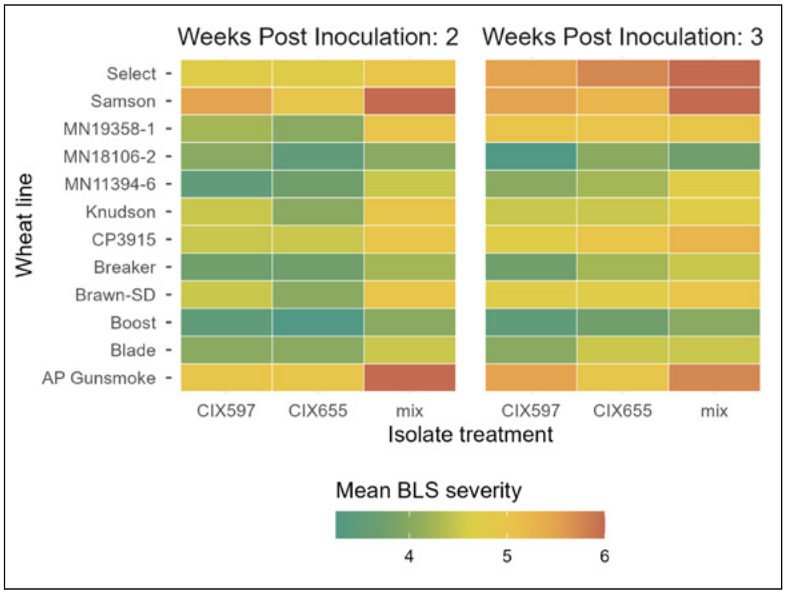


Figure 1. Mean bacterial leaf streak (BLS) severity of twelve hard red spring wheat lines inoculated with different Xanthomonas translucens isolates. The heatmap shows the mean BLS severity (scale 1-9, where 1 is resistant and 9 is highly susceptible) for each wheat line when inoculated with isolate CIX597, CIX655, or a 1:1 mixture of both. Disease severity was assessed at two time points two- (2) and three-weeks (3) post-inoculation. Lower severity values (green) indicate higher resistance, while higher values (red) indicate greater susceptibility.

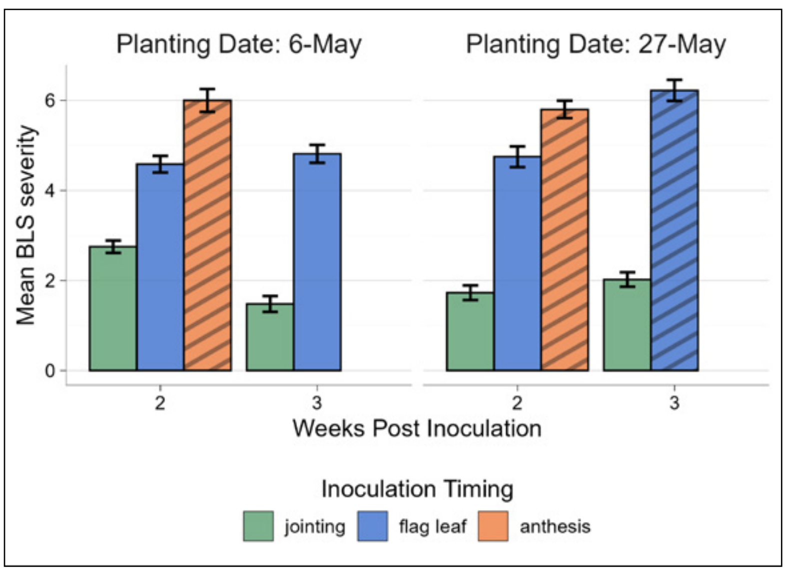


Figure 2. Mean bacterial leaf streak (BLS) severity across different inoculation timings and planting dates. The bar graph illustrates the mean BLS severity (scale 1-9) averaged across 12 hard red spring wheat lines for three inoculation timings (jointing, flag leaf, anthesis) and two planting dates (May 6 and May 27), assessed at two- and three-weeks post-inoculation. Each solid-colored bar represents 48 observations. Each striped bar indicates that disease severity could not be assessed for all plots (25-35% of total plots were assessed in these cases), due to advanced plant maturity preventing sufficient symptom observation. No observations were captured at three-weeks post inoculation for the plants inoculated at anthesis stage due to senescence.

UNIVERSITY OF MINNESOTA
EXTENSION

Breeding to Boost Seed-Filling & Increase Minnesota Wheat Yields

Walid Sadok, James A. Anderson

Research Question/Objectives:
Seed-fill is the 'money-making' window for wheat growers. During this critical phase of the crop's growth, the wheat plant invests aggressively all the carbohydrates and nitrogen that are available, to fill the developing grain with protein, starch and other nutritional factors. Based on our meta-analysis of yield and physiological data across the world (Ding et al. 2025), we recently identified a novel trait that has the potential to increase the rate of seed-fill in wheat and therefore increase yield. Our hypothesis is that increasing flag leaves photosynthesis during that window could lead to yield increases. This is because a higher rate of photosynthesis means a higher rate of translocation of sugars, proteins and other nutritional factors to the developing seed. Over the two years of this project, our main objective was to test whether historical yield increases achieved by 30 MN cultivars released over a century of breeding (1915-2022) are associated with such changes. If so, then it will mean that future increases in yield can be further increased by intentionally breeding for higher seed-fill photosynthesis. A second objectives was to identify varieties that express superior photosynthesis during seed-fill and thus, could be used as donors in next generation breeding crosses. A third objective was to develop the basis of a high-throughput technique for detecting genotypic difference in photosynthesis across genotypes to support the breeding program.

Results:
Yield results averaged over two years of trials are reported on Figure 1. The data shows that the historical panel of 30 wheat cultivars expressed indeed large variation in yield, and that the U of MN wheat breeding program has succeeded in increasing the yield potential of MN-adapted spring wheat varieties consistently from 1915 to 2022. The data shows an acceleration of the rate of genetic yield gains, picking up starting from 1970, as a rate of 30 kg/ha/yr or 0.45 bu/ac/yr. Data from both years confirms the observation that variation in flag leaf photosynthesis during seed fill positively correlated with the year of release of the tested varieties ($P < 0.0001$, $R2 = 0.16$). This result indicates that higher yields achieved by the wheat breeding program over a century of breeding are at least in part due to rising photosynthesis during seed-fill. Consistently with this hypothesis, wheat yields correlated positively with flag leaf photosynthesis ($P < 0.0001$, $R2 = 0.14$). Furthermore, we found that measurements of leaf greenness, which are 100x faster than those of photosynthesis, are highly correlated with flag leaf photosynthesis ($P < 0.0001$, $R2 = 0.67$, Figure 2). This promising result shows that it is possible to use leaf greenness as a fast and reasonably accurate way to screen for increased flag leaf photosynthesis during seed-fill. This indicates that moving forward, we can use flag leaf greenness as a high-throughput screening tool to support direct selection for higher photosynthesis during seed-fill and thus breed for higher yield.

Application/Use:
This research is enabling the development of a new breeding pipeline to rapidly screen hundreds/thousands of breeding lines for higher flag leaf photosynthesis during the seed-fill window as a new strategy to increase MN wheat yields. This pipeline will support the U of MN breeding program by making it possible to screen a larger number of breeding lines and identify promising ones at lower costs, that is, without necessarily needing multi-location yield trials at each round of selection. Additionally, once fully matured, this approach could potentially be deployed on mapping population and thus enable detecting genes underpinning higher yield and pyramid the favorable alleles in elite genetic material.

Materials and Methods:
For this study, we have grown a diverse set of 30 lines consisting of i) check cultivars (Shelly, Linkert, MN-Torgy, MN-Rothsay), ii) varieties with different years of releases and iii) a selection of highly diverse advanced breeding lines. These genotypes were field-planted in yield plots (approx. 4 ft. X 9 ft.) at the U of MN St Paul campus, using a randomized complete block design

with three replications. Plots were managed per the typical management practices. Flag leaf photosynthesis was measured at solar noon on sunny days using a portable photosynthesis system (LiCOR 6800). Photosynthesis was also measured indirectly by tracking leaf greenness both proximally and remotely. The proximal measurement consists of using a small hand-held chlorophyll meter (MC-100 Chlorophyll Concentration Meter) that clamps on the leaf to measure its greenness. The remote-sensing approach relies on scanning the entire canopy using an RGB (Red-Green-Blue) camera mounted on an unmanned aerial system (UAS; Inspire 2, DJI), following protocols developed by the wheat physiology lab (Lopez et al., 2022). These greenness measurements represent indirect measurements of photosynthesis, and therefore they are less precise, but are much faster to perform.

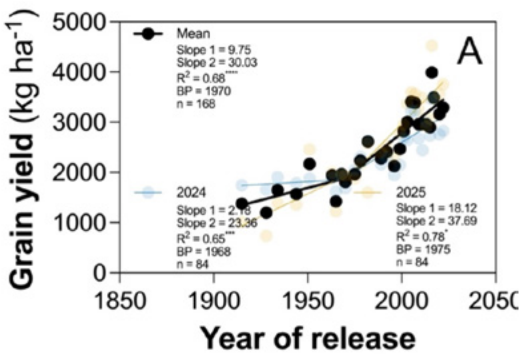


Figure 1. Yield gains as a function of the year of release across 30 varieties released by the U of MN wheat breeding program from 1915 to 2022 (two varieties are missing due to severe rust infestation).

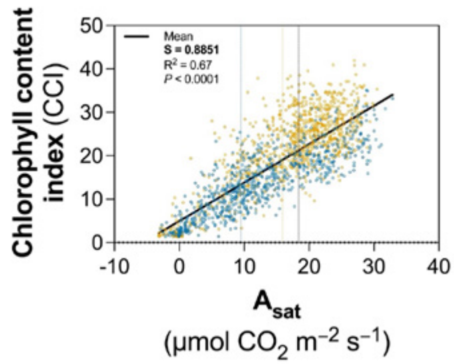


Figure 2. Strong relationship between chlorophyll content index (CCI) and light-saturated flag leaf photosynthesis (Asat) across the tested population of spring wheat varieties released by the U of MN wheat breeding program from 1915 to 2022. Data is based on > 1600 field-based observations.

Economic Benefit to a Typical 500 Acre Wheat Enterprise:
Our goal is to support the development and release of higher-yielding wheat varieties to MN growers and thus maximize farmers' economic returns. Our research has discovered that rising flag leaf photosynthesis during seed-fill has likely contributed to historic yield increases in MN-grown wheat. This means that MN wheat breeders can now intentionally breed to boost yields by specifically targeting the improvement of seed-fill photosynthesis. In addition to this important discovery, we are developing remote-sensing techniques that aim at making this screening effort cheaper and higher-throughput to accelerate the breeding effort. Both outcomes will boost the ability of the U of MN wheat breeding program to deliver more productive wheat at a faster rate to the farmer.

Related Research:
This project directly supports research benefitting the U of MN wheat breeding and wheat physiology programs. The historical yield trials are also being used to understand the role of "Green Revolution" genes on flag leaf photosynthesis and boost their combined benefits on grain yield. The approach being developed for this project is based on a global meta-analysis of worldwide wheat yield trials recently published by the wheat physiology team (Ding et al. 2025).

Recommended Future Research:
Future research will focus on developing a high throughput screen using flag leaf greenness as a proxy for higher yield for much larger breeding populations. Once the pipeline is matured, an ultimate goal would be to deploy it on mapping populations so that we will be able to map and isolate genes associated with this trait and use them for marker-assisted breeding for higher MN wheat yields.

Publications:
Lopez, J.R., Tamang, B.G., Monnens, D.M., Smith, K.P. & Sadok, W. (2022). Canopy cooling traits associated with yield performance in heat-stressed oat. European Journal of Agronomy 139, 126555.

Ding, Q., Zhen, X. & Sadok, W. (2025). Photosynthesis-driven yield gains in global wheat breeding trials. Crop Science 65 (1), e70005.

South Dakota State University Extension

Breeding Resilient Winter Wheat Varieties for FHB Resistance & Straw Strength

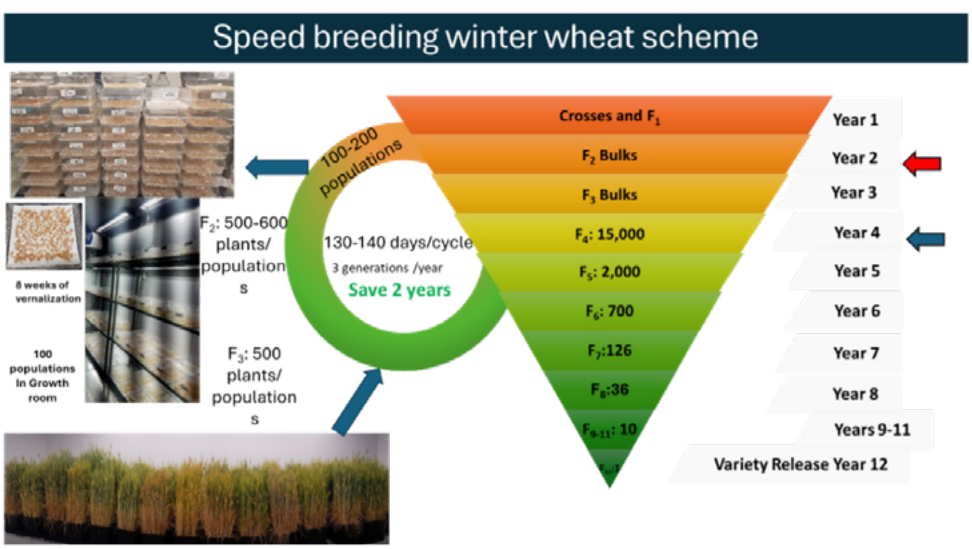
Sunish K. Sehgal, Peter Sexton

Research Question/Objectives:

Winter wheat (soft wheat and hard wheat) offers several advantages over spring wheat. It typically delivers up to 20% higher yields and integrates well into cover crop rotations, helping to conserve soil moisture, improve water quality, reduce soil erosion, and enhance soil structure and overall soil health. Adoption of winter wheat provides Minnesota farmers with a valuable opportunity to incorporate a productive fall-seeded crop into their rotation systems. To fully realize these benefits, there is a critical need to develop winter wheat varieties with improved Fusarium head blight resistance and stronger straw and good end-use quality that are well adapted to the growing conditions of this region. The primary objectives of to enhance the FHB resistance and straw strength in soft and hard winter wheat; and 2) to develop and release soft and hard winter wheat varieties for the region.

Results:

Population development and Speed breeding: We planted 100 F2:4 populations developed through speed breeding in the field in October 2024 and single plant selections were performed in July 2025 (Figure 1). New crosses (52) initiated in March of 2024 were advanced using speed breed F2:4 and have been planted in the field in October 2025 for selection in summer 2026. In March-April 2024 230 hard winter wheat and 14 soft white wheat crosses were performed. The F1's from these crosses were vernalized and are currently growing to develop F2 populations. The F2 plants carrying Fhb1 from each cross will then be advanced using the speed breeding technique to F2:4 for field selection (Figure 1).



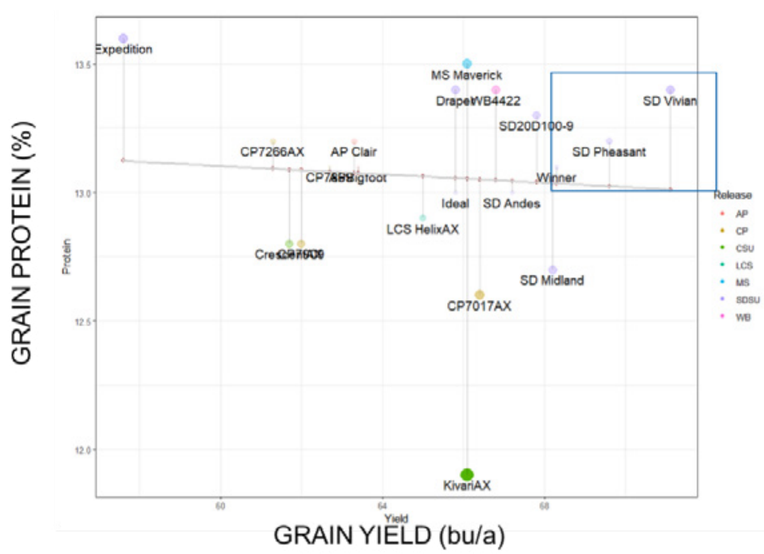
Selections in Segregating populations: Selections in space-planted 100 F2:4 populations were made for dwarf height, tillering capacity, earliness, and rust resistance. Of these 100 populations, about 15 populations carried Fhb1/Fhb6 and six populations carry Yr5+15. On average, we selected 20 desirable plants from each of the 80 populations and advanced them to 4-row early observation trials (EOT is individual plant short rows) for the 2026 season to get an observation of yield potential and agronomic traits (Fig.1). The selected lines from EOT will be advanced to preliminary yield trials (PYT) in 2027. The 65 F2:4 populations evaluated in 2024 resulted in 1,260 entries in the 2025 EOT, of which more than 300 lines were advanced to preliminary yield trials for 2026. This trial was severely affected by drought in the fall of 2024, so additional lines are being repeated in 2026.

Advanced and Elite yield trials: Hard winter wheat advanced yield trial (AYT 2025) with 126 entries and Elite yield trial (Elite 2025) with 36 entries were performed at 7 and 8 locations, respectively, across SD. In AYT, the yield ranged from 42 bu/acre at Pierre to 84 bushels/acre at Selby, SD. Superior performing entries from AYT 2025 were advanced to Elite 2026 trials, including one hard white wheat experimental line, SD23D058-2. Several lines exhibited short height, good winter hardiness, good lodging resistance, good FHB resistance, and one line was a solid stemline. Two HRW wheat lines (SD23SB072-3 and SD23SB072-8) in the AYT2025 carry Fhb1 and showed good FHB resistance and agronomic traits, and were advanced to Elite Trials for 2026.

In the elite yield trials (Elite 2025), 30 new entries were evaluated along with six check cultivars. Of the 30 entries, 25 had a lower disease index than the trial average, and 14 entries had above-average grain yield (Table 1). Three entries SD22C234-3 (Fhb1), SD21B073-3, and SD21C048-2 with good FHB resistance or below- or average height were advanced to state-wide crop performance trials (CPT) for the 2026 growing season. In 2025, MN winter wheat trials conducted by UMN, three of the top four yielding varieties, namely SD Andes (rank 1st) and SD Midland (rank 3rd), and Winner (ranked 4th) were from the SDSU winter wheat program (https://varietytrials.umn.edu/winter-wheat).

In the White Wheat (WW) advanced yield trial (2025) we evaluated 22 entries, including 4 check cultivars. The WW trials were conducted at three locations along the I-29 corridor: North Brookings, Aurora Farm, and Beresford, SD. The average grain yield, test weight, and protein content were 68.5 bu/ac, 54.9 lb/bu, and 15.3 %, respectively. Cultivar ‘Piranha’ and experimental lines SD22B039-3W(SD) topped the trials.

Application/Use:
Breeding efforts with time will result in the enhancement of FHB resistance and good straw strength in winter wheat germplasm. The improved lines will be recommended for release as varieties for production in the region. In the fall of 2025, SD20B088-2 was released as ‘SD Vivian’ with support from MNWR&PC.



New varieties:
‘SD Vivian’ is a semi-dwarf hard red winter wheat with excellent yield potential, good test weight, Vivian’ is resistant to tan spot and moderately resistant to stem rust and hessian fly. It was evaluated Wheat Quality Council Meetings for overall excellent milling and baking quality. It is moderately susceptible to FHB, so recommended for central and western SD. ‘SD Vivian’ maintains a high protein content at a higher yield (see Figure 2).and excellent grain protein content. It has medium-late maturity with good winter hardiness. ‘SD

Further, the improved germplasm will form the foundation of the next breeding cycle and will also be shared with breeding programs in the region.

Materials and Methods:
Each year we make several hundred crosses in hard winter wheat (HWW) and about 25-40 crosses/backcrosses in hard and soft white winter wheat (WW) market class. The crosses are developed for agronomic traits (grain yield, test weight, protein content,

straw strength, etc), end-use quality traits, and resistance to diseases and insect pests. However, the main goal of this project is to enhance straw strength and FHB resistance in winter wheat, along with winter hardiness, to develop varieties adapted to this region. The major sources of FHB resistance are native (Lyman, Everest Overland, and Emerson), Fhb1 and Fhb6 and for increasing straw strength, the focus is on semidwarf genotypes carrying Rht1b, Rht24 and Rht25b.

The F1's are backcrossed or seed increased in the greenhouse and then ~50 F2 plants are screened for with molecular markers (Fhb1/Fhb6) in target crosses and the selected F2 plants are advanced to the next generation as mini-bulks through speed breeding (Fig. 1) or in the field to F4 generations. The F4 population is space-planted to select plants with shorter height, tillering capacity and early maturity. The selected plants are planted in a short 5 ft 4-row early observation trial (EOT). The EOT entries are screened for FHB markers (for confirmation) and selected based on winter hardiness, resistance to other diseases (rust and Bacterial Leaf Streak), and agronomic traits like plant height, maturity, yield, test weight, and grain protein. The best-performing breeding lines from EOT are advanced to preliminary (three locations), then to advanced yield trials (AYT) at 3 (WW-AYT) and 7 (HWW-AYT) locations, and finally, the hard winter wheat lines are advanced to elite yield trials (Elite) at 8 locations. Currently, we are evaluating 15-20 WW lines in our WW-AYT, 126 in our HWW-AYT, and 36 lines in our HWW-Elite trials. The AYT and Elite lines are evaluated for FHB resistance in our mist-irrigated FHB field nursery. Further, all quality parameters of the advanced and Elite lines are evaluated. GS approaches are also being evaluated in the breeding program for various traits. The 2-3 lines showing superior performance in AYT and Elite trials are submitted to the Minnesota State Variety trials conducted by Dr. Jochum J. Wiersma at 5 locations in MN.

Genotype	Rank	Yield (bu/ac)	Protein (%)	TW (lb/bu)	Heading	Height (inches)	Lodging	FHB Index
SD21C048-2	21	62.2	13.8	57.1	30.7	154.3	3.9	4.0
EXPEDITION	36	41.9	14.1	58.1	31.4	153.9	5.7	4.0
WINNER	2	67.8	13.6	59.3	31.5	152.8	3.8	5.9
SD22C234-3	10	64.3	13.9	59.2	31.7	154.2	4.0	8.3
SD21B073-3	5	65.9	13.9	58.1	31.8	153.2	4.4	8.4
SD ANDES	8	65.2	13.8	60.9	32.6	156.0	3.4	8.5
SD21C078-3	4	66.1	13.9	57.9	33.5	155.3	3.5	9.1
SD21D025-3W	15	63.0	13.8	59.9	30.4	154.0	3.0	9.4
SD22W240-10-1tW	13	63.2	14.1	60.3	31.8	156.7	3.1	10.5
SD22D140-2	24	61.9	13.5	56.9	32.3	155.9	5.6	11.1
SD22D163-2	34	59.1	14.1	58.8	29.9	154.9	4.0	11.2
SD22B114-5	27	61.3	14.3	58.1	31.7	156.2	2.8	11.4
SD22B114-4	33	59.6	14.5	58.4	30.9	155.7	2.7	12.2
SD22D177-8	20	62.2	14.2	59.9	32.2	157.0	3.7	12.7
SD22B039-3W	22	62.1	13.6	59.3	31.3	152.9	4.6	12.9
SD21B042-2	28	61.0	14.0	59.8	32.0	154.3	3.2	13.4
SD22B118-8	16	63.0	13.7	58.7	32.9	156.6	5.3	13.8
SD21D107-1W	26	61.8	13.5	58.2	32.0	155.8	3.8	13.9
SD22B025-10	18	62.5	14.5	59.9	33.5	153.8	2.9	14.2
SD22W240-10-2tW	17	62.6	14.0	60.3	32.4	158.3	2.9	14.3
SD21B001-6	7	65.3	14.0	59.5	30.7	154.7	4.7	14.6
SD21D078-1	11	63.3	13.8	58.5	34.4	156.0	4.7	15.3
SD22C237-2	1	69.7	13.3	59.0	33.5	154.1	3.5	15.4
SD21D032-5	30	60.5	14.2	57.1	31.9	157.0	3.5	15.5
KELDIN	3	67.6	13.7	60.0	33.6	157.4	3.1	15.5
SD22D146-6	35	55.0	14.5	59.1	27.1	152.2	2.6	16.3
SD22D147-1	23	62.0	13.6	58.5	30.0	155.6	5.4	16.7
SD22B028-1	19	62.5	13.6	58.2	32.6	155.0	2.6	17.7
SD21B051-6	29	60.7	14.4	59.2	30.4	155.3	2.7	21.2
SD22B052-2	14	63.1	13.8	58.4	31.7	155.7	4.1	21.3
SD22W240-1-2tW	6	65.7	14.0	60.6	32.1	158.4	3.1	21.9
SD22B057-9	31	60.2	14.4	60.2	31.0	154.8	4.0	22.5
AP CLAIR	25	61.8	14.1	58.6	28.8	154.7	2.6	24.2
SY MONUMENT	32	59.6	13.6	57.0	31.3	154.9	3.8	31.0
SD22D138-6W	12	63.3	13.7	56.4	31.2	155.5	3.9	31.9
SD21B113-3	9	64.3	14.0	58.4	30.6	156.9	2.8	32.9
Grand Mean		62.3	13.9	58.8	31.6	155.3	3.7	15.8
LSD		3.6	0.3	0.7	0.8	2.1	1.4	9.6
CV		7.6	3.8	1.3	3.1	0.9	21.1	43.3

Table 1. South Dakota State University hard winter wheat Elite yield trial (Elite) entries ranked according to FHB disease index values (lowest to highest – collected at Volga farm) presented along with agronomic data obtained from three replication trials conducted at five test environments in 2025. The heading data is days to on Julian calendar and Lodging was rated at harvest on a scale of 0-9; 0- no lodging and 9- complete lodging.

University of Minnesota
EXTENSION

Three-Year Evaluation of Johnson-Su Bioreactor Extract as Seed Treatment

Dr. Lindsay Pease, Associate Professor & Extension Specialist, University of Minnesota Northwest Research & Outreach Center, Crookston, MN (2023-2025); Melissa Carlson, VP of Research, MN Wheat Research and Promotion Council, Red Lake Falls, MN (2023-2024)

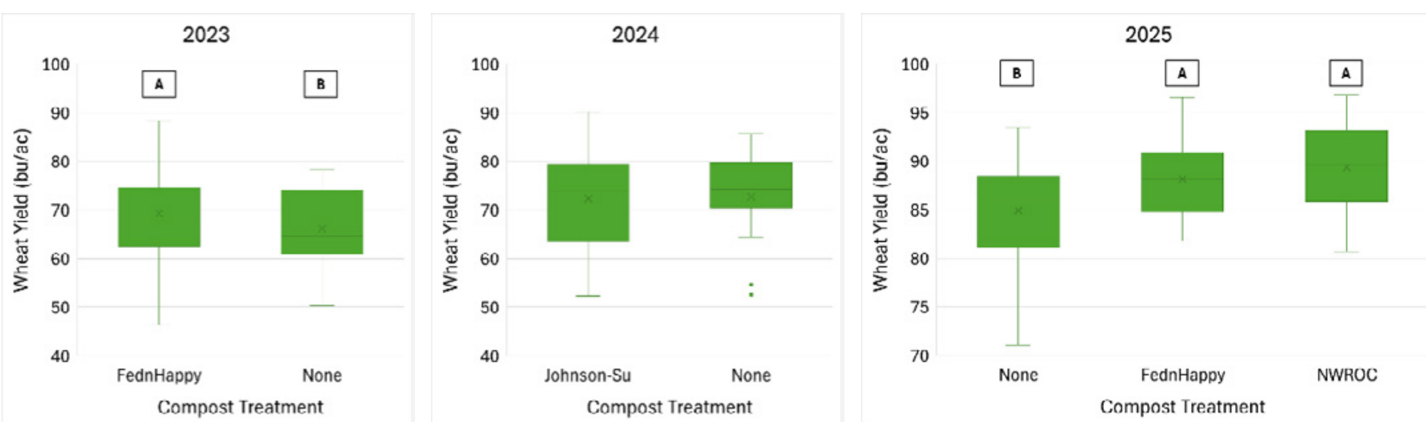
Research Question/Objectives:
The goal of this project is to determine whether applying Johnson-Su compost extract can reduce the N and P fertilizer requirements of spring wheat when used as a seed treatment.

Results:
Spring Wheat Yield

2023
The application of "Fed 'n Happy" compost extract as a seed treatment immediately before planting improved wheat yield by 3 bu/acre (figure 1a). We saw a positive yield response from nitrogen fertilizer, but not phosphorus fertilizer. Optimal soil nitrogen availability at the beginning of the growing season (Fall soil nitrate + fertilizer applied) was 168 lb N/ac. Soil Test P at the beginning of the growing season was 6 ppm Olsen ("low").

2024
We did not see any effect of Johnson-Su compost extract on wheat yield (figure 1b). We again saw a positive yield response from nitrogen fertilizer, but not phosphorus fertilizer. Optimal soil nitrogen availability at the beginning of the growing season was 103 lb N/ac. Soil Test P at the beginning of the growing season was 8 ppm Olsen ("medium").

2025
In our side-by-side comparison of the "Fed 'n Happy" and our self-composted Johnson-Su extracts, both yielded 3-4 bu/ac better than the non-treated control but were not different from one another (figure 1c). In contrast to previous years, we did not see a grain yield response to N rate. We again saw no grain yield response to P rate. Soil Test P at the beginning of the growing season was 5 ppm Olsen ("low").



Application/Use:
We saw a small but statistically significant effect of using compost extract as a seed treatment in two out of three years in our small plot trials. This small increase in yield may not pencil out for all enterprises given the labor required to apply compost extract as a seed treatment immediately before planting. We also did not see any interaction between the compost extract and either N rate or P rate that would suggest that you can reduce your fertilizer application rates when applying compost extract.

Materials and Methods:
Site Description and Experimental Design
Field trials were established at the University of Minnesota Northwest Research and Outreach Center in Crookston, MN from 2023 to 2025 on Wheatville loam soils. Field treatments in the fertility field trials were broadcast then incorporated in a split-plot design with four replicates in the spring prior to planting. Treatments were three replicates of a full factorial of compost extract inoculant, three N rates, and three P rates applied to wheat. In crop year 2023 and 2024 we tested two different compost sources while in 2025 we tested each of the compost sources against one another. Plot sizes for both fields and all years were 11 ft x 20 ft.

Johnson-Su Bioreactor Construction
Four Johnson-Su Bioreactors were built by hanging bulk seed tote bags inside the cages of bulk shuttle totes and hanging 5 perforated sewer pipes inside the tote to serve as the air chimneys. The bottom 6-8 inches of the inner plastic bladder were cut out and placed back inside the cage to catch any excess leachate from potentially overwatering the bioreactor. Pallets were cut to fit inside the cages and placed inside the plastic liner, below the tote bags to allow extra water to drain out of the tote bag and into the cut out bottom of the plastic bladder, which could be drained using the shuttle tote's ball valve if too much liquid accumulated.

Compost materials included a mix of approximately 50% rye straw chopped with a bale processor, 10% partially decomposed wood chips, 10% mulched oak leaves, and 20% horse manure mixed with hay. The manure was free of dewormer, and the straw was free of chemical residues. Materials were mixed in a wheelbarrow, then transferred to laundry baskets and submerged in water until they were sufficiently soaked, drained for a few minutes and then distributed around the chimneys inside each of the bioreactors.

An automatic sprinkling system was setup using garden irrigation drip line and an automatic timer for garden hoses to keep the compost moist. Bioreactor compost was also partially covered using scrap pieces of landscape fabric to reduce evaporation. The bioreactors went through their heating cycle over the course of the first week and peaked at about 130 F. After the bioreactor internal temperature dropped back down below 80F, approximately 2 lbs of red composting worms were added to each bioreactor.

Bioreactors were maintained in heated shops above 60F throughout the remainder of the year, adding water as necessary to maintain moisture so that the compost wasn't overly drenched, but a handful of compost squeezed in the hand could squeeze out a drop of water (figure 2).

Extraction and Application
Fed N Happy worm castings were used in place of Johnson-Su compost in the 2023 growing season, since we did not have access to suitable Johnson-Su compost for the first year. We went with worm castings since the Johnson-Su process with worms essentially results in matured vermicompost, and Fed N Happy's method of raising worms would result in a similar product suitable for comparison. A BeCrop DNA analysis of the worm castings revealed about 848 species of bacteria and 137 species of fungi present in the castings.

In 2024, compost extract from the Johnson-Su compost created in 2023 was used on-farm and in small plots. A RhizeBio DNA analysis of Johnson-Su compost revealed about 6000 species of bacteria/archaea and 60 fungal organisms present in the four bioreactor containers.

Extract was initially made for the small plot research and the wheat seed treatments by vigorously bubbling 2 lbs of material (worm castings or compost)/gal in a 5 gal bucket using a circular lawn sprinkler attached to an air compressor at approximately 15-20 psi for at least 30 min. The extract was filtered first through a 5 gal paint filter, and then through a finer cone paint filter (micron/mesh size unknown). When piloting this process for on-farm use in 2023, the extract for the on-farm field plots was additionally run through a system of T-line filters attached to a small sprayer pump set up by one of our cooperating farmers fitted with a 30 mesh and a 50 mesh filter.

For on-farm plots in 2023, wheat seed was treated by spraying the filtered extract onto the wheat seed as it was being augered from a truck to the seed tender/gravity box at a rate of 9 0z/cwt, which is a similar volume rate for commercial seed treatments. Wheat seeds were covered and thouroughly mixed by augering, but were not so wet as to cause bridging or clogging problems. A 60 gal mixing cone held the extract and was attached to the T-line filter/pump sprayer set up with a fine nozzle tip.

An additional sunflower plot used a liquid in-furrow drip application at planting instead of a seed treatment. For this extraction, we used 1/3 lb compost/gal, applied at a rate of 6 gal/acre to reach a the rate of 2 lbs compost applied/acre suggested by David Johnson. Compost was again first bubbled inside a 5 gal paint filter hung inside a 60 gal mixing cone. A trash sump pump was also hung inside the mixing cone with a 1.5 inch hose attached, which was used to circulate and agitate the water and compost during the extraction. The initial extract was run through the T-line filtration set up and filtered down to 50 mesh before being transferred to the air seeder's [rinsed] starter fertilizer tank

Statistical analysis
Wheat yield comparisons within site-years were analyzed with a linear mixed effects model with "block" and "block x compost" as random effects. Post-hoc testing was done via multiple comparisons with Least Square means using the Tukey-HSD test. Estimations of optimal soil nitrogen availability for 2023 and 2024 were conducted by evaluating the quadratic relationship between N rate and yield within each year. Analysis across years was conducted using multiple linear regression with yield transformed by square root. All statistical analysis was completed using JMP Student Edition 18.2.2 (JMP Statistical Discovery LLC, 2024-2025) at α=0.05.

Economic Benefit to a Typical 500 Acre Wheat Enterprise:
High yielding wheat crops require high amounts of applied N and P fertilizer. We wanted to determine if fertilizer rates can be reduced in wheat by seed-applying Johonson-Su bioreactor compost extract. The extract is meant to work by inoculating the soil with beneficial microorganisms to work symbiotically with crop roots to supply additional soil nutrients that are inaccessible by the crop. Although we did not show that fertilizer rates could be reduced with the application of compost extract to wheat seed, we did observe a small but significant boost in wheat yield. At a wheat commodity price of $6 per bushel, application of compost extract to wheat seed would have resulted in an additional $9,000 for a typical 500 acre wheat enterprise. Given that these bioreactors can be constructed for a very low cost, the primary expense in using this technology is the labor required to initially construct the bioreactors, and each spring to seed-treat wheat immediately before planting.

NDSU | EXTENSION

Enhancing Spring Wheat Yields through Split In-Season Nitrogen & Sulfur Applications in Conventional & No-Till Systems

Sergio Cabello-Leiva, Szilvia Yuja, Mike Ostlie, Rupak Karn. North Dakota State University
Jesse Bealsburg, Jake Jungers. University of Minnesota

Research Question/Objectives:
Hypothesis: The use of a split application of nitrogen and sulfur significantly increases wheat yield under conventional and no-till cropping systems

Objectives:
- Determine the combined effect of nitrogen and sulfur split rates, finding the correct ratio to achieve the highest wheat yield and quality in conventional and no-till systems
- Determine the effect, in wheat yield and quality, of nitrogen and sulfur split application in conventional and no-till systems
- Determine the best method to predict nitrogen and sulfur plant status and fertilizer rates, considering regular soil testing, plant analysis, and multispectral data from active and passive sensors. If the multispectral data is significant, we will proceed to use the most accurate vegetation index to predict and correct in-season N and S fertilizer rates in wheat

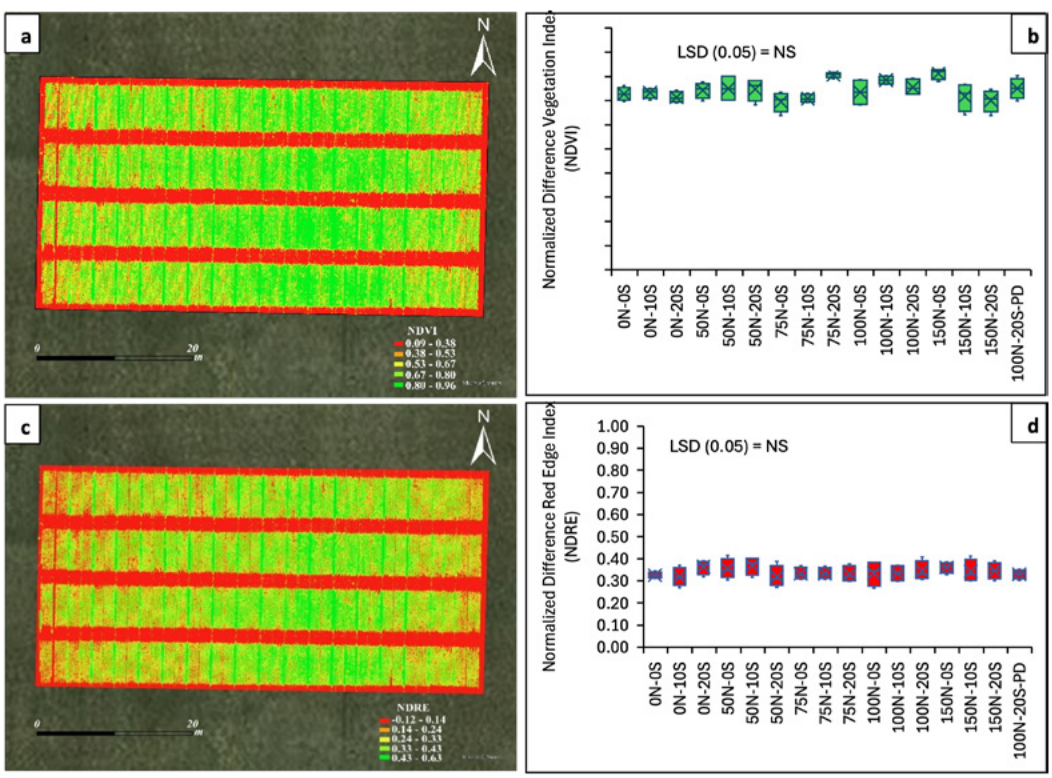


Figure 1. Spring wheat at Carrington, ND, June 25, 2025. (a) NDVI aerial photograph, wheat Feekes 5; (b) NDVI values derived from drone imagery plots; (c) NDRE aerial photograph, wheat Feekes 5; (d) NDRE values derived from drone imagery plots.

Results:

Rainfall Impact on Nutrient Use and Yield

In 2025, rainfall played a significant role in our wheat-growing regions. From April to August, Carrington received 15.176 inches of rainfall, 18% above the average, while Saint Paul saw 24.13 inches, a substantial 20% above average. These high rainfall levels provide sufficient water during the growing season, although sunny days and maximum temperatures were affected, resulting in values lower than those of average years.

Carrington, ND (Figures 1 and 2)

In Carrington in 2025 (Figure 1), above-average rainfall and a cool spring created very favorable early-season conditions for wheat. The site has fertile loamy soil, long-term no-till, high organic matter, and naturally high soil nutrient supply. When we measured the Normalized Difference Vegetation Index (NDVI) and the Normalized Difference Red Edge Index (NDRE) at Feekes 5, the values were high and uniform across treatments. NDVI averaged 0.74, and NDRE followed the same pattern, showing no significant differences among any of the nitrogen and sulfur rates. Even at this early stage, it was clear that fertilizer treatments were not separating, and yield potential appeared similar across the entire field.

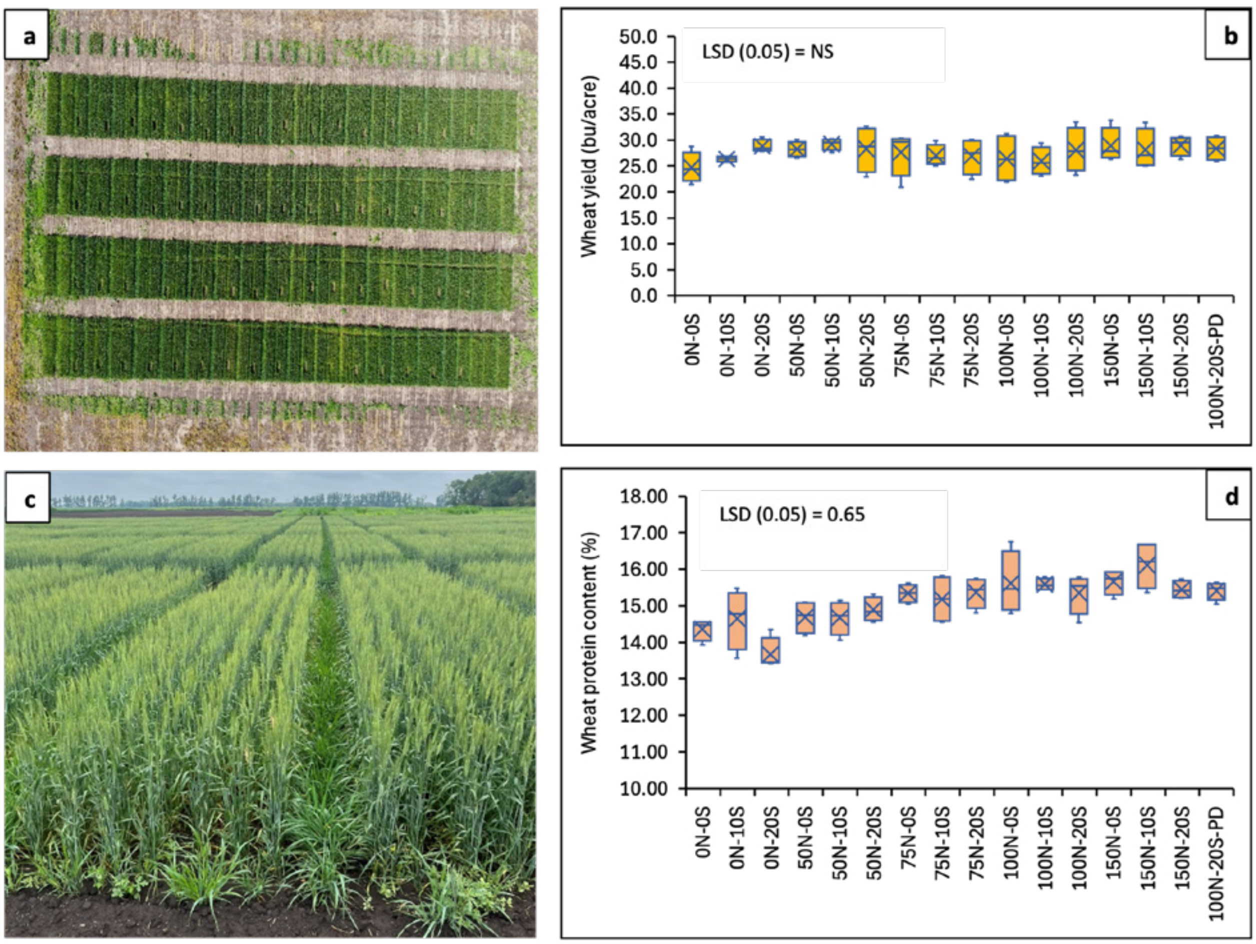


Figure 2. Spring wheat yield and quality, 2025, Carrington, ND. (a) Drone image at flowering stage, not simple differences observed; (b) Wheat yield graph; (c) Wheat at heading stage; (d) Spring wheat protein content graph.

As we approached harvest, visual observations, drone images, and plot photos (Figure 2) all showed an even crop across all treatments. The yield data confirmed that there were no significant differences among treatments, with an average of 27.6 bu/acre. This yield is low for the area and was the result of several factors: heavy lodging after a wet August, declining numbers, and intense pressure from bacterial blight and Fusarium. The older variety used, MN Rothsay, also struggled under these conditions. While yield did not respond, protein did. Treatments with more than 75 lb N/acre produced noticeably higher protein, and combinations around 150 lb N with 10–20 lb S reached values above 16 percent. In this location, higher N and S improved quality, even though yield was limited by the season.

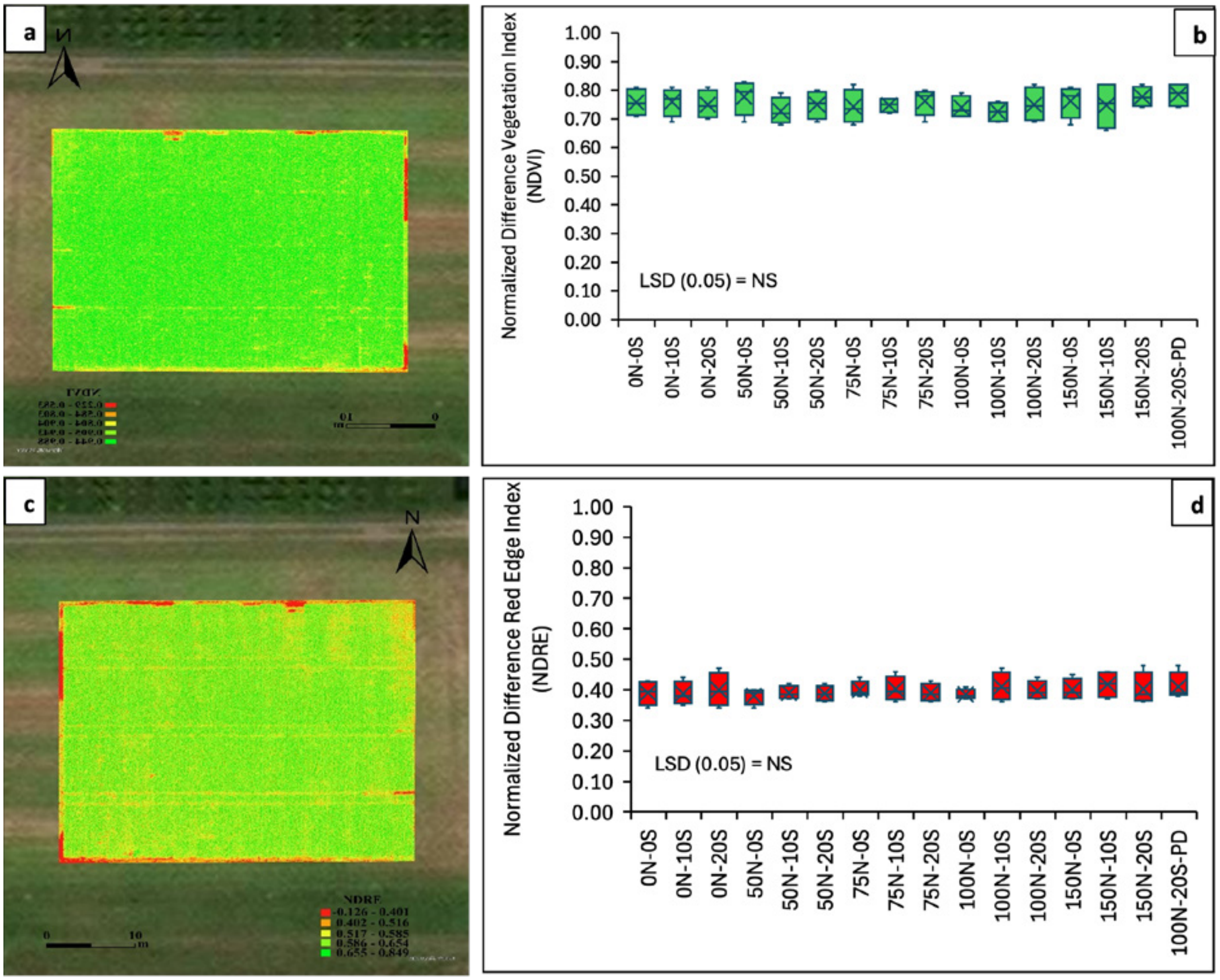
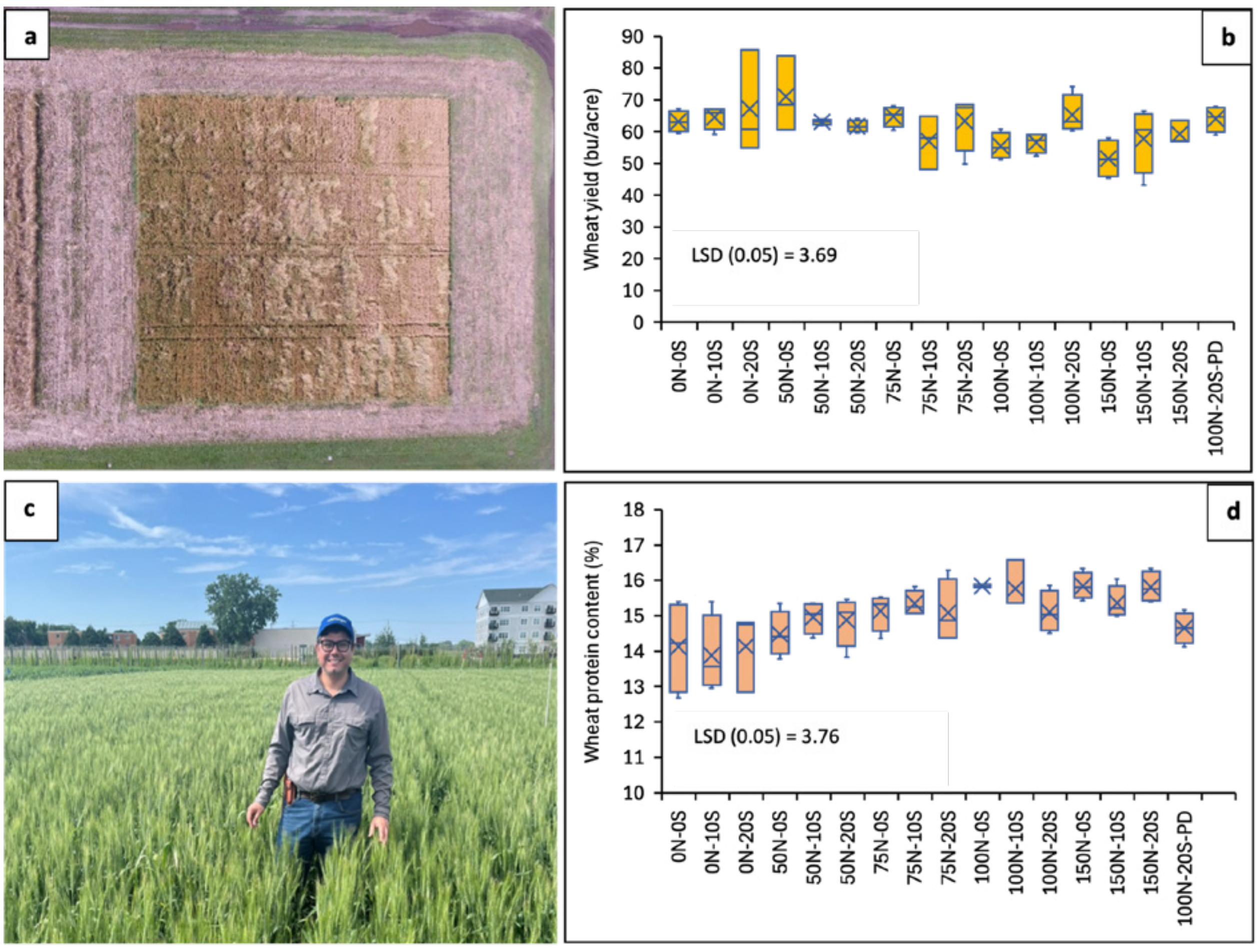


Figure 3. Spring wheat at Saint Paul, MN, June 6, 2025. (a) NDVI aerial photograph, wheat Feekes 5; (b) NDVI values derived from drone imagery plots; (c) NDRE aerial photograph, wheat Feekes 5; (d) NDRE values derived from drone imagery plots

St. Paul (Figures 3 and 4)

In St. Paul, we experienced one of the wettest growing seasons on record, with rainfall almost 20 percent above average, along with a cool spring. The soil is a sandy loam under conventional tillage, with naturally high fertility. Drone imagery at Feekes 5 (Figure 3) showed a very uniform crop, and the NDVI and NDRE values confirmed this. NDVI averaged 0.75 and NDRE averaged 0.40, with no significant differences among N and S treatments. Just like in Carrington, early indicators suggested that yield differences would be minimal.

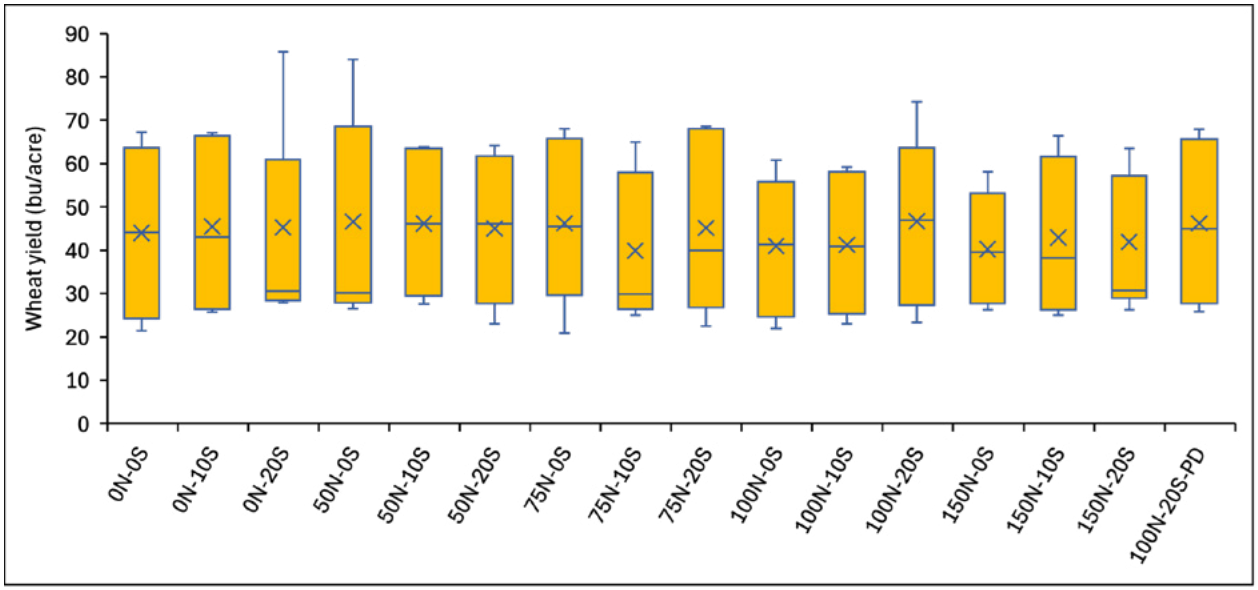
Later in the season (Figure 4), drone photos revealed heavy lodging caused by the extremely wet conditions. Yield data, however, did show significant differences. The highest yield, 71 bu/acre, occurred with the 50 lb N treatment and no sulfur. This plot had slightly less early vigor than the higher-N treatments, which may have allowed for better standability and more effective seed set under the lodging pressure. Protein content responded strongly to nitrogen. A split application of 100 lb. N with 10 lb. S reached 15.8 percent protein, clearly higher than the 14.1 percent observed in the 0N–0S treatment. Overall, St. Paul demonstrated that protein gains from N and S were consistent, even when lodging and weather limited yield.

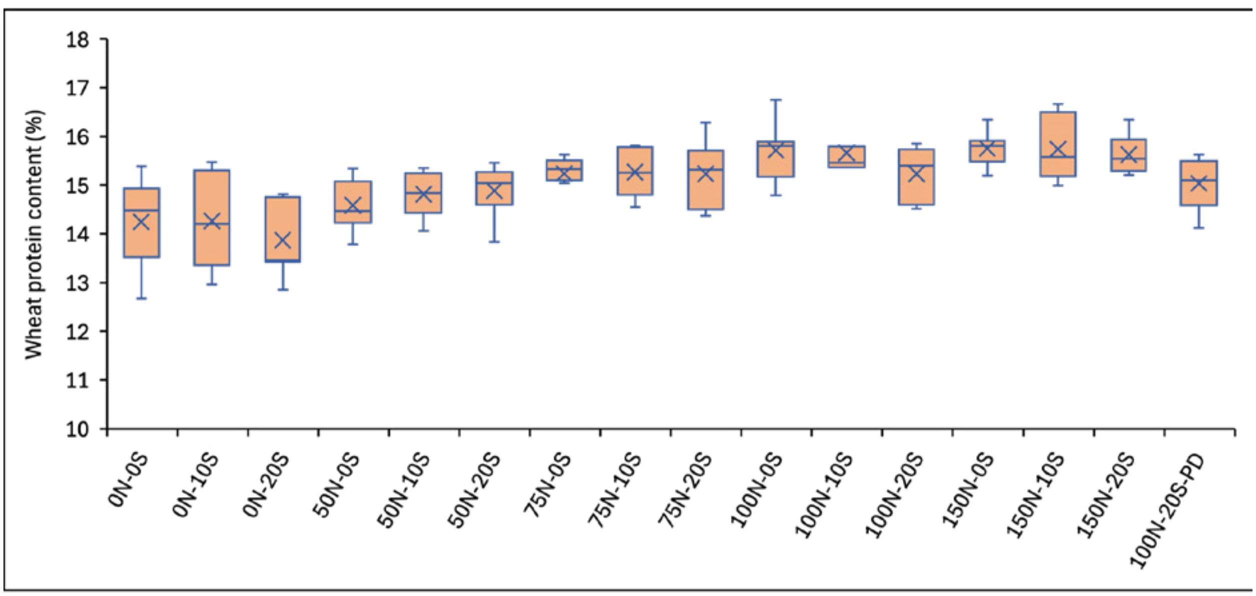


Wheat yield and protein, combined analysis across Carrington, ND, and Saint Paul, MN (Figure 5)

When we combine Carrington and St. Paul (Figure 5), the overall pattern becomes very clear. Across both sites, spring wheat yield did not differ among fertilizer treatments, averaging 44 bu/acre. The weather, soil conditions, and crop varieties created an environment in which even significant differences in N and S rates did not affect yield outcomes. This trend was already visible early in the season at Feekes 5, when both NDVI and NDRE showed no significant separation among treatments. Those early measurements correctly predicted the results.

Protein content, on the other hand, did respond. The combined average was 15.07 percent, and treatments with more than 75 lb. N/acre, especially with split applications, produced noticeable improvements in protein. While these gains are valuable, the decision to increase rates should consider whether protein premiums are strong enough to offset the additional fertilizer cost when yield does not respond.





Conclusions
This season showed how rainfall, temperature, soil dynamics, and variety choice can shape yield responses. Even with split nitrogen and sulfur applications, there were no meaningful differences in yield across treatments. One of the most important lessons from this project is that by Feekes 5, we already had enough information to know that the yield was set. NDVI and NDRE clearly indicated there was no response to additional fertilizer, and the results supported this. This represents a significant practical opportunity for growers to save fertilizer and money. In some treatments, the difference between applying and not applying ranged from 150 lb. N per acre to 20 lb. S per acre.

Protein increases were significant at N rates above 75 lb. per acre with split applications, but it is worth asking whether these increases justify the additional cost when yield is unchanged. Precision ag tools, whether drone imagery, NDVI sensors, or handheld devices, offer a quick and reliable way to assess crop status at Feekes 5. With a split application system in place, growers have the flexibility to adjust rates or skip applications entirely, making more confident, economically sound decisions.

Application/Use:
The results from this study are directly relevant to wheat producers in Minnesota and North Dakota. Split applications of nitrogen and sulfur are an essential management tool because they give farmers the flexibility to adjust in-season fertilizer based on real-time crop conditions. Using NDVI or NDRE measurements at Feekes 5, as demonstrated in this year's study, farmers can decide whether the second split of N and S is necessary. In some cases, as observed in 2025, the crop may not require additional fertilizer, allowing growers to save on inputs and reduce costs without compromising yield.

Split applications can be made with the same equipment used for single fertilizer applications, and the necessary N and S sources are readily available across Northern Great Plains cropping systems.

As precision agriculture technologies become more accessible, farmers and crop advisors have excellent opportunities to increase profitability, improve nutrient-use efficiency, and minimize environmental impact. Continued development of simple, user-friendly tools and methods will make it even easier for growers to implement split-application decisions confidently in the field.

Overall, the split-application approach, guided by early-season crop monitoring, provides a practical, flexible, and economically sound strategy to optimize wheat yield and quality under variable seasonal conditions.

Materials and Methods:
Field establishment: The first location was Carrington, ND, where plots were located on dryland, no-till loamy soils. The second location was Saint Paul, MN, under conventional tillage. The experimental unit was 25 ft by 10 ft.

Spring Wheat MN Rothsay (seeding rate of 2.3 bu/acre) was randomized in a complete block design (RCBD) with four replicates in late April. Sixteen treatments were applied with urea and ammonium sulfate, with the following N and S nutrient rates (lb/acre): 0N-0S, 0N-10S, 0N-20S, 50N-0S, 50N-10S, 50N-20S, 75N-0S, 75N-10S, 75N-20S, 100N-0S, 100N-10S, 100N-20S, 150N-0S, 150N-10S, and 150N-20S. In addition, 100N-20S was applied at planting as a control. N and S rates were split 60% as a starter and 40% as the wheat Feekes 5 stage.

Plant Sampling: Mid-season biomass samples were taken from a four square foot section of the wheat plot at Feekes 5 stage. These samples were weighed and tested for nitrogen (N) and sulfur (S) content. The sulfur-to-nitrogen ratio indicates sulfur sufficiency in plant tissue. Wheat biomass was retaken close to harvest from a four-square-foot section, and these samples were weighed but not analyzed (this data will be published in a future report). Each plot was harvested to determine grain yield, test weight, and protein content.

Soil sampling: Composite samples were taken at 0-6- and 6-24-inch depths in early spring for NO3-N, soil pH, P, K, Sulfate-S, Zinc, and organic matter. Samples taken at 6-24 inches were tested for NO3-N and Sulfate-S. These samples were used to determine the N and S recommendations. In-season soil sampling was done in wheat at Feekes 5 stage, testing for NO3-N and Sulfate-S. After harvest, samples were collected at 0-24 inches in depth for NO3-N and Sulfate-S testing. This data will be published in future reports.

Multispectral wheat canopy data:
The Greenseeker hand-held sensor collected NDVI in each plot at Feekes stages 3, 5, and 10.5 of the wheat stages. A DJI Phantom 4 drone equipped with a MicaSense Red-Edge multispectral camera will collect canopy reflectance images at 550, 670, 715, and 840 nm (green, red, red-edge, and near-infrared). Data collection will be at Feekes stages 3, 5, and 10.5 of the wheat stages. This data is partially published in this report.

Weather and soil data: Daily temperature (min and max), relative humidity, and rainfall were obtained from the NDAWN weather station in North Dakota. This data will be used in a prediction model for N and S rates.
Statistical analysis was conducted using standard procedures for a randomized complete block design (RCBD). The variance analysis was performed using the MIXED procedure of SAS 9.4 for all variables above. A mean separation test was performed using the least significant difference (LSD) ($P \leq 0.05$).

Economic Benefit to a Typical 500 Acre Wheat Enterprise (Table 1):
This season, a combined economic analysis for a 500-acre wheat operation across Carrington, ND, and St. Paul, MN (Table 1), shows a very different outcome compared with higher nitrogen rates. Table 1 highlights that treatments with no nitrogen applied had the highest partial net value and ROI compared with almost all higher fertilizer rates. For example, the 0N-0S treatment resulted in a partial net value of –$10,916 and an ROI of –8.2%, which was clearly better than many of the higher nitrogen treatments, such as 100N-0S, which had a partial net value of –$37,090 and an ROI of –23.1%. This pattern was consistent across multiple N and S combinations.

These results strongly reinforce the value of split applications and early-season crop monitoring. By measuring NDVI and NDRE at Feekes 5, growers can accurately determine whether the crop needs additional nitrogen and sulfur. In 2025, early-season readings showed no response to the first fertilizer application, indicating the second split application was unnecessary. Following the data this season would have allowed farmers to avoid unnecessary input costs while maintaining yield and protein levels, saving money and improving overall efficiency.

It is important to note that conditions may differ next year. Weather, soil fertility, and variety performance can all influence whether a second fertilizer application is beneficial. That is why measuring NDVI and NDRE at Feekes 5, using drones or handheld sensors, is critical. These measurements give farmers the flexibility to decide whether to apply additional N and S, ensuring split applications are used effectively and economically.

In conclusion, the 2025 season demonstrates that more fertilizer is not always better. With split applications guided by NDVI and NDRE at Feekes 5, growers can make timely, data-driven decisions, reducing unnecessary input costs, protecting the environment, and maintaining wheat quality and profitability. This approach provides a practical strategy for optimizing fertilizer use in spring wheat production across the Northern Great Plains.

Related Research:
Dr. Franzen in North Dakota and Dr. Kaiser in Minnesota have conducted similar research. Our study supports several of their findings while introducing the split application component. It was tested across two environments with varying soil types, tillage systems, and irrigation methods, and a modeling component with precision ag tools was added.
While further research is needed to fine-tune the split application of nitrogen (N) and sulfur (S) under different weather conditions, these initial results are promising.

Recommended Future Research:
Using data from both the 2024 and 2025 seasons, we can develop a robust decision-making model to guide split nitrogen and sulfur applications in spring wheat. This model could be applied directly on farms to determine fertilizer needs at Feekes 5. If NDVI and NDRE readings are high at this stage, the model could recommend skipping the second split to avoid unnecessary fertilizer applications. If NDVI values fall below a defined threshold, the model could calculate the optimal N and S rates to apply, ensuring both yield potential and grain quality are maximized. Testing and refining this model in future seasons will help establish a practical, data-driven approach for spring wheat production in Minnesota and North Dakota, providing economic and environmental benefits while supporting sustainable management of in-season fertilizer.

Treatment split application	Protein	Yield	Wheat gross value†	Urea‡	Ammonium sulfate§	Farming cost₣	Split application cost††	Partial Wheat net value	ROI
lb acre-1	(%)	bu	--------------------------------USD$--------------------------------						%
0N-0S‡‡	14.24	21,985	122,166	5,712	0	127,370	0	-10,916	-8.2
0N-10S‡‡	14.26	22,730	126,452	2,855	1,361	127,370	4,610	-9,744	-7.2
0N-20S	13.87	22,635	123,098	0	2,722	127,370	4,610	-11,603	-8.6
50N-0S	14.59	23,295	132,055	14,273	0	127,370	4,610	-14,199	-9.7
50N-10S	14.81	23,070	132,403	11,419	1,361	127,370	4,610	-12,356	-8.5
50N-20S	14.88	22,500	129,636	8,564	2,722	127,370	4,610	-13,630	-9.5
75N-0S	15.24	23,115	135,842	21,410	0	127,370	4,610	-17,548	-11.4
75N-10S	15.25	19,930	117,188	18,555	1,361	127,370	4,610	-34,708	-22.8
75N-20S	15.23	22,565	132,538	15,701	2,722	127,370	4,610	-17,864	-11.9
100N-0S	15.71	20,480	123,437	28,547	0	127,370	4,610	-37,090	-23.1
100N-10S	15.66	20,635	124,041	25,692	1,361	127,370	4,610	-34,992	-22.0
100N-20S	15.23	23,345	137,119	22,837	2,722	127,370	4,610	-20,420	-13.0
150N-0S	15.75	20,105	121,434	42,820	0	127,370	4,610	-53,366	-30.5
150N-10S	15.74	21,475	129,640	39,965	1,361	127,370	4,610	-43,666	-25.2
150N-20S	15.63	20,970	125,854	37,111	2,722	127,370	4,610	-45,959	-26.7
100N-20S-PD§§	15.03	23,120	134,318	22,837	2,722	127,370	0	-18,611	-12.2

† Wheat gross value was USD$5.48 per bushel, adjusted with +0.08/bu for each 0.25% protein above 14.0%
‡ Urea cost was USD$579 per metric ton
§ Ammonium sulfate cost was USD$144 per metric ton
₣ Farming cost of USD$254.74 per acre, including land rent, tillage, planting, seed, fungicide, and harvesting. Drying and hauling costs were calculated per bushel. 2024 North Dakota custom rates
†† Split application cost considered broadcast application at USD$9.22 per acre
‡‡ These treatments considered urea application to equalize N application from ammonium sulfate treatments
§§ 100N-20S-PD treatment considered a full rate of nitrogen and sulfur fertilizer applied at planting date

References:

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Ullah, I., D. Muhammad, and M. Mussarat. 2023. Effect of Various Nitrogen Sources at Various Sulfur Levels on Maize–Wheat Yield and N/S Uptake under Different Climatic Conditions. J Plant Growth Regul 42(3): 2073–2087. doi: 10.1007/s00344-022-10682-6.

Publications:

This research project acknowledged Minnesota Wheat Research and Promotion Council support, and results were published at:

- NDSU All Ag Conference, poster: Enhancing Spring Wheat Yields through Split In-Season Nitrogen and Sulfur Applications in Conventional and No-Till Systems. Fargo, ND, 11/06/2024
- All Innovations for Changing Climate, ASA, CSSA, SSA International Annual Meeting. An oral presentation titled Enhancing Spring Wheat Yields through Split In-Season Nitrogen and Sulfur Applications in Combination with RGB Smartphone Images and NDVI-Based Yield Prediction Models. San Antonio, TX, 11/13/2024.
- 2024 Minnesota Wheat Research Review. Split In-Season Nitrogen and Sulfur Applications Increase Spring Yield and Quality in Conventional and No-Till Systems. Published in December 2024
- Annual Reports Carrington Research Extension Center, NDSU. Extension publication titled: Split In-Season Nitrogen and Sulfur Applications Increase Spring Yield and Quality in Conventional and No-Till Systems. Published in December 2024.
- 2025 Soil Water Workshop, NDSU. Split In-Season Nitrogen and Sulfur Applications Increase Spring Yield and Quality in Conventional and No-Till Systems. Fargo, ND, 01/22/2025
- Gearing up for the 2025 growing season, NDSU. Split In-Season Nitrogen and Sulfur Applications Increase Spring Yield and Quality in Conventional and No-Till Systems. Langdon, ND, 03/25/2025.
- 2025 Minnesota Wheat Research Review. Split In-Season Nitrogen and Sulfur Applications Increase Spring Yield and Quality in Conventional and No-Till Systems. Published in December 2025
- Annual Reports Carrington Research Extension Center, NDSU. Extension publication titled: Split In-Season Nitrogen and Sulfur Applications Increase Spring Yield and Quality in Conventional and No-Till Systems. It will be published in December 2024

Influence of Hard Red Spring Wheat Flour Quality & Particle Size Distribution on Pasta Characteristics

Amrita Ray

Research Question/Objectives:

This project investigates whether commercial spring wheat flours and farina can effectively replace durum semolina in producing high-quality stick-mac and elbow macaroni. It examines how key flour characteristics—such as particle size, protein content, and gluten strength—influence pasta texture, cooking properties, and overall performance compared to durum. Pasta samples will be produced and evaluated for firmness, chewiness, cooking loss, and structural integrity. By linking flour qualities to pasta outcomes, the project aims to identify which spring wheat traits support desirable mac and cheese product quality. The findings will help assess the feasibility of using Minnesota-grown spring wheat in higher-value pasta markets and reducing reliance on durum.

Results:

This project analyzed and compared 2 hard red spring wheat farinas and 4 hard red spring flours against a durum semolina control. The samples were subjected to flour chemical and physical attribute analysis that led to the production of pasta samples from each of the samples. The pasta samples produced underwent quality analysis and cooking analysis.

Application/Use:

This project's results can be used by pasta and mac-and-cheese manufacturers to identify spring wheat flours that match durum quality for stick-mac and elbow macaroni. The findings support developing cost-effective, higher-quality mac and cheese products. They also help regional processors adopt locally grown spring wheat. This can expand market opportunities for Minnesota wheat growers.

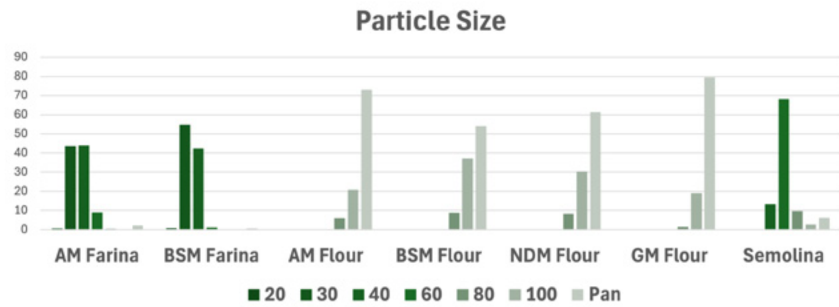
Materials and methods:

Each flour and farina sample was subjected to tests to analyze the following attributes: particle size, color, moisture content, falling number, gluten content and Proximate analysis. AACC methods were followed for evaluation.

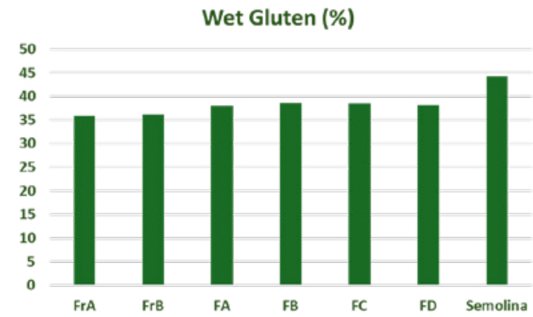
The pasta produced from each of the flour, farina and durum samples were subjected to cooking analysis, color analysis and texture analysis (AACC). The cooking analysis of the pasta that was completed was cooking loss, cooked weight and optimal cook time. Texture analysis was performed with a texture analyzer in accordance to AACC pasta firmness analysis.

Recommended Future Research:

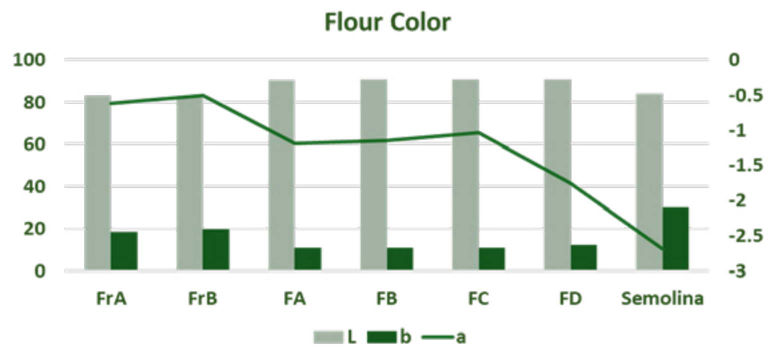
Future research should examine additional spring wheat varieties, blends, or milling treatments to further optimize pasta quality. One or two finalized pasta samples from the project can be further investigated for improved appearances or flavor profile.



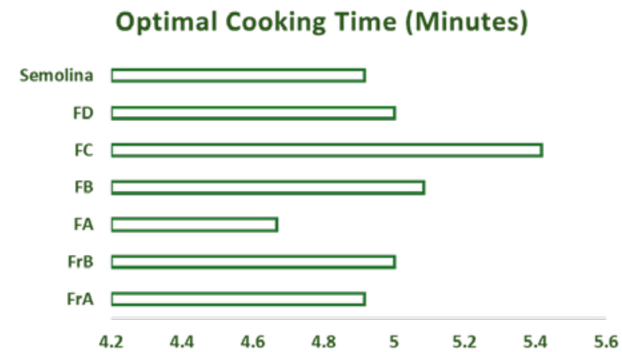
The varied particle size distribution was observed.Farina shows particle size distribution narrowed at 30-40 mesh. Flours showed predominance < 100 mesh.



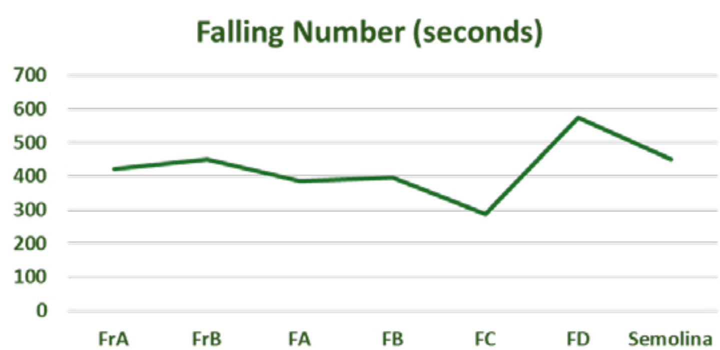
Durum semolina showed highest gluten content amongst all samples followed by flours



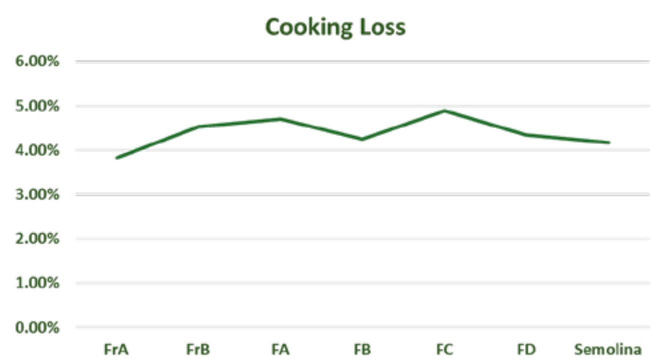
Highest yellowness reported in semolina, followed by farina. Brightness is seen highest for flours



All samples ranged between 4.5-5.4 minutes



Falling numbers were found in the range of 400 seconds



All samples showed less than 6%, much below the highest acceptable values

Minnesota Soybean in 2025: Opportunities, Challenges, & Research

Sergio Cabello-Leiva, Director of Research, MSR&PC

Season Overview and Yields

The 2025 growing season brought a mix of encouraging results and new challenges for soybean growers across Minnesota. Statewide acreage decreased slightly from the previous year, moving to just over seven million harvested acres. Even with fewer acres, soybean performance improved. As shown in Table 1, the statewide average yield increased to 51 bushels per acre, more than 13 percent higher than in 2024, and total soybean production rose nearly 10 percent to more than 361 million bushels. These gains reflect strong crop development across much of the state.

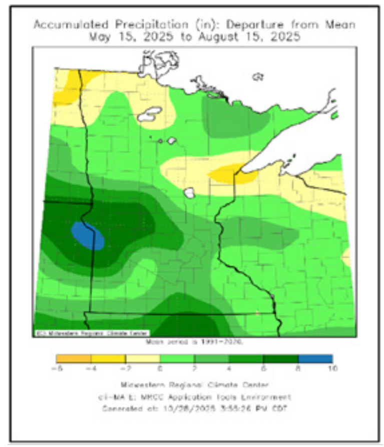


Figure1. Minnesota rainfall 2025

Rainfall played a major role in shaping the season. Many regions received two to six inches more precipitation than average between mid-May and mid-August (Figure 1). In well-drained fields, the additional moisture supported rapid vegetative growth and good pod formation. Many producers reported yields above expectations. In other areas, however, the same high moisture created saturated soils, delayed field operations, and increased disease pressure. This variation illustrates the importance of localized management and site-specific decision-making.

Table1. Minnesota Soybean acreage harvested, yield, and production. Seasons 2024 and 2025			
Season	Acreage	Yield	Bushels
	1,000 acres	bu/acre	1,000 bushels
2024	7,320	45	329,400
2025	7,080	51	361,080
Difference between seasons (%)	-3.28	13.33	9.62
Table Adapted from USDA Crop Production report, November 2025, ISSN:1936-3737			

Key Challenges

Despite favorable growing conditions, 2025 highlighted several significant challenges. The emergence of Red Crown Rot, reported in Minnesota for the first time, is a major concern for soybean production. This disease can significantly reduce yield potential and requires careful monitoring and management. In addition, sudden death syndrome (SDS) and iron deficiency chlorosis (IDC) (Figure 2) were observed in fields across central and northern Minnesota, particularly in areas with heavy rainfall and poorly drained soils. Soybean cyst nematode remains prevalent in many fields, underscoring the importance of resistant varieties and regular scouting (see Figure 3; soybean cyst nematode in roots).

Figure 2. Soybean Iron deficiency chlorosis, central Minnesota, July 2025

MSR&PC Research Efforts and Collaboration

MSR&PC continues to support practical, field-based research across Minnesota. The 2024 research report, From Seed to Solutions (QR code in Figure 4), summarizes the Council's investments in agronomy, pest management, and statewide research projects. This collaborative effort with farmers and scientists provides actionable insights that help growers improve crop performance and manage risks effectively.

MSR&PC research is addressing these challenges directly. Ongoing and future projects include screening and evaluating soybean varieties with improved tolerance to Red Crown Rot, SDS, and IDC, as well as investigating integrated management strategies for soybean cyst nematode (Figure 3), which remains the primary soybean disease in the state. Even without visible symptoms, SCN can reduce yields by more than 30 percent, making resistant varieties and soil testing essential for variety selection and rotation planning.

Figure 3. Soybean Cyst nematode, Cyst female in soybean roots, North-Western MN, September 2025

Breeding Achievements

The U.S. Soybean Genetics Collaborative 2026 Seed Guide highlights breeding achievements supported by MSR&PC, the University of Minnesota, Missouri Soybean, North Dakota Soybean, the Kentucky Soybean Board, the Iowa Soybean Association, the Wisconsin Soybean Program, and more. This includes 20 conventional soybean varieties (in collaboration with U of M and MSR&PC) for tofu, soy milk, and other specialty products, as well as short-maturity varieties suited for northern states. These achievements are intended to provide farmers with additional options for specialty markets and are included in the published seed guide (see the QR code in Figure 5).

Figure 2. From Seeds to Solutions, MSR&PC

Conclusion

The 2025 season reinforced the importance of proactive research and careful monitoring. While environmental conditions favored early growth, the emergence of new diseases and persistent pests highlighted the need for vigilance. Farmers who engage with MSR&PC research trials and extension resources are better prepared to anticipate problems and implement effective management strategies.

Minnesota soybean production in 2025 illustrates both the crop's resilience and the challenges that require continued attention. MSR&PC-funded research provides practical, field-based information that helps growers make informed decisions, maintain high yields, and manage emerging threats such as Red Crown Rot. By leveraging research, monitoring, and collaboration, Minnesota soybean farmers can continue to build profitable, resilient, and sustainable operations. MSR&PC is always ready to work with farmers, agricultural professionals, and scientists to improve Minnesota cropping systems. Contact MSR&PC Research Director Sergio Sergio Cabello Leiva at scabelloleiva@agmgmtsolutions.com if you're interested in collaborating.

Figure 3. 2026 Seed Guide, US Soybean Genetics Collaborative

University of Minnesota Extension

2025 On-Farm IDC & SCN Test Plots & Field Day

Angie Peltier & Heather Dufault, Cooperator: Corey and Craig Hanson, Hanson Farms

Research Question/Objectives:
1) Conduct an on-farm strip trial testing an in-furrow iron chelate product and a soybean seed treatment labeled for SCN management.

Results:
Stand Count. Soybean stand counts ranged from 139,260 plants/acre in the plots in which chelated iron was applied in-furrow at planted and planted to seed treated with Saltro to 149,820 plants/acre in the untreated control plots (Figure 1). There were no treatment differences observed in this trial for stand count.

IDC. Severe and prolonged symptoms of iron deficiency chlorosis occurred in this trial due to prolonged cool, wet and smoky conditions after establishment. In the study field, IDC symptoms among plants being rated ranged from 1.5 to 4.5 (see Figure 5 for ratings information). IDC symptoms significantly differed among experimental treatments, with greater symptom severity in plots that had not received in-furrow iron at planting than in plots that had in-furrow iron applied at seeding (Figure 2). Interestingly, plots without iron, but planted to Saltro-treated seed had significantly less IDC symptom severity than the untreated control plots.

Soybean yield. Soybean yields averaged between 60.4 and 64.8 bushels/acre (Figure 3) when corrected to 13.5% moisture. Untreated control plots, in which neither treatment was applied, had the numerically lowest but statistically similar yields to the Saltro-only plots. The plots in which iron was applied in-furrow at planting, either to seed with or without the Saltro seed treatment were statistically similar and greater than either of the no-iron treatments.

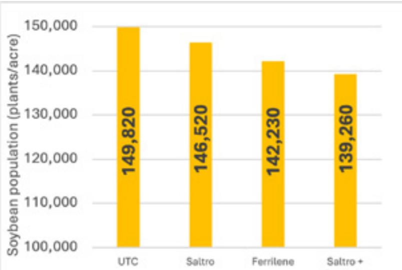


Fig. 1. Per acre soybean plant population {*P* = 0.197, CV = 5.94%}.

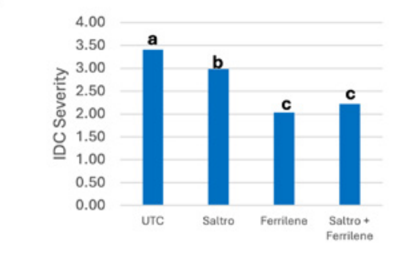


Fig. 2. IDC symptom severity {*P* < 0.0001, LSD(0.05) = 0.29, CV = 8.99%, treatments with different letters are significantly different at P=0.05).

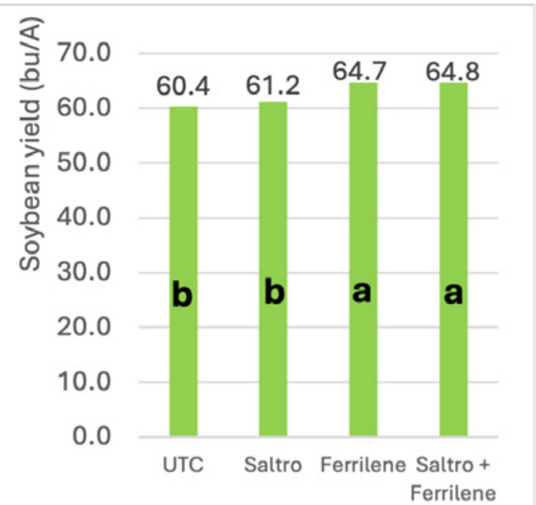


Fig. 3. Soybean yield {*P* < 0.0001, LSD(0.05) = 1.33, CV = 1.73%, treatment bars with different letters are significantly different from one another at P=0.05}.

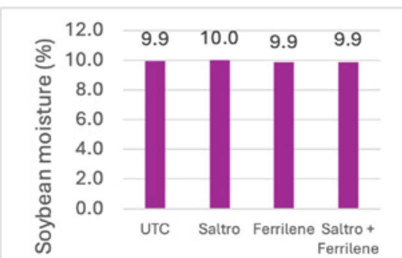


Fig. 4. Soybean moisture {*P* = 0.613, CV = 1.81%}.

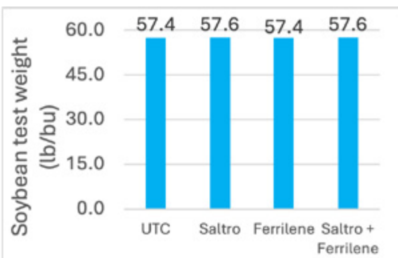


Fig. 4. Soybean test weight {*P* = 0.639, CV = 0.583%}.

Soybean moisture. The tail end of the 2025 growing season immediately before harvest was unseasonably warm and dry, with days of very high winds accelerating grain drying. Treatments did not have an impact on soybean moisture, which ranged from 9.9 to 10.0% (Figure 4).

Soybean test weight. Soybean test weights were remarkably and statistically similar among treatments, ranging from 57.4 to 57.6 pounds/bushel (Figure 4).

Soybean cyst nematode. To estimate SCN population densities, fifteen 8-inch soil cores were collected at an angle from within root zone of each plot on June 11 and October 24, 2025 when soybeans could be rowed and after the growing season, respectively. Egg counts can provide information about how experimental treatments may impact population growth during the growing season.

Spring SCN egg counts ranged from 1,500 to 5,600 eggs/100 cc, higher than when this experiment was planted in a different field across the gravel road in 2024. At the low end, these densities would result in lost yield potential in SCN-susceptible soybean varieties and at the high end would result in lost yield potential in SCN-resistant soybean varieties (Table 1).

Table 1. SCN egg count in spring, fall and the difference between spring and fall (egg count growth) at the Hanson Farm near Gary, MN

Treatment	Spring egg count	Fall egg count	Egg Count growth
	Mean SCN eggs per 100 cubic centimeters of soil		
Untreated control	3,483	5,208	1,725
Saltro alone	3,333	5,175	1,842
Ferrilene alone	2,975	4,300	1,325
Saltro + Ferrilene	2,825	4,641	1,817
P=	0.8201	0.7956	0.9781
CV(%)	42.91	38.09	138.73

Fall SCN egg counts showed population growth in 79% of plots over the growing season. Fall egg count ranged from 4,300 to 5,208 eggs/100 cc and the differences between spring and fall egg counts ranged from and 1,325 and 1,842, with results statistically similar among treatments (Table 1). This is the second year of this trial conducted in similar soils in the same MN township, although with a higher initial SCN population density in 2025 than in 2024. While trends pointed to lower in-season SCN population growth in plots planted to seed treated with Saltro in 2024, no such trend was observed in 2025. These results are in agreement with a multi-state, multi-year, 51 site-year series of trials in which seed treatments labeled for SCN management including Saltro, were tested in crop production fields infested with SCN. This multi-state trial showed that none of the seed treatments tested offered significant SCN control when compared to untreated check (Bissonnette et al. 2024).

Materials and Methods: The experiment was planted into soil characterized as a Grimstad or Rockwell fine sandy loam or Roliss loam at 168,000 seeds/ A on May 28 using seed treated with a base fungicide and insecticide package either with or without 0.75 fl oz/140,000 seeds Saltro (a.i. pydiflymetofen). Saltro is labeled for plant parasitic nematodes including soybean cyst nematode. Ferrilene, a liquid, EDDHA-chelated form of iron (6%) was also applied at 27 lb/A (3 gallons of product + 2 gallons of water/A) to some plots in-furrow at planting.

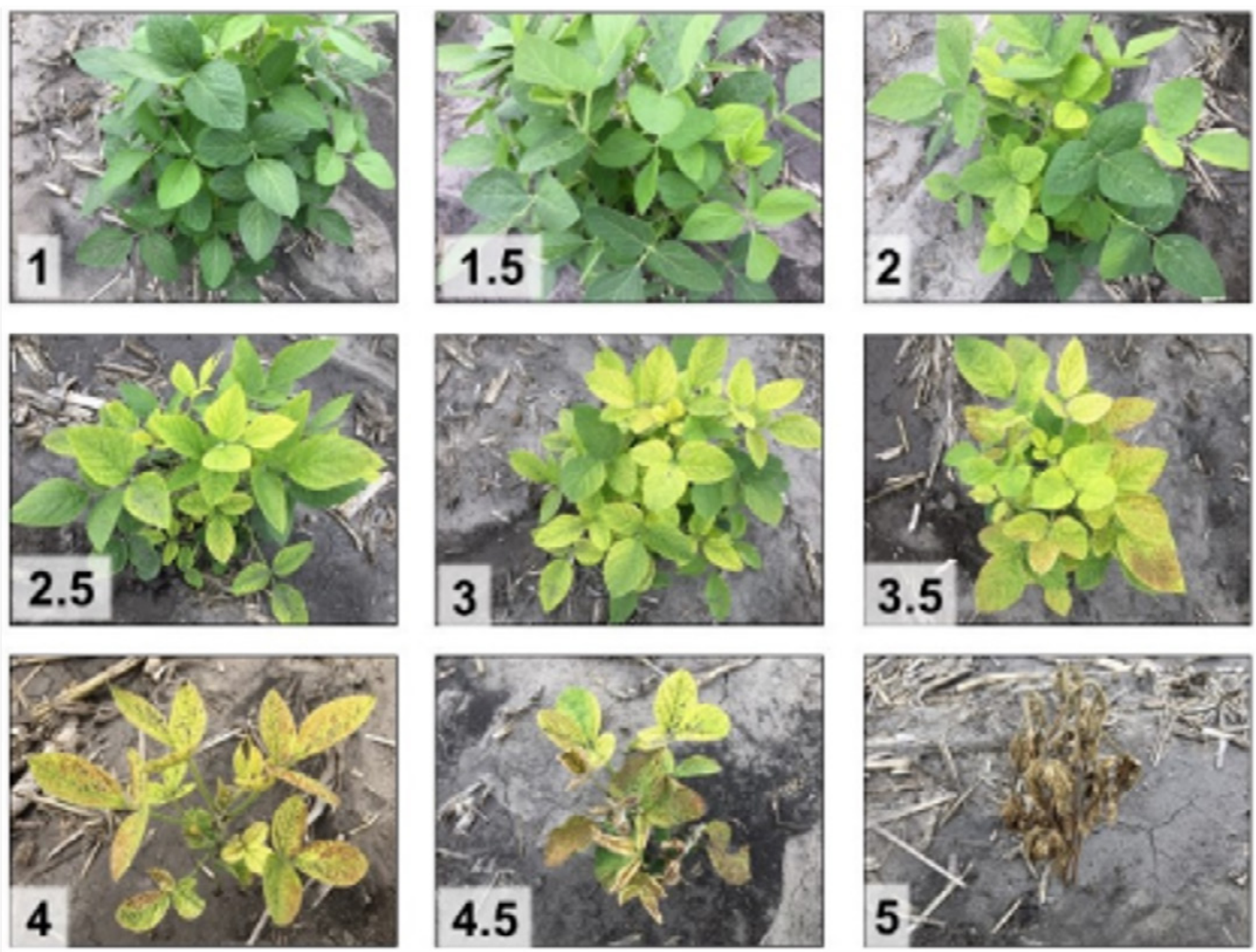
Treatments included, 1) a no Saltro + no Ferrilene untreated control (UTC), 2) Saltro + Ferrilene, 3) Saltro + no Ferrilene and 4) no Saltro + Ferrilene. Each on-farm 700 ft long strip plot was planted in a randomized complete block design with six replicates in ten 22 inch spaced rows with two unplanted rows between each plot. Only 600 ft of each strip plot was harvested on October 10 with a 12-row reel on a farm-scale John Deere combine. Plot yields were determined with a weigh wagon, with samples collected to estimate soybean moisture and test weigh.

Ratings of IDC foliar symptoms were collected from three locations in each plot using a 1-5 ratings scale (Figure 5). Soybean stand counts were collected from two rows in two locations in each plot.

A field day focused on IDC and SCN was held at the plot location in Norman County on September 3, 2025.

Economic Benefit to a Typical 500 Acre Soybean Enterprise: SCN is the most yield-limiting pathogen of soybean in MN, responsible for significant yield losses each growing season. What makes SCN particularly pernicious is that it is capable of causing up to 30% yield losses without there being any above-ground symptoms to alert producers to its presence. Because this pathogen is so devastating, there is a sense of desperation for those producing soybeans in fields with heavy infestations, leading to expensive input decisions such as seed treatments. Other than an errant frost, drought or flooding, we argue that IDC is the abiotic disease most limiting to soybean yield potential in western Minnesota, capable of resulting in an average loss in yield potential of 20% for each increase in the IDC severity score of '1' (Figure 5). The goal of this experiment, which was initiated by the farmer cooperator, was to attempt to actively manage both diseases using products widely used in Norman county, MN.

Figure 5. Iron deficiency chlorosis foliar ratings scale, where a score of 1 indicates green, healthy leaf tissue and a score of 5 indicates severe symptoms leading to plant death, used to estimate foliar symptoms of IDC. Source: North Dakota State University.



Costs were $24.50/ acre for the seed treatment and $28.68/A for the chelated iron, and soybeans at the Ulen, MN CHS elevator had a $10.27 cash price for harvest-time delivery (spot price: Nov 11, 2025). In a wet, cool spring like 2025 that favored IDC symptom development, the 4.3 to 4.4 bu/A yield advantage with the in-furrow iron would have more than paid for itself:

$10.27/bu x 4.35 bushel yield advantage =
$44.67 - $28.68 iron cost = a gain of $15.99/A

However, as there was no yield advantage observed when using treated seed, the seed treatment would have resulted in a loss of $24.50/A in fields not also infested with the pathogen that causes sudden death syndrome.

Summary. The goal of this experiment in 2024 and 2025 was to test means of managing the most yield-limiting biotic and abiotic soybean diseases in NW MN. In 2024, this experiment was planted in a field with a moderate SCN population density and SCN egg counts and while there was a numerical trend pointing to less population growth during the growing season in plots seeded with Saltro-treated seed, population growth was statistically similar among treatments. While the initial SCN egg counts in 2025 were higher, the results were similar to 2024. Particularly in this high input price-low soybean price farm economy, every input must at least pay for itself by protecting yield potential. While the seed treatment results observed in Norman County, MN and throughout the Midwest (Bissonnette et al. 2024) are not promising from an SCN management standpoint, research has shown promising yield potential impacts of the seed treatment should Fusarium virguliforme, the fungal pathogen that causes sudden death syndrome in soybeans, also be present. While subsurface drainage in the trial field in 2024 did not favor IDC development, the undrained field used in 2025 along with adequate rains throughout all but the tail end of the growing season led to conditions favorable for IDC symptom development and a good test of the in-furrow chelated form of iron. While it might not be economical to use the iron on every acre, most farmers know those acres that tend to exhibit IDC whenever soybean are grown in a field and so could selectively deploy an ortho-ortho chelated form of iron as was used in this trial for better whole-field returns on investment.

Literature cited.
Bissonnette, K.M. et al. 2024. Plant Disease. 108:1729-1739.

Disclaimer. No endorsement of products mentioned here nor lack of endorsement through omission in this report is intended.

Acknowledgements. The authors would like to thank the farm families of Minnesota that contribute to the soybean checkoff program through the Minnesota Soybean Research & Promotion Council for funding the 2024 and 2025 trials. The authors would also like to thank Libby Dulmage, Stephen McFadzen, Craig Hanson and Floyd Hanson for their assistance in this trial.

UNIVERSITY OF MINNESOTA
EXTENSION

Farmer-Driven Research into Planting Green Along the Red

Angie Peltier & Jodi DeJong Hughes, UMN Extension; Anna Cates, UMN Extension & Minnesota Office for Soil Health; Lindsay Pease, UMN Extension & Northwest Research & Outreach Center; Dorian Gatchell, Minnesota Agricultural Services; Kat LaBine & Heidi Reitmeier, UMN research technicians

Purpose of Study:
MN farmers face difficult choices when deciding to prioritize either long-term soil health goals or the immediate benefits of tillage for residue management and seedbed preparation. Despite the reported soil health benefits of cover crops, a short growing season makes delays to spring field work risky. Research on cover cropping suggests that early season cover crops can stabilize yields by mitigating excess and limited soil moisture, improving field trafficability, and reducing wind erosion. Reliable advice on agronomic outcomes of cover cropping is critically needed by MN farmers interested in adopting reduced-tillage and cover cropping systems. To meet this need, we partnered with MN farmers to design replicated, production-scale research and demonstration trials that were sown to cereal rye in Fall 2024 (Figure 1, Table 1). Soybeans were seeded in spring 2025 and cover crops terminated before, at or after soybean planting; 2025 is the last of four seasons for this work. See the reports summarizing the results from 2022 here, 2023 here and 2024 here.

On-farm Experimental Design:
Treatments were arranged as large strips wide enough to accommodate farmers' equipment in a randomized complete block design with three replications. Nutrient cycling, soil health, rye biomass at termination, weed density and biomass, IDC and other disease ratings, soybean stand count, yield, moisture & test weight data were collected from each plot.

Treatments: 1) Current tillage practice without a fall-seeded rye cover crop (CC),
2) CC terminated 1-2 weeks before soybean planting,
3) CC terminated at soybean planting,
4) CC terminated 1-2 weeks after soybean planting.

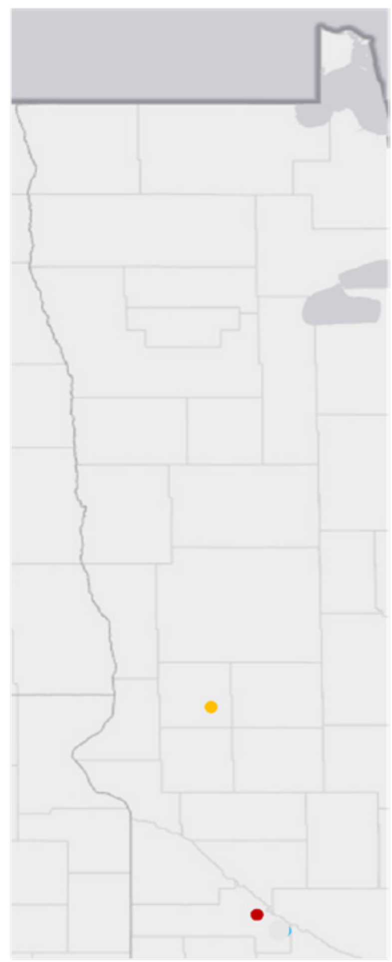


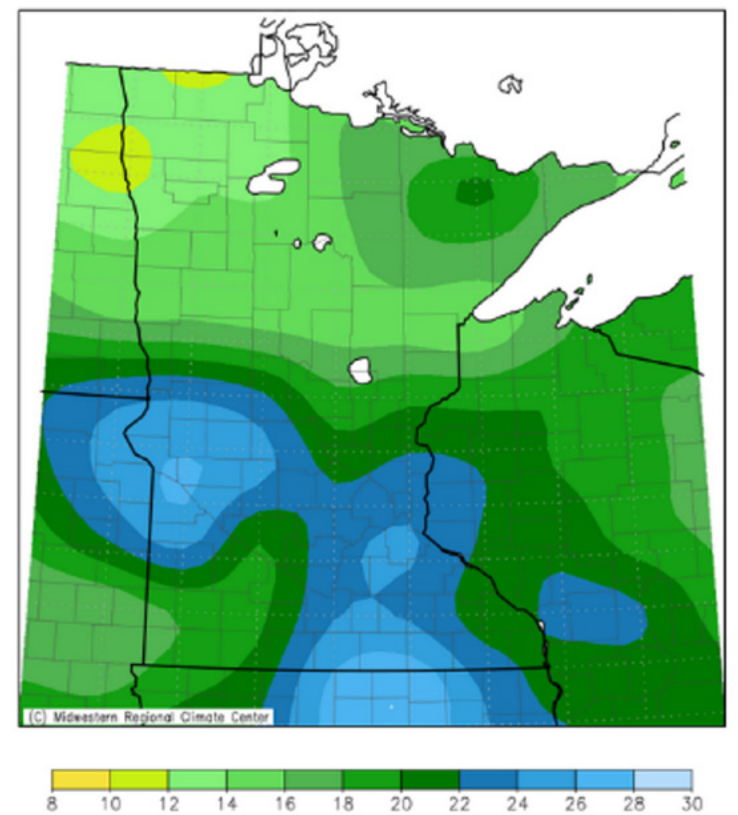
Figure 1. Locations of on-farm and small plot research trials seeded to rye in fall 2024 and to soybean in 2025; orange dot = Barrett location, red dot = Granite Falls location. Each trial location grew different soybean varieties and had different soybean seeding dates and rates and therefore different dates of rye termination and so results are presented by location.

Table 1. Locations of on-farm strip trials, any tillage that took place between 2024 crop harvest and rye seeding, rye seeding date and method, 2025 soybean seeding date, soil texture and May-September 2025 precipitation totals

MN Town/ County	Tillage	Rye seeded (2024)	Soybean seeded (2025)	Soil texture	May-Sept. rainfall (inches)*
Granite Falls/Yellow Medicine	Fall chisel plow/spring cultivator in no rye plots, NT in rye plots	Sept. 13 Bdcst.	May 13	clay loam	22-24
Barrett/Grant	Fall vertical tillage in no rye plots, NT for rye plots	Sept. 13 Bdcst.	May 8	clay loam	24-26

*Rain estimates were provided by the Midwest Regional Climate Center's cli-MATE application tools environment maps of gridded accumulated precipitation for the period of May 1-September 30, 2025 (see Figure 2).

Figure 2. Accumulated precipitation (in inches), May 1-September 30, 2025. Rainfall totals were 6-8 inches above normal in Barrett and 4-6 inches above normal in Granite Falls. Source: Midwestern Regional Climate Center cli-MATE: MRCC Application Tools Environment. Generated Nov 10, 2025.



2024-25 West-central Minnesota On-farm Summary
Barrett, MN.
In Barrett, the "after-planting" rye termination timing plots accumulated more biomass than the "no rye" plots and the rye plots terminated before or at soybean planting; however, the small biomass accumulation in this trial location was unlikely to affect soybean (Table 2). Soybean yields and stands were statistically similar among treatments. However, in this wetter than average growing season, each subsequent delay in rye termination resulted in numerically higher yields and stand counts than the earlier termination. Soybean moisture content was statistically similar and lower than any farmer who sells grain on a weight basis would have wanted. Soybean test weight was also statistically similar among treatments.

Table 2. The effect of rye termination timing on rye biomass, soybean stand count, yield, moisture and test weight at a farm near Barrett, MN in 2025

Rye termination timing	Rye biomass (lb/A)	Soybean stand count (plants/A)	Yield (bu/A)	Moisture (%)	Test weight (lb/bu)
Before planting	3 b[x]	171,013	50.3	8.9	56.8
At planting	5 b	174,885	51.1	8.8	57.8
After planting	61 a	185,727	53.8	8.9	56.5
No rye	0 b	179,725	54.2	9.0	57.4
LSD (90% CL)	17	NS[z]	NS	NS	NS
CV (%)	87.5	4.5	6.1	0.8	1.5

y Treatment means within a column that are followed by different letters are significantly different at P = 0.10.
z Treatment means not significantly (NS) different from one another.

Granite Falls, MN
Significantly more rye biomass accumulated at the Granite Falls location with each subsequent delay in termination (Table 3). Soybean stand count, grain moisture and test weights were statistically similar among treatments. In this abnormally wet growing season, having an actively growing cover crop to take up excessive soil moisture resulted in significantly higher soybean yield than in plots without a rye cover crop. Soybeans do not like to have their roots sitting in water and so the longer that the cover crop survived in this field, the less of a negative impact the wet spring had on the soybean crop. .

Table 3. The effect of rye termination timing on rye biomass, soybean stand count, yield, moisture and test weight at a farm near Granite Falls, MN in 2025 in which the preceding crop was corn grown for grain

Rye termination timing	Rye biomass (lb/A)	Soybean stand count (plants/A)	Yield (bu/A)	Moisture (%)	Test weight (lb/bu)
Before planting	101 c[y]	105,512	56.5 a	10.1	57.0
At planting	291 b	102,930	56.7 a	10.1	56.5
After planting	720 a	106,157	58.2 a	9.3	56.0
No rye	0 c	104,221	53.2 b	9.3	56.3
LSD (90% CL)	132	NS[z]	2.9	NS	NS
CV (%)	20.6	3.4	3.3	1.4	0.8

y Treatment means within a column that are followed by different letters are significantly different at P = 0.10.
z Treatment means not significantly (NS) different from one another.

Summary
In a wet spring such as 2025, an actively growing cover crop can help to draw down soil moisture content, assisting with water infiltration and cash crop growth and development.
Terminating rye before soybean planting only lowered soybean yields at two of the 13 location-years over the course of this study. On average, but particularly in dry springs, the risk of yield loss increases with each delay in termination, with delaying termination to soybean planting resulting in significant yield losses in six of the 16 location-years and significant yield losses in eight of 17 location-years when termination was delayed until after soybean planting. Having an actively growing rye cover crop in spring but terminating the rye before planting soybean strikes the most favorable balance between soil health and cash crop yield.

UNIVERSITY OF MINNESOTA
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2025 Western Minnesota Soybean IPM Survey

Angie Peltier& Anthony Hanson, UMN Extension

Project Summary:
The western Minnesota soybean IPM survey expands our ability to obtain field reports on crop conditions and pest activity to tailor educational outreach to crop managers through radio, digital newsletters and through print in the ag press. Should something for which additional information is needed in-person, the primary investigators partner with company-sponsored plot tour events to provide education regarding new or emerging pest and disease issues. The goal is to provide information regarding pest and disease pressure to producers to assist them in making economical pest management decisions.

Minnesota soybean farmers continue to face new and emerging pests. This survey expands our ability to obtain field reports on crop conditions and pest activity to tailor outreach to crop managers. With the discovery of two new invasive soybean pests in Minnesota within the last five years, having “boots in the field” trained to look for both current and invasive pests Minnesota, soybean producers would not be alerted to potential current or emerging management challenges, such as when pyrethroid insecticide-resistant soybean aphids were first observed.

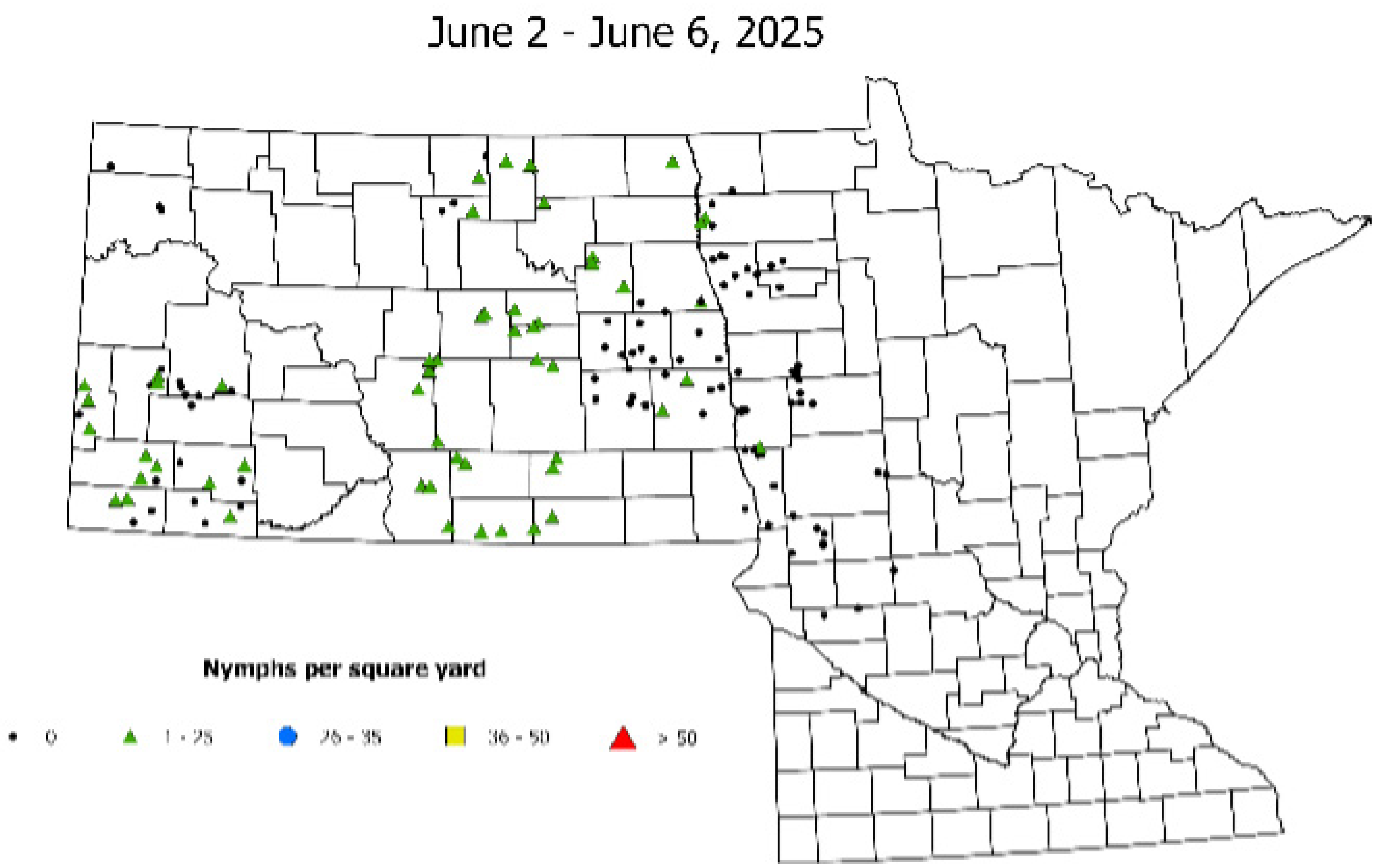
Proposal Objectives:
1) 2025 Western Minnesota Soybean IPM Survey (PI: A. Peltier & A. Hanson)
a) Conduct field surveys to report soybean crop stage and pest conditions in NW and WC MN.
i) Partner with the NDSU IPM program in conducting and reporting field and pest conditions across a region that includes NW and WC MN and eastern ND.
ii) Deliver timely crop updates based on field observations with an emphasis on soybean aphid, two-spotted spider mite and other crop pest conditions as they develop.

Leveraged funding:
To provide a more diverse summer experience for this program’s interns and to share costs, we also sought and obtained funding from the Minnesota Wheat Research and Promotion Council for a similar small grains-version of the soybean survey.

Project Methodology:
The MSRPC-sponsored IPM Survey was funded and conducted for the first time in 2015. UMN Extension continued this project in 2025 in coordination with similar efforts in North Dakota. As soon as MSRPC funding decisions were finalized, UMN Extension personnel began to advertise these positions to potential student interns to work out of regional Extension offices in Crookston, Moorhead and Morris, MN. We were able to identify and hire one scout to work out of the Crookston office (Stephen McFadzen & Libby Dulmage) one out of the Moorhead office (Jordan Hunnicutt) and one out of the Morris office (Zoe Hoaglund) to work on this project this summer.

Project Deliverables:

The IPM scouts began the season scouting small grains fields, switching over to soybeans mid-season. A total of 469 soybean fields were visited throughout the scouting season, resulting in several articles, webinars and radio interviews. At each field, the scout collected data both inside and outside fields. Outside each field, grass areas that bordered fields were swept for grasshopper nymphs (Figure 1) and adults (Figure 2). Soybeans were inspected for growth stage (Figure 3), soybean aphid incidence (Figure 4), soybean aphid severity (Figure 5), presence of aphids colonized by parasitic wasps (Figure 6), number of bean leaf beetles (Figure 7) and the severity of chewing injury they caused (Figure 8), two spotted spider mite (TSSM) presence on the field edge (Figure 9) and inside the field (Figure 10), soybean gall midge presence within the field (Figure 11), and along the field's edge (Figure 12), soybean tentiform leafminer presence on field edge (Figure 13), incidence of foliage-feeding caterpillars (Figure 14), percentage defoliation injury caused by foliage-feeding caterpillars (Figure 15), percent Japanese beetle incidence (Figure 16), frogeye leaf spot incidence (Figure 17), frogeye leaf spot severity (Figure 18), Cercospora leaf blight incidence (Figure 19), Cercospora leaf blight severity (Figure 20) and Phytophthora root and stem rot incidence (Figure 21).



To view the remaining figures and maps please visit this QR code

Assessing the Efficacy of Seed Treatment Nematicides for Management of SCN, SDS & Impacts on Soybean

Fariba Heydari,Senyu Chen, and Dean Malvick

Summary

Soybean cyst nematode (SCN; Heterodera glycines) and sudden death syndrome (SDS; caused by Fusarium virguliforme) are among the most significant yield-limiting threats to soybean production in North America. SCN alone accounts for an estimated $1.5 billion in annual yield losses. When both pathogens occur together, SDS severity can increase due to synergistic interactions. Seed-treatment nematicides, often formulated with fungicidal properties, provide an integrated tool for early-season protection against both pests. However, the relationship between SCN and SDS is complex; some studies report weak or inconsistent correlations in field severity, complicating management strategies. This project evaluates the efficacy of the seed treatments TYMIRIUM® and ILEVO® in managing both SCN and SDS and in improving soybean health under growth-room and greenhouse conditions.

Three experiments were conducted. In Experiment 1, the SDS dose response to F. virguliforme was assessed using a sorghum-seed fungal culture. Ratios of fungal culture to soil (weight of sorghum seeds to soil: sand mixture) at 1:10, 1:20, 1:30, 1:40, 1:50, and 1:60 were tested in soils with and without SCN. Root-rot severity and foliar symptom expression were recorded. All fungal doses induced root rot, with severity increasing at higher inoculum levels. SCN presence further increased root-rot severity. Based on these results, the fungal inoculation level of 1:30 (sorghum: soil weight) was selected for subsequent seed-treatment experiments, as it provided adequate disease pressure and symptom expression without excessive pathogenicity or phytotoxicity.

Experiments 2 and 3 evaluated chemical seed treatments under controlled conditions: cone-tainers (4 cm × 13.5 cm) in a growth room in Waseca, MN, and 7-inch clay pots in a greenhouse in St. Paul, MN, respectively. The growth-room experiment assessed seed-treatment effects on the first SCN generation, while the greenhouse experiment evaluated effects across two SCN generations as well as plant growth. Both experiments followed a factorial design with three factors: seed treatment, SCN, and SDS. Seed-treatment levels included three concentrations of TYMIRIUM®, one standard concentration of ILEVO®, and an untreated control. Pathogen treatments included SCN alone, SDS alone, SCN + SDS, and a non-inoculated control. The treatments were arranged in a complete randomized blocks. Data collection for both experiments is ongoing, and results will be presented at the Prairie Grains Conference in Grand Forks, ND, on December 11, 2025.

Experiment 1: Evaluate dose response of SDS to sorghum culture of Fusarium virguliforme.
(Table 1 and Fig 1.)

Table 1. Treatments using different ratios of SDS-infected sorghum inoculum to soil, with and without SCN

Treatment #	SCN / No SCN	Treatment
1	No SCN	No infected sorghum SDS
2	No SCN	1:20 autoclaved infected sorghum SDS-recommended ratio
3	No SCN	1:10 infected sorghum SDS
4	No SCN	1:20 infected sorghum SDS
5	No SCN	1:30 infected sorghum SDS
6	No SCN	1:40 infected sorghum SDS
7	No SCN	1:50 infected sorghum SDS
8	No SCN	1:60 infected sorghum SDS
9	SCN	No infected SDS
10	SCN	1:20 autoclaved infected sorghum SDS-recommended ratio
11	SCN	1:10 infected sorghum SDS
12	SCN	1:20 infected sorghum SDS
13	SCN	1:30 infected sorghum SDS
14	SCN	1:40 infected sorghum SDS
15	SCN	1:50 infected sorghum SDS
16	SCN	1:60 infected sorghum SDS

Figure 1. Soybean root rot symptom ratings across different treatments. (1 to 8 without SCN- top and 9 to 16 with SCN-bottom)

Experiment 2. Seed treatment efficacy on first generation of SCN – growth room study.

Experiment 3. Seed treatment efficacy on two generations of SCN, and plant growth – greenhouse study. (Fig 2.)

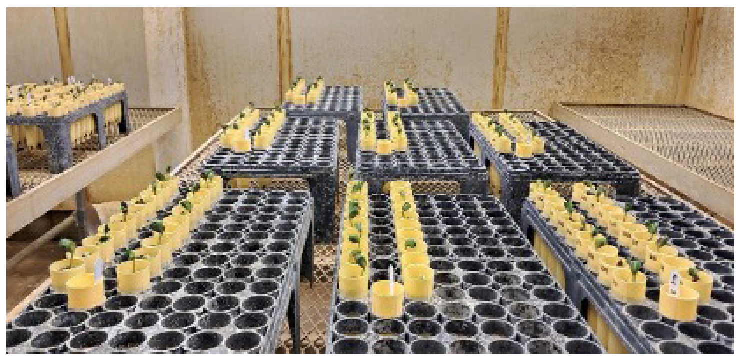


Figure 2. Pots and cones treated with nematicides were maintained in the St. Paul campus greenhouse (top) and the Waseca growth room (bottom).

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Advancing IPM for Soybean Aphid and Soybean Gall Midge

Robert Koch

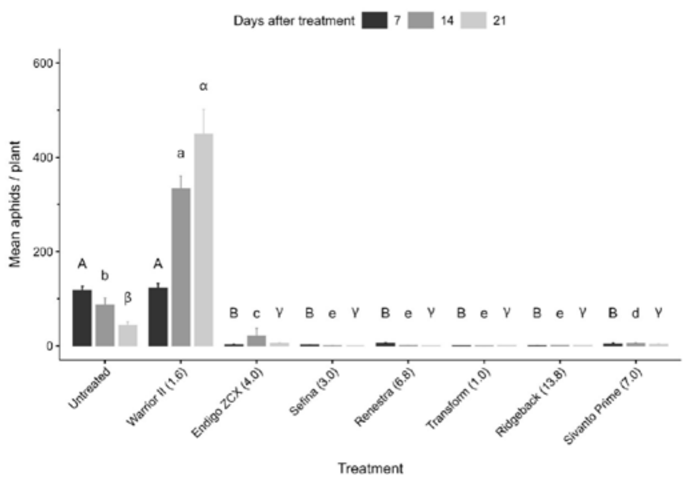
Soybean aphid

Soybean aphid remains an economic threat to soybean production in Minnesota and surrounding states. Management of this pest has been complicated by its development of resistance to pyrethroid insecticides. To evaluate the efficacy of commercially available insecticides for management of soybean aphid, an experiment was conducted at the University of Minnesota's Rosemount Research and Outreach Center. The experiment was performed as a randomized complete block design, with 4 replications of 8 treatments (7 insecticides and an untreated check). On August 21, 2025, insecticides were applied to late-planted soybean with a CO2-pressurized backpack sprayer using 20 gpa at 30 psi (Figure 1). The day prior to application, the aphid infestation was only 80 aphids per plant. These applications were made below the recommended threshold of 250 aphids per plant to ensure that this experiment could be completed prior to the departure of summer field staff; however, this timing also provided an opportunity to assess the potential value (or lack thereof) of applications made below the recommended threshold.

Figure 1: Application of insecticides to plots in an insecticide efficacy experiment in soybean.

In the untreated plots, the aphid populations increased over the first seven days, but then began to decrease naturally (Figure 2). At 7 days after treatment, all insecticides, except Warrior II (a pyrethroid insecticide), had significantly fewer aphids per plant compared to the untreated check (Figure 2). At both 14 and 21 days after treatment, plots treated with Warrior II had significantly more aphids per plant compared to the untreated check, while all other insecticides had significantly fewer aphids per plant compared to the untreated check (Figure 2). The untreated check never reached the economic threshold; however, by 14 days after treatment, the plots treated with Warrior II had aphid population which had increased beyond threshold and continued to increase afterwards.

Figure 2: Soybean aphid populations (aphids/plant) in an insecticide efficacy experiment conducted near Rosemount, MN in 2025 with seven insecticides treatments and an untreated check. Aphid populations were assessed at 7, 14 and 21 days after treatment. Statistical analysis compared treatments within each sample date, with different letters indicating differences among treatments (upper-case letters for 7 days, lower-case letters for 14 days, and Greek letters for 21 days).



Lessons learned from this experiment were:

• These applications of insecticides were made when aphid populations werewell below the recommended threshold of 250 aphids per plant, and were not necessary. Aphid populations in the untreated plots increased over the first 7 days from the initial 80/plant to 117 aphids per plant (still well below threshold), but then decreased naturally, likely due to the abundance of predatory and parasitic insects remaining in these plots.

• Pyrethroid resistance is still present in soybean aphid populations, and applications of pyrethroid products can flare (make worse) soybean aphid infestations. This is likely due to the insecticide killing the predatory and parasitic insects, but not killing the pyrethroid resistant aphids in the plots. By 21 days after treatment, there were about 10 times more aphids in the plots treated with Warrior II (i.e. a pyrethroid insecticide) than in the plots where no insecticide was used.

• The newer insecticides, such as Transform (sulfoxaflor), Sefina (afidopyropen), Sivanto Prime (flupyradifurone), remain effective against pyrethroid-resistant soybean aphids. The additional value of the mixtures containing these newer products mixed with a pyrethroid (e.g., Renestra and Ridgeback) likely provide minimal benefit over the products containing only the single active ingredient of the newer insecticides when soybean aphids are the targeted pest of concern.
A multistate publication about managing insecticide-resistant soybean aphids has been updated:
https://www.ndsu.edu/agriculture/extension/publications/management-pyrethroid-resistant-soybean-aphids

Soybean gall midge

Soybean gall midge is a new pest of soybean in Minnesota and several other Midwest states. This insect was first discovered around 2019, and has since spread across much of southern Minnesota. Observations from Nebraska suggest that significant infestations of this pest can cause total loss of yield on field edges and up to 30% losses in field interiors. Management of soybean gall midge has proven challenging, with insecticides providing relatively low and inconsistent levels of control. Therefore, additional management strategies, such as host-plant resistance (use of pest-resistant crops), are needed.
A series of laboratory experiments are being conducted to evaluate several genotypes of soybean that have been previously identified as having potential resistance to soybean gall midge. To perform these experiments, the various soybean genotypes are being grown in the laboratory and infested with soybean gall midge from a continuously reproducing laboratory colony of soybean gall midge maintained in the laboratory. The numbers of soybean gall midge larvae and adults produced on each soybean genotype will be compared for these experiments. Results of this research will help advance efforts to breed for soybean resistance to soybean gall midge.

The current range of soybean gall midge in the Midwest can be found at www.soybeangallmidge.org.

2025 Adjuvant Tank Mix Impact on 2,4-D, Lactofen, & Glufosinate on Waterhemp & Giant Ragweed in Soybean

Jenna Whitmore and Andrew Lueck

Objectives were to evaluate adjuvant recommendations or absence thereof for active ingredients, 2,4-D, Lactofen, and Glufosinate and to evaluate the potential impact of an oil-based herbicide tank mix on weed control. Growers should always read and follow label recommendations.

Materials and Methods

Waterhemp studies were conducted on a moderate infestation of waterhemp and giant ragweed studies were conducted on a severe infestation of giant ragweed near Renville, Minnesota, in 2025. Soil was a fine-textured webster-clay loam soil with 4.6% organic matter and a 6.6 soil pH. Spring tillage was a field cultivator at 3" depth. Becks 1860E soybean was seeded 1.25 inches deep on 30-inch row spacings at 140,000 seeds per acre on in the waterhemp area May 3 and emerged May 12, while the giant ragweed study soybeans were planted May 8 and emerged May 15. Postemergence herbicide treatments for all studies were applied to soybean on June 4 (Table 1). Enlist treatments were applied with bicycle sprayer in 15 GPA spray solution through AIXR11002 air-induction flat fan nozzles pressurized with CO2 at 25 PSI to the center two rows of four row plots 40 feet in length. Lactofen and Liberty ULTRA treatments were applied with bicycle spray in 20 GPA spray solution through AIXR11002 airinduction flat fan nozzles pressurized with CO2 at 40 PSI to the center two rows of four row plots 40 feet in length. All field areas had moderate levels of ALS and glyphosate-resistant target weeds. Source water had an overall water hardiness of 473 mg/L as CaCO3 and a pH of 7.43. Other elements in units of mg/L included Ca, Fe, K, Mg, and Na at 105, 0.38, 5.19, 51.3, and 26.7, respectively.

Waterhemp control for all active ingredients was evaluated June 11, and June 17. Giant Ragweed control for all active ingredients was evaluated June 11, June 17, and June 24. Evaluations were a visual estimate of percent fresh weight reduction in center two treated rows compared to adjacent untreated strips. Experiment design was a randomized complete block with 4 replications. Data were analyzed with GLM procedure of SAS (Statistical Analysis Software, SAS Academic Studio June 25, 2025, SAS Institute, Inc.) at alpha=0.10 or alpha=0.01 denoted in each tables' lowest row and differences are determined with 90% or 99% confidence respectively; meaning, if the study were repeated 100 times that 90 (or 99) times out of 100, we would expect treatments that are statistically different, or similar, (based on LSD value) to continue to be different, or similar, at that confidence level

Table 1. Application information for Renville adjuvant efficacy trials in 2025.					
	Waterhemp			Giant Ragweed	
Herbicide Active Ingredient	2,4-D				
(Enlist One)	Lactofen (Cobra)	Glufosinate (Liberty ULTRA)	2,4-D		
(Enlist One)	Glufosinate (Liberty ULTRA)				
Application Code	A	A	A	A	A
Date	June 4	June 4	June 4	June 4	June 4
Time of Day	12:30 PM	12:30 PM	12:30 PM	9:00 AM	9:00 AM
Air Temperature (F)	82	82	82	71	71
Relative Humidity (%)	36	36	36	50	50
Wind Velocity (mph)	4	4	4	3	3
Wind Direction	NW	NW	NW	N	N
Soil Temp. (F at 6”)	65	65	65	59	59
Soil Moisture	Good	Good	Good	Good	Good
Cloud Cover (%)	20	20	20	10	10
Crop Growth Stage (avg)	V2	V2	V2	V1	V1
Pest Height	4”	4”	4”	4”	4”

Results and Discussion

2,4-D (ENLIST ONE) IN WATERHEMP AND GIANT RAGWEED

Waterhemp: Enlist One alone or with just NIS added was slightly less effective than when Enlist One was mixed with AMS or an oil-based adjuvant or herbicide at the 7 DAA evaluation (Table 2). However, there was increased plant injury when adding both an oil-based herbicide and an oil-based adjuvant in the same tank mix. A grower may consider using an oil-based herbicide or an oil-based adjuvant, but should not include both in their herbicide mix. At the 14 DAA evaluation, there were no differences in waterhemp control or crop injury.

Giant Ragweed: The 7 DAA evaluation showed treatments were affecting giant ragweed at the same rate, no matter the tank mixes, there were no differences in control across treatments (Table 2). There was mild crop injury, again, in treatments that had both an oil-based herbicide and an oil-based adjuvant mixed in. There were some differences at the 14 DAA evaluation as giant ragweed began to become more impacted by the systemic flow of Enlist One. Treatments that included an oil-based herbicide, with or without an oil-based adjuvant, had better giant ragweed control at the 14 DAA. Only a couple single adjuvant tank mixes showed some impact, with the NIS only treatment having the least impact on increasing giant ragweed control and the AMS only treatment providing the greatest impact on giant ragweed control. The other single adjuvant added treatments, COC only, MSO only, and HSMOC only, did not show any impact on giant ragweed control compared to Enlist One alone. Including an MSO based product in addition to an oil based residual herbicide with Enlist One provided the greatest giant ragweed control at 21 DAA. Potentially, the addition of an oil-based herbicide versus an oil-based adjuvant is more effective. More research with other oil-based residual herbicides could be considered.

Labeled recommendations should always be read and followed.

Table 2. Enlist One adjuvant tank mix efficacy in Waterhemp and Giant Ragweed.							
	Waterhemp			Giant Ragweed			
Tank Mix Components	% Control		% Injury	% Control			% Injury
	7 DAA	14 DAA	7 DAA	7 DAA	14 DAA	21 DAA	7 DAA
None	85	90	0	90	82.5	81.25	0
AMS 8.5 lb/ 100 gal (1.7/A)	87.5	90	0	90	85	82.5	0
NIS	85	90	0	90	80	81.25	0
COC	90	90	0	90	82.5	83.75	0
MSO	90	90	0	90	82.5	85	0
HSMOC	87.5	90	0	90	82.5	82.5	0
Dual Magnum	87.5	90	0	90	86.25	85	0
Dual Magnum + MSO	87.5	90	5	90	86.25	90	2.5
Dual Magnum + HSMOC	90	90	5	90	88.75	88.75	5
Dual Magnum + HSMOC +	Good	Good	Good	Good	Good		
AMS 8.5 lb/100 gal (1.7/A)	90	90	8.75	90	90	85	5
LSD (0.1)	3.88	NS	0.95	NS	3.94	4.43	1.10

Lactofen (Cobra) in Waterhemp

Waterhemp: Tank mixing Cobra with NIS or AMS seemed to reduce waterhemp control at the 7 DAA evaluation, although these treatments had the least amount of crop injury when comparing to the treatments with an oil-based adjuvant or herbicide added into the tank mix (Table 3). The treatment of adding only COC and the treatment of adding both Dual Magnum and HSMOC to the tank mix appeared to not affect the waterhemp control compared to Cobra alone. There is no statistical advantage to adding multiple oil-based adjuvants or herbicides into the tank mix in regards to waterhemp control or any statistical disadvantage to crop injury. Cobra applied alone without any adjuvants provided similar waterhemp control to those that included an oil-based adjuvant or herbicide while also providing less injury. There were no statistical differences in waterhemp control 7 or 14 DAA and injury was less in tank mixes with only NIS or AMS. Label recommendations should be read and followed.

Table 3. Cobra adjuvant tank mix efficacy in Waterhemp.			
	Waterhemp		
Tank Mix Components	% Control	% Injury	
	7 DAA	14 DAA	7 DAA
None	87.5	82.5	12.5
AMS 8.5 lb/ 100 gal (1.7/A)	80	82.5	12.5
NIS	85	82.5	17.5
COC	87.5	82.5	22.5
MSO	88.75	82.5	20
HSMOC	90	82.5	20
Dual Magnum	91.25	82.5	20
Dual Magnum + MSO	90	82.5	20
Dual Magnum + HSMOC	87.5	82.5	20
Dual Magnum + HSMOC + AMS 8.5 lb/100 gal (1.7/A)	91.25	82.5	22.5
LSD (0.1)	NS	NS	3.49
Crop Growth Stage (avg)	V2	V2	V2
Pest Height	4”	4”	4”

Glufosinate (Liberty Ultra) in Waterhemp and Giant Ragweed

Waterhemp: At the 7 DAA evaluation, Liberty ULTRA mixed singly with dry AMS at 1.7 lb/A, MSO, HSMOC, or an oil-based herbicide, with or without a secondary oil-based adjuvant, provided the greatest waterhemp control (Table 4). At 99% confidence (alpha=0.01), with the water source used for this study, the higher rate of AMS did not show greater control than the lower rate, therefore, this study, on this specific water source and the environment on the day of application, would not support the investment in the higher rate of AMS. However, the rate of AMS can be dependent on the water hardness and the grower's water source should be considered against the water sample provided in this publication. No injury was recorded for any tank mixes 7 DAA despite all the oil-based adjuvant and herbicide.

Waterhemp control at 14 DAA was significantly better with an oil-based residual herbicide in the tank mix, with or without a secondary oil-based adjuvant. There was no injury recorded. Again, at the 21 DAA evaluation, tank mixes with an oil-based herbicide, with or without a secondary oil-based adjuvant, provided the greatest waterhemp control. Across all three evaluations, Liberty ULTRA alone or just NIS added, consistently placed below the topperforming tank mixes.

In summary, adding NIS alone or applying Liberty ULTRA alone provides the least impact on waterhemp control. On this specific water source and application environment, the low AMS rate of 1.7 lb/A provided similar waterhemp control as the high AMS rate of 3 lb/A provided; however, a specific water source hardness would impact the amount of AMS a grower should consider using. Adding an oil-based residual herbicide, with or without a secondary oil-based adjuvant, had the greatest knockdown and duration of waterhemp control.

Giant Ragweed: Liberty ULTRA control on giant ragweed had no differences at the 7 DAA evaluation (Table 4). Additionally, there was no crop injury recorded. At the 14 DAA evaluation, with 90% confidence, Liberty ULTRA alone, mixed singly with AMS at both the low and high rate, COC, or mixed with an oil-based residual herbicide, with or without a secondary oil-based adjuvant, provided the greatest control. Giant ragweed control did not improve with the addition of NIS, MSO, or HSMOC alone. Liberty ULTRA giant ragweed control at the 21 DAA evaluation was consistent with the 14 DAA conclusions.

In summary, at 90% confidence, with this specific water source used and environment of the application, both the low and high rates of AMS were statistically similar as Liberty ULTRA alone across all three evaluation timings. However, differences in water hardness should be considered on a per grower basis. Although Liberty ULTRA applied alone at 21 DAA was not statistically less than in tank mix, it tended to be less effective than when mixed with any rate of AMS or the addition of an oil based residual herbicide with or without any secondary adjuvants. It is unlikely the residual herbicide that was used provided any control of emerging giant ragweed. These findings are similar to those of waterhemp control. More research should be considered for Liberty ULTRA and multiple oilbased residual herbicide tank mixes in both waterhemp and giant ragweed to see if the active ingredient herbicide increases uptake or translocation of product on the leaf surface.

When spraying Liberty, ideal weather conditions for greatest efficacy is 140-150 when adding the humidity as a whole number percentage (i.e 70%=70) and temperature in Fahrenheit (i.e. 80 degrees F=80). The weather conditions at the time of application totaled 118, consequently, weather conditions at the time of application were not ideal for optimal Liberty ULTRA efficacy. Label recommendations should always be read and followed.

Table 4. Liberty ULTRA adjuvant tank mix efficacy in Waterhemp and Giant Ragweed.								
	Waterhemp				Giant Ragweed			
Tank Mix Components	% Control			% Injury	% Control			% Injury
	7 DAA	14 DAA	21 DAA	7 DAA	7 DAA	14 DAA	21 DAA	7 DAA
None	80	85.75	62.5	0	90	90	77.5	0
AMS 8.5 lb/ 100 gal (1.7/A)	88.75	90	70	0	90	90	80	0
NIS	81.25	88.75	62.5	0	90	87.5	75	0
COC	85	88.75	72.5	0	90	90	77.5	0
MSO	88.75	90	67.5	0	90	86.25	75	0
HSMOC	87.5	90	65	0	90	86.25	72.5	0
Dual Magnum + AMS 1.7 lb/A	92.5	95	83.75	0	90	90	80	0
Dual Magnum + MSO + AMS	87.5	90	5	90	86.25	90	2.5	
1.7 lb/A	91.25	95	85	0	90	90	80	0
Dual Magnum + HSMOC + AMS	Good	Good	Good	Good	Good			
1.7 lb/A	93.75	93.75	86.25	0	90	90	82.5	0
AMS 3 lb/A	82.5	88.75	72.5	0	90	90	80	0
LSD (0.1)	4.56	3.06	5.72	NS	NS	2.17	NS	NS
LSD (0.01)	7.41	4.97	9.31	NS	-	-	-	-

Conclusion

In general, both waterhemp and giant ragweed pressure were sufficient and uniform across all studies. The findings for 2,4-D (Enlist One) showed that adding an oil-based herbicide may increase waterhemp and giant ragweed control. However, there is an increased crop injury risk when adding both an oil-based herbicide and an oil-based adjuvant together in a tank mix. For Lactofen (Cobra), Cobra applied alone provided similar waterhemp control to those that included an oil-based adjuvant while also providing less injury. The findings for Glufosinate (Liberty ULTRA) in both waterhemp and giant ragweed control were very similar. Adding an oil-based herbicide, with or without a secondary oil-based adjuvant, appeared to improve Liberty ULTRA control for both waterhemp and giant ragweed. More research should be considered for Liberty ULTRA and other oil-based residual herbicide tank mixes in both weed species.

Label recommendations should always be considered and followed.

This publication and more MSRPC funded research conducted by Next Gen Ag LLC can be found online at www.nxtgenag.com under the “Latest News” tab and “Public Grant Research Studies” page.

UNIVERSITY OF MINNESOTA
EXTENSION

Developing Resistance Management Guidelines & Evaluating Quantitative Resistance to Phytophthora Sojae in Minnesota

Kathleen Markham, Megan McCaghey, Dean Malvick, Aaron Lorenz

Research Question/Objectives:

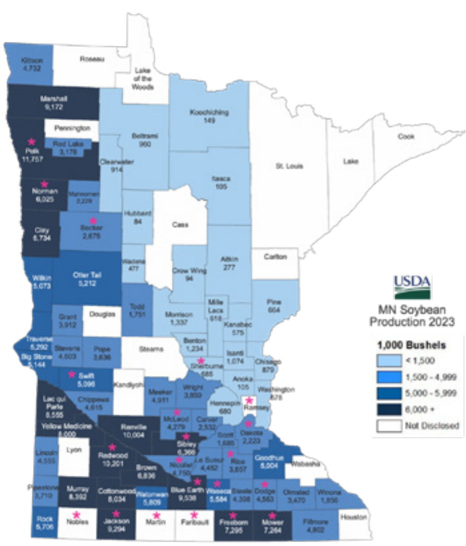
Over the past five growing seasons, parts of Minnesota have experienced above-average soil moisture potentially promoting the development of Phytophthora sojae, a soil-borne pathogen that attacks soybeans at all growth stages. Planting resistant soybean varieties is a key management strategy. However, resistance genes (Rps) must align with the P. sojae pathotypes in the field to be effective. This project aims to reduce yield loss by delivering rapid diagnostics and variety recommendations that are more aligned to local pathotypes, enhancing disease resistance, while also exploring partial resistance to improve long-term management strategies.

Objectives:

Develop improved management recommendations for Phytophthora species affecting soybean in Minnesota, including suggested Rps genes that should be deployed.
Evaluate current, commercial varieties for quantitative resistance to Phytophthora sojae.
Evaluate breeding lines for tolerance to PRSR and to identify potential, future genetic resources.

Results:

In our FY23 and FY24 cycles, we collected 97 soil and tissue samples from 21 counties (Fig. 1) to determine the current Phytophthora sojae population in Minnesota. We have thus far cultured 30 isolates using a baiting method that we optimized during the FY23-24 cycles. Of the 30, 25 isolates from Norman, Redwood, Rice, Mower, and Waseca counties tested positive via PCR for Phytophthora-specific, P. sojae-specific, and P. sojae avirulence (Avr) genes, confirming their P. sojae identity.



In Objective 1, we are utilizing this PCR-based molecular identification method developed by Dussault-Benoit et al. (2020) to predict the pathotypes of these current P. sojae isolates. We have preliminary pathotype predictions for 16 of the 25 isolates thus far (Table 1, A-D). Our molecular predictions suggest that the P. sojae pathotypes in Minnesota are complex, with 68% of the 16 isolates having the potential to defeat at least 5 Rps resistance genes in soybean. Importantly, our molecular predictions reveal that Rps3a and Rps6 resistance genes may potentially be immune to the current isolates (Table 1, E). We are therefore testing these predictions on soybean varieties that carry Rps3a, Rps6, as well as Rps1c and Rps1k (resistance genes that are no longer effective, but still widely deployed) (McCoy et al. 2023). In these tests, we inoculate soybean varieties containing differential Rps genes by injecting 7-day-old seedlings with an isolate, then assessing for rot 7 days later. Our initial results indeed show that Rps3a and Rps6 soybeans are immune and Rps1c soybeans are not immune to the current isolates tested (Table 1, F-H), potentially suggesting that Rps3a and Rps6- containing varieties might be good candidates to deploy more widely in the state. Efforts are ongoing to continue inoculating Rps3a, Rps6, Rps1c, and Rps1k soybeans with all current isolates. We will disseminate these results along with Rps gene recommendations to growers in the form of a peer-reviewed research publication and newsletters disseminated by extension educators.

A	B	C	D	E	F	G	H
Isolate #	Isolate Name	Predicted molecular pathotype	County	Potentially Effective Soybean Variety	Rps1c	Rps3a	Rps6
1	GRW001-1-LJ	1a, 1b, 1c, 1d, 1k	Norman	Rps3a or Rps6			
2	GRW001-3.3	1a, 1b, 1c, 1d, 1k	Norman	Rps3a or Rps6			
3	GRW001-4.5	1a, 1b, 1c, 1d, 1k	Norman	Rps3a or Rps6			
4	GRW001-5.1	1a, 1b, 1c, 1d, 1k	Norman	Rps3a or Rps6	V	A	A
5	GRW001-7.6	1a, 1b, 1c, 1d, 1k	Norman	Rps3a or Rps6	V	A	A
6	GRW009-1-LJ	1a, 1c, 1d, 1k	Redwood	Rps3a or Rps6	V	A	A
7	GRW016-2.4	1a, 1b, 1c, 1d, 1k, 3a	Rice	Rps6			
8	GRW016-4.4	1c, 1d	Rice	Rps3a or Rps6	V	A	A
9	GRW016-5.4	1c, 1d, 1k	Rice	Rps3a or Rps6	V	A	A
10	GRW036-3.1	1a, 1b, 1c, 1d, 1k, 3a	Rice	Rps6			
11	GRW036-5.2	1a, 1c, 1d, 1k	Rice	Rps3a or Rps6	V	A	A
12	GRW036-6.8	1a, 1c, 1d, 1k	Rice	Rps3a or Rps6			
13	GRW041-3.1	1a, 1b, 1c, 1d, 1k	Mower	Rps3a or Rps 6	V	A	A
14	GRW041-5.2	1a, 1b, 1c, 1d, 1k	Mower	Rps3a or Rps6			
15	GRW041-7.1	1a, 1b, 1c, 1d, 1k	Mower	Rps3a or Rps6			
16	SCN002-3.1	1a, 1b, 1c, 1d, 1k	Waseca	Rps3a or Rps6	V	A	A

Table 1. Preliminary identification of 16 (of 25) P. sojae-confirmed isolates recovered from soil collected around MN in 2023-2025. (A-D) There are 5 unique pathotypes across 5 counties thus far. (E) Based on the predicted molecular pathotypes, soybeans carrying Rps3a or Rps6 genes could be effective against the isolate. (F-H) To test our molecular predictions, soybeans carrying Rps1c, Rps3a, or Rps6 resistance genes were inoculated with an isolate using a hypocotyl inoculation method. Isolates were either virulent (V) and resulted in a rotted plant or avirulent (A) and resulted in a healthy plant 7 days after inoculation. Blank cells indicate testing is in progress or has not yet been performed.

In Objective 2, we aim to screen current, commercial varieties for partial (quantitative) resistance to P. sojae. Quantitative resistance can offer small to moderate, additive protection against a broad range of P. sojae pathotypes, which could result in more consistent yield. To measure quantitative resistance, we will take soybean varieties with different genetic backgrounds carrying the most widely deployed Rps genes in the state (Rps1c, Rps1k, Rps3a) and inoculate them with a MN isolate comprising the most common combination of Avr genes predicted (e.g. GRW001-3.3, Table 1) or one comprising the smallest combination of Avr genes predicted (i.e. GRW016-4.4, Table 1). To this end, we have selected four lines with varying genetic backgrounds carrying stacked Rps1c+Rps3a or Rps1k+Rps3a (Table 2). Using the "tray test" method (Dorrance 2008), we will inoculate seedlings with the isolate, then measure lesion length 7 days later. Quantitative resistance will be quantified based on lesion length.

	Pedigree	Rps gene	Source
1	XO 1225E	Rps1c+Rps3a	M.S. Technologies, L.L.C.,
2	XO 1446E	Rps1c+Rps3a	M.S. Technologies, L.L.C.,
3	XO 1545E	Rps1c+Rps3a	M.S. Technologies, L.L.C.,
4	EL60-083	Rps1c+Rps3a	Proseed
5	P18A82	Rps1k+Rps3a	Pioneer
6	P19A37E	Rps1k+Rps3a	Pioneer
7	P21A31PR	Rps1k+Rps3a	Pioneer
8	P22Z02E	Rps1k+Rps3a	Pioneer

Table 2. Current, commercial soybean lines that we selected to evaluate quantitative resistance to P. sojae.

In Objective 3, we aim to screen breeding lines generated by Aaron Lorenz for quantitative resistance to P. sojae. Results from this objective may lead to the identification of potential genes that could confer quantitative resistance, which could lead to its incorporation into soybeans for improved future resistance. To measure quantitative resistance, we will take 15 breeding lines, each with a different genetic background, and inoculate them with a MN isolate comprising the most common combination of Avr genes predicted (e.g. GRW001-3.3, Table 1) or one comprising the smallest combination of Avr genes predicted (i.e. GRW016-4.4, Table 1), as in Objective 2. We are selecting 15 lines from 19 available lines in the Lorenz Lab that encompass the most common Rps genes. As in Objective 2, we will use the tray test method and measure lesion length to quantify resistance.

Application/Use:
Results from Objective 1 will inform growers which Rps genes should be in the soybean varieties they use to increase the likelihood that their crops stay healthy and resistant to the potential rot-causing P. sojae population in their fields. Results from Objectives 1 and 2 will inform growers and researchers on the susceptibility of soybean lines in the event P. sojae overcomes Rps-mediated resistance. It may also pave the way for resistance-gene loci discovery to improve the durability of future resistance breeding.

Materials and Methods:
Soybeans: The following differential lines are being used in Objective 1: Sloan (rps, Williams background), L75-375 (Rps1c, Williams background), Williams 82 (Rps1k, Williams background), L83-570 (Rps3a, Williams background), and Harosoy 62xx (Rps6, Harosoy background).

P. sojae cultures: Isolates of P. sojae are maintained on clarified V8 agar media in room temperature and ambient lighting inside a clear closed container. Isolates used for inoculation are 3-4 weeks old.

Polymerase chain reaction (PCR) molecular method: Primers used to amplify Phytophthora-specific (Otsubo et al. 2024), P. sojae-specific (Bienapfl et al. 2011), and P. sojae Avr genes (Dussault-Benoit et al. 2020) were incorporated into DreamTaq Green Master Mix (Thermo Scientific) and ran using specific PCR parameters.

Hypocotyl inoculation: Differential soybean seeds are surface-sterilized using bleach, then 6-9 seeds are sown on germinating soil mix per pot and allowed to grow in a growth chamber for 7 days. Seedlings are inoculated at 7 days old, where a 1 cm slit using an 18-gauge needle syringe is made, then a slurry (200 uL) of an isolate is adhered to the wound. The inoculated seedlings are moved into a clear plastic bag to maintain high humidity conditions for 24 hours to support infection, then moved out of the bag to continue its development in the growth chamber. Plants are watered every 1-2 days.

Economic Benefit to a Typical 500 Acre Soybean Enterprise: Ultimately, this work will assist growers with variety selection.

We are releasing information on the most effective, current resistance gene combinations to P. sojae in MN (Rps3a and Rps6). Further, we are informing the most useful introgression of resistance genes in breeding efforts. Appropriate Rps gene deployment improves soybean stands and reduces yield losses attributable to P. sojae. Additionally, information on quantitative resistance may improve the durability of resistance, as the contributions of multiple genes to resistance is more difficult to overcome. This, in turn, will reduce yield losses.

Related Research: The Soilborne Fungi and Oomycete Lab (McCaghey Lab) at UMN conducts multiple projects to improve the management of diseases caused by soilborne fungi including Sclerotinia stem rot, charcoal rot, and Rhizoctonia seedling diseases and root and stem rot using genetic and cultural strategies such as cover cropping and chemical control. Future work will continue to understand the molecular interactions of P. sojae with soybean hosts. We also, recently contributed to a publication for the rapid diagnostics of P. sojae from plant samples using a newly developed LAMP assay (Zarouri et al., 2025).

Recommended Future Research:
In Objective 1, we are using Rps-containing differential lines to test which Rps varieties could be most resistant to the current P. sojae population. Differential lines, however, are typically used for pathogenicity assays in the laboratory. Using commercially available, Rps-containing industry lines instead could be more readily translatable to growers. We recommend checking the predicted molecular pathotypes against commercially available lines that have Rps3a or Rps6 genes.

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Publications:
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University of Minnesota
EXTENSION

Multifaceted Approaches in Understanding Sclerotinia Stem Rot Disease Avoidance & Resistance

Megan McCaghey, Aaron Lorenz and Suma Sreekanta

Research Question/Objectives:
Soybean canopy architecture influences the development and severity of Sclerotinia stem rot (SSR) by altering light intensity and microclimatic conditions within the canopy. Specifically, “bushy” architectures may create denser canopies that promote disease compared to more “upright” types. This is supported by previous work which observed a lower disease severity index of upright lines (Fig 1) in a field setting that differed from greenhouse evaluations where the lines were challenged directly with the pathogen. This research aims to characterize architectural traits of contrasting soybean lines, evaluate their relationship to SSR development, and compare architectural and chemical management strategies for disease control. In addition, a legacy panel of soybean lines is being evaluated to determine whether breeding for yield has influenced SSR resistance over time. The findings will inform both breeding and management strategies for reducing SSR impact in soybean production.

Objective 1: Characterize architectural attributes of “bushy” vs “upright” commercial lines.

This objective aimed to characterize key architectural traits distinguishing “bushy” and “upright” soybean lines using field-based imaging and canopy measurements. Six commercial varieties: XO 1822E
AG15XF2, XO 1545E (bushy), CT0324E, CZ 1660 GTLL and XO 1776E (upright) were grown in a randomized complete block design at the St. Paul research site. Over 200 high-resolution images were collected in the field all on a single day to avoid variation due to growth and change in developmental stages (Fig 2a). ImageJ was used to quantify morphological traits such as petiole and internode length, leaf shape traits, node number etc (see full list in Table 1). Stem segments bearing branches were harvested. Over 1200 images of individual branches were also taken separately to get an accurate measure of branch angle (Fig 2b). UAV-based imaging was conducted weekly to assess canopy coverage dynamics as a proxy for biomass accumulation and rate of canopy closure (Fig 2c).

Data analysis is currently in progress to identify traits that are associated with bushy and upright architectures and to evaluate how these characteristics influence the rate of canopy closure. The resulting insights combined with disease estimates will help in understanding how plant architecture may contribute to conditions favorable to development of SSR.

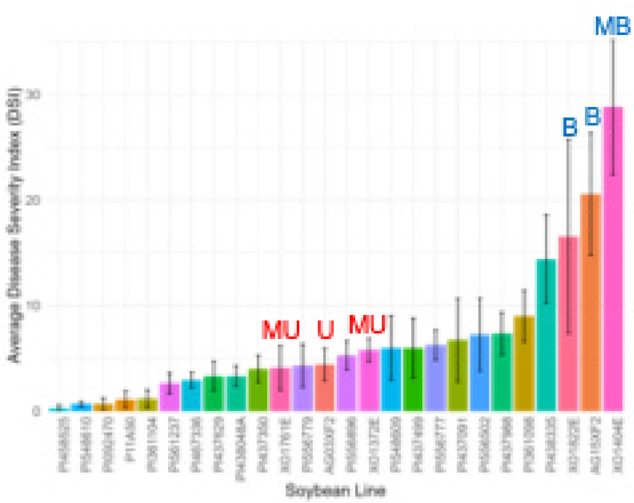

Figure 1. Field assessments of lines and varieties with diverse architectures from Saint Paul in 2024. These evaluations indicated the upright (U) and moderately upright (MU) were less susceptible that the bushy (B) and moderately bushy (MB) lines evaluated.

Figure 2. a) Individual plants (Six plants per plot) were harvested and subjected to destructive sampling at R1 developmental stage. The plants were placed on a blue background and imaged using an iPad mounted on an imaging platform assembled in house. Image J was employed to measure different traits from such images. b) Stem segment with all the branches were harvested and individual branches ere imaged to capture branch angle.
c) An Orthomosaic composite from 56 images of different varieties grown at the St Paul facility. The image was captured at 150ft above ground level using DJI Phantom 4 drone.

Arch traits	data collection completed (%)
Bra ang	0%
Leaf shape	100%
Petiole length	100%
Internode length	100%
First branch height	0%
Branching zone	0%
no of nodes	100%
number of branches	0%
plant length	100%
canopy coverage	100%

Table 1: Architecture traits measured in the study using the images captured in field. Image J is used to quantify the traits and amount completed is recorded as percentage.

Objective 2: Assess SSR development in current, commercial varieties of varied architectures

This objective aimed to evaluate SSR and apothecia development in soybean varieties differing in canopy architecture. In 2025, three bushy and three upright commercial soybean varieties were planted at the St. Paul research site (See obj 1 above). Sclerotia were obtained from a sunflower processing facility. They were cold conditioned in the lab (Pethybridge et al., 2015) and applied to the field to promote disease. Sclerotia depots were also constructed and placed under bushy and upright canopies to monitor germination and apothecia formation under varieties with different canopies. Irrigation was implemented prior to flowering to create favorable conditions for pathogen development, and disease incidence and severity were scored starting at R1 stage.

All planned field activities were completed as proposed. However, no apothecia and limited SSR symptoms were observed during the 2025 season. This may be attributed to other unfavorable environmental conditions during the season that were suboptimal for disease establishment despite irrigation in the field. Also, the use of sclerotia that had not overwintered may have resulted in a lack of apothecia. Cold conditioning in the lab may have be insufficient or ineffective to induce apothecia production under field conditions. To address these issues, sclerotia depots have been prepared and buried in the field to overwinter and will be used in next year's trials. Disease development was successful in 2023-2024, and an additional year of field evaluations are needed to compare the performance of lines.

Objective 3: Compare architecture and chemical management for disease control
This objective aimed to evaluate whether fungicide application can offset disease losses in bushy versus upright soybean varieties and to assess the economic benefits of each approach. In 2025, field experiments were conducted at the St. Paul research site using one bushy and one upright variety due to a reduced project scope (three varieties were proposed). Endura (boscalid) fungicide was applied at early flowering, and disease and yield data were collected as planned. However, as noted in Objective 2, no apothecia or SSR were observed this season, limiting our ability to compare the effects of chemical control versus canopy architecture (disease avoidance) under disease pressure. Yield data analysis is underway to determine whether fungicide application affected yield in the absence of disease, which, although not a primary objective, may still provide useful insights into potential yield drag or physiological effects of fungicide use under low-disease conditions.

Objective 4: Conduct field tests to evaluate the susceptibility of a legacy panel of soybean lines to S. sclerotiorum
This objective aimed to determine whether changes in soybean architecture and breeding for yield over time have influenced resistance to SSR. We selected a legacy panel of 20 soybean varieties representing public and commercial releases from the 1940s through the 2010s (Table 2) were grown at the St. Paul research site as proposed. Apothecia development and disease was scored in the field starting at R1 and at R6 stage. As noted previously, no apothecia or SSR symptoms were observed this season, which limited assessment of disease resistance trends across the legacy panel. Yield data is being processed to confirm progressive yield improvements in modern cultivars. The trial will need to be repeated next year to capture disease response under more conducive conditions. The results will provide valuable insights into how long-term breeding for yield and architecture may have affected SSR resistance in soybeans.

Cultivar	Originator	Status	YOR	MG
'Wis. Manchu 3'	Wisconsin Agr. Exp. Station	Public	1940	I
'Blackhawk'	Iowa Agr. Exp. Station and the U.S. Regional Soybean Laboratory	Public	1951	I
'Harosoy'	Dominion Exp. Farm, Ontario, Canada	Public	1951	II
'Hark'	Iowa Agr. Exp. Station and the U.S. Regional Soybean Laboratory	Public	1966	I
'Beeson'	Purdue Agr. Exp. Station and USDA Agr. Research Service	Public	1969	II
'SRF 100'	Soybean Research Foundation, Inc.	Expired PVP	1971	I
'Harcor'	Agr. Canada Research Station, Ontario, Canada	Public	1975	II
'FFR 111'	FFR Cooperative	Expired PVP	1975	I
'Harcor'	Agr. Canada Research Station, Ontario, Canada	Public	1975	II
'S 1346'	Novartis seeds, Inc.	Expired PVP	1975	I
'MN0902CN'	Minnesota Agr. Exp. Station	Public	1997	
'91M10'	Pioneer Hi-Bred International, Inc.	Expired PVP	2003	I
'MN1410'	Minnesota Agr. Exp. Station	Public	2007	I
'MN1701CN'	Minnesota Agr. Exp. Station	Public	2008	I
'IA2102'	Iowa Agr. Exp. Station	Public	2011	II
'MN1312CN'	Minnesota Agr. Exp. Station	Public	2014	I

Table 3: Varieties grown in 2025 in St Paul to asses disease resistance. Source of the variety, maturity group, the year of release (YOR) as well as the current status for each variety is also listed.

Application/Use:
The findings from this project will provide soybean growers with new insights into how plant architecture influences Sclerotinia stem rot (SSR) development. By identifying architectural traits that reduce disease severity, this research can guide breeders in selecting and developing varieties with improved tolerance to SSR. The results will also inform growers' management strategies in SSR infested fields by integrated disease control through genetic and architectural management tools. In addition, the project will foster collaboration among researchers across institutions, enhance outreach to growers through meetings and educational materials, and train students in applied plant pathology and breeding research, contributing to the long-term sustainability of soybean production in Minnesota.

Materials and Methods:
Field Imaging:
Field experiments were conducted at the University of Minnesota's St. Paul research site during the 2025 growing season to investigate the role of soybean canopy architecture in Sclerotinia stem rot (SSR) development and management. Six commercial varieties representing contrasting architectures, three bushy and three upright were grown in a randomized complete block design with five replications per line.

Images were acquired and measures as described previously (Sreekanta et al., 2024). Six plants were sampled per field plot. Plants were defoliated and placed on a dark background. The top five petioles were removed and placed on a dark background along with a representative fully expanded trifoliate leaf harvested from the center of the plant. Samples were imaged using an ipad at a consistent height of approximately 1.82 m above the samples. ImageJ (https://imagej.nih.gov/ij/; Schindelin et al., 2012), an open-source image analysis software, was used to measure the different traits. Images of branch angles were separately imaged using a blue background behind each individual branch and average branch angle per plant was calculated. Canopy coverage was estimated as previously described (Virdi et al., 2023)

Disease scoring: Disease severity and incidence were evaluated from the center row of each four row plot. Plants were scored either 0 (no infection), 1 (infection on branches), 2 (infection on, but not girdling, the main stem), or 3 (infection on the main stem resulting in death or poor pod fill).

Sclerotia depot construction and application:
Sclerotia depots were constructed as described: www.canolacouncil.org/make-a-sclerotia-depot/. These depots were cold conditioned using the Pethybridge protocol (Pethybridge, et al., 2015) where the depots were submerged in water in a cold room with continuous light and aeration using an aquarium pump. The water was replaced weekly to prevent algal growth, and sclerotia were maintained under these conditions for at least four weeks. The depots were then buried 1" beneath the soil surface. Sclerotia depots were monitored for % sclerotia germination and apothecia number from early flowering through full bloom.

Economic Benefit to a Typical 500 Acre Soybean Enterprise:
This work is intended to ultimately inform breeding efforts and farmers' variety selection to reduce yield losses from SSR. Conceptually, breeding for architectures with disease avoidance paired with genetic resistance could improve plant protection from S. sclerotiorum infection. Further, this work aims to provide additional management options for a persistent, yield limiting soybean disease in Minnesota.

Related Research:
The Soilborne Fungi and Oomycete Lab at UMN has several ongoing projects to better management SSR through genetics and cropping considerations. Additional projects include work to understand aggressiveness determinants of S. sclerotiorum to identify targets for gene silencing and work to understand the relationship between cover crops, pathogen survival, and disease occurrence. Ultimately, we aim for projects to have field relevance by informing the management of soilborne diseases.

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UNIVERSITY OF MINNESOTA
EXTENSION

Soybean Cyst Nematode Virulence Genetics, SNP Chip Development, & Survey of Field Populations

Senyu Chen

Summary:
The soybean cyst nematode (SCN; Heterodera glycines) is the most damaging pathogen of soybean and is widespread in Minnesota as well as most soybean-growing regions worldwide. SCN exhibits considerable variation in virulence (its ability to reproduce on different SCN-resistant soybean lines) and morphology.

In this project, we conducted virulence phenotyping of 182 SCN inbred lines on six sources of SCN-resistant soybean: PI 88788, Peking (PI 548402), Pickett (PI 548988), PI 567516C, PI 438489B, and PI 90763 (Figure 1). Eight SCN races were identified among the inbred lines: race 1 (25.3%), race 2 (4.9%), race 3 (21.4%), race 4 (2.2%), race 5 (15.9%), race 6 (14.3%), race 9 (4.9%), and race 14 (11.0%). The relatively low number of SCN lines with FI < 10 on PI 88788 suggests that cultivars derived from PI 88788 may provide insufficient resistance in many Minnesota fields. Peking type of resistance is distinct to the resistance in PI 88788, and most SCN lines were avirulent to Peking-type resistance. Rotation of PI 88788-derived cultivars with Peking-derived cultivars remains a good strategy for managing SCN in Minnesota.

Whole-genome sequencing was conducted on 178 of the 182 SCN lines to assess genetic diversity. Population genetic analyses revealed that a few inbred lines were genetically distinct from the rest. Phenotypic and genotypic data were used to conduct a Genome-wide Association Study (GWAS) to identify genomic regions, or quantitative trait loci (QTLs) associated with SCN virulence. Sixteen QTLs were identified, with only one associated with virulence to more than one soybean line. Specifically, one QTL was associated with virulence to Pickett, two to Peking, two to PI 88788, four to PI 90763, three to PI 438489B, and three to PI 567516C. Except for one, all QTLs were specific to a single soybean line, suggesting that these loci may control virulence to particular resistance sources (Figure 2).

Currently, we are (1) identifying candidate genes associated with SCN virulence phenotypes and morphological traits; and (2) developing molecular tools for HG type testing of field SCN populations.

This study advances our understanding of SCN virulence diversity and genetics, providing valuable insights to help soybean breeders select effective resistance sources and evaluate SCN resistance in commercial breeding programs. The findings could support the development of molecular tests for SCN virulence, offering a cost-effective alternative to the traditional greenhouse bioassay used in HG type testing. Improved SCN management through the technologies developed in this study could lead to significant economic benefits for soybean growers by increasing yield and profitability.

Figure 1. Growth room bioassay evaluating the ability of soybean cyst nematode (SCN) to parasitize soybean lines, each containing a distinct type of SCN resistance.

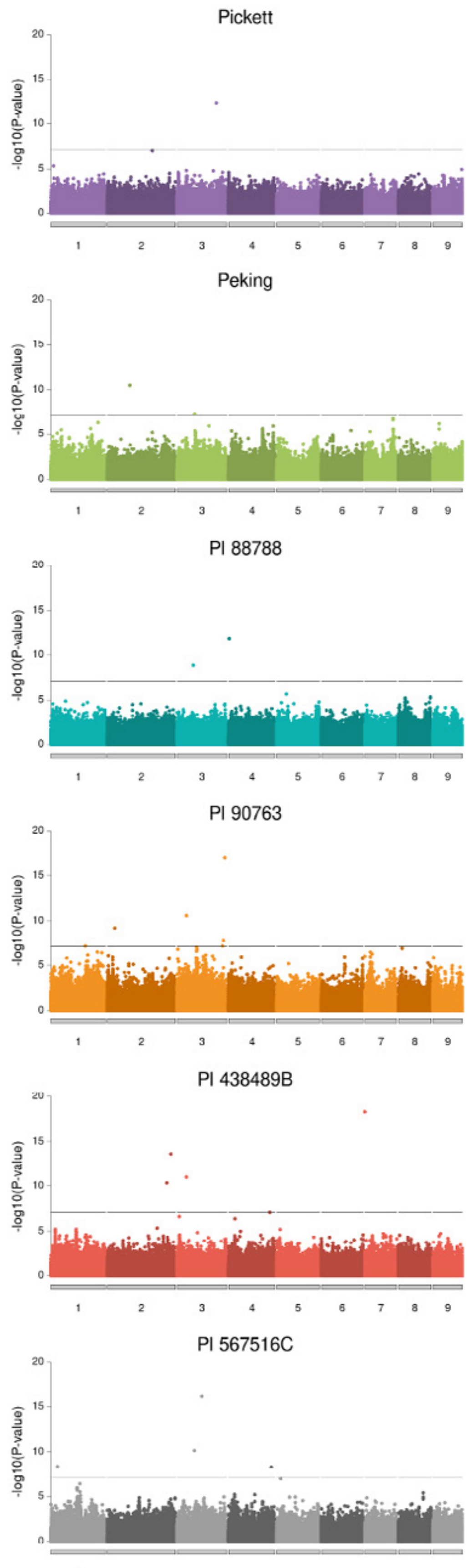

Figure 2. The Genome-wide Association Study (GWAS) identified sixteen variants associated with virulence on soybean lines. Only one variant, chr3_2868305, was associated with virulence on more than one soybean line (PI 90763 and PI 438489B). The associated loci also were not evenly distributed throughout the genome. Eight of the sixteen variants were found on chromosome 3, four were found on chromosome 2, two were found on chromosome 4, and one each was found on chromosomes 1 and 7.

University of Minnesota
EXTENSION

Soybean Breeding & Genetics

Aaron Lorenz

Creating new soybean varieties with enhanced value, novel pest resistance, and high yield helps producers maximize value per acre. The benefits of creating and choosing new varieties to maximize yield are clear, as on-farm yields have increased over the years. At least half of this on-farm increase in yield can be attributed to development of better varieties. Much of this activity is conducted in the private sector. Our public sector efforts strive to complement private sector research through licensing of germplasm, pursue long-term research, educate future plant breeders, and advancement of new breeding methods.

Research Question/Objectives:
Objective 1: Develop general-purpose and food-type soybean varieties adapted to Minnesota, and new sources of pest and disease resistance for application to Minnesota-adapted varieties.

Objective 2: Continue testing public and private soybean varieties available to Minnesota soybean producers.

Objective 3: Discover and develop new sources of resistance to soybean pests and diseases.

Results: As described in the previous Q1 report, all breeding nurseries and yield trials were successfully planted at 12 locations across the state of MN. In terms of materials in the field for the breeding programs, we planted 48 unique breeding parents and used them to design and successfully make 60 unique breeding crosses. F1 seeds from these crosses were harvested and sent to the Chile winter nursery for generational advancement. This past summer we grew 90 F2 populations and 79 F4 populations. The F2 populations were advanced to the F3 generation by single-seed descent, and F3 seeds were sent to Chile for generational advancement. The F4 were advanced to F4:5 families through individual plant harvest. Individual plant harvests were performed the last quarter and seed is currently being threshed.

Approximately 7400 plant rows were grown this year, and 1316 were selected on the basis of standability and maturity. These were harvested and will go into preliminary yield trials next year. Yield trials were harvested across 11 MN locations. Data has been imported into our database and analysis is ongoing as we prepare reports and make selections. All seed increases were harvested on time. The most important seed increase were the purified seed increases which produce breeder's seed for variety licensing and release. We had six of these at this stage, with four being new high oleic varieties that are being tested nationally. Over the coming month we will analyze the data and determine which varieties to advance and report this during our Crop Variety Review Committee.

Additionally, we completed the UMN State Soybean Variety Trials and published a preliminary report at https://varietytrials.umn.edu/soybean. A final report is being compiled right now in which we will include composition data.

Clockwise from top left corner: 1) Image of graduate student Isabella Fiore standing in front of an iron deficiency chlorosis (IDC) nursery. Each year we work with cooperators and station staff to plant and manage an IDC nursery to screen breeding materials for resistance to this abiotic stress. 2) Lorenz and Stupar speaking at a field day held on campus. Each summer we speak to numerous groups, educating them about the importance of cultivar development for soybean production. 3) Planting variety trials for the breeding program. Each spring, or small-plot planter plants tens of thousands of small plots to compare soybean breeding lines for advancement.

North Dakota Hard Red Spring Wheat

Clair Keene, Andrew Green, Shahidul Islam, Andrew Friskop, Tim Friesen, Zhaohui Liu, Upinder Gill, Michael Leng (NDSU Main Station); Yue Jin (USDA-ARS St. Paul, MN); John Rickertsen (Hettinger Research Extension Center); Leandro Bortolon, Austin Kraklau, Jayden Hansen, and Alexius Holter (North Central Research Extension Center, Minot); Rutendo Nyamusamba and Lawrence Henry (Langdon Research Extension Center); Glenn Martin (Dickinson Research Extension Center); Gautam Pradhan (Williston Research Extension Center); and Kristin Simons (Carrington Research Extension Center)

Hard red spring (HRS) wheat was planted on 5.1 million acres in 2025, down from 5.4 million acres in 2024. The average yield of HRS wheat was 55 bushels/acre (bu/a) across the state, down slightly from the record-high 59 bu/a recorded in 2024. The 2025 growing season was overall favorable for good HRS wheat yields with abundant rainfall in May and June across much of the state. Unusually, the only area of the state that was consistently dry throughout the growing season was the northeast. Many farmers were able to start seeding early relative to recent years with many starting to plant in mid to late-April and continuing more or less uninterrupted through mid-May. In the middle two weeks of May, much of the state, and especially the central region, recorded well above average rainfall with some locations receiving 5-7 inches of precipitation. Fields that were not seeded prior to this stretch of rainy weather were planted late as farmers had to wait for fields to dry. This had the effect of staggering the maturity of the HRS wheat crop with early-planted fields ready for harvest by mid-August and later-planted fields not ready until September.

WB9590 was again the most popular HRS wheat variety in North Dakota in 2025, reportedly planted on 15.9% of acres, followed by SY Valda (9.0%), AP Murdock (8.2%), MN Torgy (7.7%), and AP Smith (3.2%) as the top five varieties. WB9590 is a WestBred/Monsanto release and SY Valda, AP Murdock and AP Smith are Syngenta/AgriPro varieties. MN Torgy is a University of Minnesota release. NDSU varieties Elgin ND, Faller, and Glenn were reported on 2.2%, 1.5%, and 1.1% of acres, respectively. Glenn is considered a very high-quality HRS wheat and is still contracted on a few acres by the North Dakota Mill to ensure high-quality flour demanded by discerning buyers.

As of early fall, the 2025 HRS wheat crop is showing average to above-average protein levels with few quality issues reported. Cool overnight temperatures and rainy weather in August reduced falling numbers in portions of the affected crop. Locally heavy rains in early August in the central portion of the state reduced quality in early-planted fields that were ready to harvest when the rain fell. The August rains did not appear to harm later-planted fields.

Successful HRS wheat production depends on numerous factors, including selecting the right variety. The information included in this publication is meant to aid in selecting a variety or group of varieties. Characteristics to consider in selecting a variety 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 over several years.

Selecting varieties with good milling and baking quality is important to maintain market class recognition and avoid discounts. HRS wheat from the northern Great Plains is known around the world for its excellent end-use quality. It is recommended that producers balance their variety selection by taking into consideration not only yield, but also the quality rankings presented on Table 6 in this publication.

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 (superior bread-making quality is indicated by strong gluten proteins, high baking absorption and large bread loaf volume). These data are presented in Tables 6 and 7.

Gluten strength and milling and baking quality ratings are provided for individual varieties based on the results from the NDSU field trials conducted across multiple locations in 2024 (Table 7). 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 trials 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 shown at the bottom of the table, it means that with 90% confidence (LSD probability 0.10), the higher-yielding variety has a significant and real yield advantage. When the difference between two varieties is less than the LSD value, no significant difference was found between those two varieties under the growing conditions. Ideally, aim to select varieties that are high-yielding, preferably across locations and years, for your region of the state, along with those varieties that appear in the top half of the Wheat Quality Index ratings (Tables 6 and 7).

NS is used to indicate no significant difference for that trait among any of the varieties tested at the 90% level of confidence. CV stands for coefficient of variation and is expressed as a percentage. The CV is a measure of variability in the trial. Large CVs (CV > 10%) indicate a large amount of variation could not be attributed to differences among the varieties. Yield is reported on a 13.5% moisture basis, while protein content is reported at 12% moisture content, per industry standards.

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 or altered, appropriate footnotes are given, and the order of the data is not rearranged. Additional data from county sites are available from each NDSU Research Extension Center and at https://www.ag.ndsu.edu/varietytrials/variety-trial-results.

Overall, the 2025 HRS wheat crop experienced lower disease pressure relative to 2024. However, moderate temperatures and high humidity and/or rain resulted in some localized areas of Fusarium Head Blight (scab). Multiple rounds of strong thunderstorms impacted the crop in the central and southeast parts of the state in mid-summer which contributed to pockets of bacterial leaf streak (BLS) within fields. The disease observations below provide a brief summary of issues that likely impacted yields at selected locations.

Location	**2025 Disease and damage observations of note**
Casselton	Moderate to high levels of FHB which reduced yield of many varieties. Severe lodging occurred after a period of intense rain and wind and the trial was harvested after a prolonged period of rain.
Forman	Moderate bacterial leaf streak (BLS), trace levels of late-season leaf rust, and high levels of FHB. Grain was harvested late after multiple rain events delayed harvest and caused sprout damage.
Prosper	Moderate levels of FHB, which reduced yield of many varieties. Strong winds caused a fair amount of lodging in the trial.
Thompson	Moderate levels of FHB, which reduced yield of many varieties. Some lodging occurred due to late-summer thunderstorms.
Williston	A late July hailstorm reduced small grain yields by 30%-40% across the research station.

List of Tables

Table 1. North Dakota hard red spring wheat variety descriptions, agronomic traits, 2025.

Variety	Agent or Origin[1]	Year Released	Height (inches)[2]	Straw Strength[3]	Days to Head[4]	Reaction to Disease[5] Stem Rust[6]	Leaf Rust	Tan Spot	Bact. Leaf Streak	Head Scab	Stripe Rust	DRI Value[8]
AAC Hockley	**Evolution Genetics**	**2022**	**31**	**4**	**57**	**2**	**2**	**3**	**7**	**4**	**NA**	**49**
AAC Hodge	**Evolution Genetics**	**2022**	**35**	**4**	**57**	**2**	**4**	**4**	**6**	**4**	**NA**	**49**
AP Dagr	**Syngenta/AgriPro**	**2024**	**29**	**5**	**60**	**2**	**2**	**3**	**6**	**5**	**NA**	**51**
AP Elevate	**Syngenta/AgriPro**	**2024**	**29**	**4**	**59**	**2**	**4**	**3**	**5**	**5**	**3**	**50**
AP Gunsmoke CL2	Syngenta/AgriPro	2021	30	6	58	2	3	6	8	5	4	62
AP Iconic	**Syngenta/AgriPro**	**2024**	**31**	**4**	**59**	**2**	**3**	**6**	**5**	**5**	**NA**	**53**
AP Murdock	Syngenta/AgriPro	2019	30	4	58	2	6	3	6	5	3	54
AP Smith	Syngenta/AgriPro	2021	29	3	60	1	4	5	5	6	4	58
Ascend-SD	SD	2022	35	5	60	2	3	6	4	5	3	51
Brawn-SD	SD	2022	33	5	58	2	2	5	5	6	6	57
CP3678	**Croplan**	**2025**	**31**	**4**	**60**	**2**	**6**	**6**	**5**	**6**	**NA**	**61**
Dagmar	MT	2019	32	4	57	1	8	7	7	8	NA	80
Driver	SD	2019	33	3	60	2	2	6	6	5	2	56
Enhance-SD	**SD**	**2025**	**33**	**4**	**56**	**2**	**3**	**3**	**6**	**6**	**NA**	**58**
Faller	ND	2007	34	7	59	2	8	3	5	5	8	53
LCS Ascent	Limagrain	2022	31	5	56	2	7	5	6	5	2	58
LCS Cannon	Limagrain	2018	30	4	55	2	6	6	7	5	4	61
LCS Rimfire	**Limagrain**	**2024**	**28**	**4**	**57**	**2**	**8**	**2**	**7**	**5**	**NA**	**57**
MN-Lang	MN	2017	32	4	60	2	2	7	4	6	NA	57
MN- Rothsay	MN	2022	29	3	61	2	7	5	6	5	6	58
MN-Torgy	MN	2020	31	4	58	1	2	4	6	4	3	47
Mott[7]	ND	2009	36	4	57	2	8	7	5	5	NA	58
MS Charger	Meridian Seeds	2022	30	7	58	1	4	5	7	5	8	58
MS Cobra	Meridian Seeds	2022	30	4	58	1	2	6	7	6	3	63
MS Nova	**Meridian Seeds**	**2024**	**31**	**4**	**57**	**1**	**4**	**6**	**7**	**5**	**3**	**59**
MT Carlson	MT	2023	30	7	58	2	7	4	7	8	4	76
ND Frohberg	ND	2020	34	4	58	2	4	7	4	5	3	53
ND Heron	ND	2021	32	5	55	1	6	4	7	4	6	52
ND Horizon	**ND**	**2025**	**31**	**3**	**58**	**2**	**5**	**4**	**5**	**5**	**NA**	**52**
ND Roughrider	**ND**	**2025**	**32**	**6**	**60**	**2**	**4**	**3**	**6**	**6**	**NA**	**58**
ND Stampede	**ND**	**2024**	**32**	**4**	**58**	**1**	**2**	**5**	**7**	**5**	**9**	**56**
ND Thresher	ND	2023	30	4	59	2	5	4	4	4	6	44
PFS Muffins	**Peterson Farm Seeds**	**2025**	**29**	**4**	**58**	**2**	**2**	**3**	**6**	**7**	**NA**	**63**
PFS Rolls	**Peterson Farm Seeds**	**2023**	**32**	**4**	**60**	**2**	**5**	**4**	**5**	**7**	**6**	**63**
PG Predator	**Premier Genetics**	**2025**	**29**	**4**	**60**	**2**	**3**	**4**	**5**	**6**	**NA**	**56**
Shelly	MN	2016	30	4	60	1	6	6	7	5	4	60
SY 611CL2	Syngenta/AgriPro	2019	29	3	58	2	6	4	6	4	4	50
SY Ingmar	Syngenta/AgriPro	2014	30	4	59	1	4	4	6	5	4	53
SY Valda	Syngenta/AgriPro	2015	30	5	59	1	3	4	7	5	8	56
TCG-Badlands	**21st Century Genetics**	**2024**	**32**	**4**	**58**	**1**	**6**	**4**	**6**	**7**	**3**	**66**
TCG-Wildcat	21st Century Genetics	2020	31	4	59	1	7	6	6	7	6	69
TCG-Zelda	**21st Century Genetics**	**2024**	**29**	**4**	**57**	**1**	**2**	**6**	**7**	**7**	**8**	**69**
TW Olympic	**Thunder Seed**	**2021**	**32**	**4**	**58**	**2**	**8**	**7**	**6**	**5**	**NA**	**61**
TW Trailfire	**Thunder Seed**	**2022**	**31**	**8**	**56**	**2**	**7**	**6**	**6**	**6**	**NA**	**65**
WB9590	WestBred	2017	27	3	57	2	3	6	8	8	8	78

[1]Refers to agent or developer: MN = Univ of Minnesota; MT = Montana State Univ; ND = North Dakota State Univ; SD = South Dakota State Univ

Varieties in bold text are a recent release or first year entry in NDSU trials with limited data available and the potential for future ratings to change.

[2]Height data averaged from 9 locations in 2025.

[3]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.

[4]Days to Head = the number of days from planting to head emergence from the boot, averaged based on data from 7 locations in 2025.

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

[6]Stem rust scores determined from field severity ratings and *Puccinia graminis* f. sp. *tritici* race QFCQ

[7]Solid stem or semi-solid stem for increased resistance to wheat stem sawfly.

[8]Disease Risk Index Value = Value to assess overall disease risk associated with a variety. The higher the value indicates higher disease risk. Value created using a weighted formula based on ranked importance of wheat diseases. Value does not include stripe rust (incomplete data due to minimal stripe rust occurrence in 2025).

Table 2. Yield of hard red spring wheat varieties at six locations in eastern North Dakota 2023-2025.

	Carrington		Casselton		Forman		Langdon		Prosper		Thompson		Average	
Variety	2025	3 Yr.	2025	3 Yr.	2025	3 Yr.	2025	3 Yr.	2025	3 Yr.	2025	2 Yr.	2025	3 Yr.
							(bu/a)							
AAC Hockley	**66.4**	**--**	**77.3**	**--**	**62.0**	**--**	**80.5**	**--**	**85.8**	**--**	**65.7**	**--**	**72.9**	**--**
AAC Hodge	**72.7**	**--**	**86.7**	**--**	**71.8**	**--**	**87.3**	**--**	**91.6**	**--**	**72.0**	**--**	**80.4**	**--**
AP Dagr	**81.7**	**--**	**87.7**	**--**	**72.0**	**--**	**87.4**	**--**	**93.0**	**--**	**77.0**	**--**	**83.1**	**--**
AP Elevate	**78.7**	**--**	**92.9**	**--**	**68.4**	**--**	**90.4**	**--**	**99.5**	**--**	**79.6**	**92.7**	**84.9**	**--**
AP Gunsmoke CL2	76.9	68.6	89.9	86.1	70.2	68.4	81.7	78.6	89.1	89.6	80.1	87.2	81.3	79.7
AP Iconic	**76.2**	**--**	**89.5**	**--**	**66.0**	**--**	**89.6**	**--**	**99.0**	**--**	**80.1**	**--**	**83.4**	**--**
AP Murdock	84.2	76.0	92.1	91.3	67.1	68.7	93.6	84.0	99.9	93.5	81.3	93.5	86.4	84.5
AP Smith	75.1	72.2	85.9	86.4	62.7	65.6	83.8	81.7	87.5	88.4	74.4	88.2	78.2	80.4
Ascend-SD	79.8	79.7	95.6	92.3	73.6	67.0	96.4	85.9	94.0	99.3	79.0	92.2	86.4	86.1
Brawn-SD	85.3	76.5	89.2	90.5	67.9	67.1	89.7	85.9	104.9	101.6	76.0	94.3	85.5	86.0
CP3678	**71.8**	**--**	**94.4**	**--**	**68.4**	**--**	**88.5**	**--**	**89.9**	**--**	**64.4**	**--**	**79.6**	**--**
Dagmar	81.3	--	91.0	--	60.2	--	86.2	--	96.9	--	80.0	--	82.6	--
Driver	70.9	72.4	93.5	89.7	74.7	68.1	90.7	85.6	93.4	92.7	72.5	85.9	82.6	82.4
Enhance-SD	**87.5**	**--**	**90.6**	**--**	**75.0**	**--**	**92.4**	**--**	**103.4**	**--**	**78.5**	**94.9**	**87.9**	**--**
Faller	86.4	78.7	95.4	--	77.7	--	98.2	89.4	100.0	--	81.3	92.2	89.8	86.8
LCS Ascent	77.9	71.9	80.4	89.7	68.9	67.4	92.1	86.6	100.2	--	80.0	94.4	83.2	82.0
LCS Cannon	72.2	70.4	83.5	87.2	74.3	69.4	87.3	84.9	96.8	93.9	82.3	92.3	82.7	83.0
LCS Rimfire	**82.0**	**--**	**85.9**	**--**	**65.8**	**--**	**89.6**	**--**	**97.7**	**88.4**	**70.3**	**--**	**81.9**	**88.4**
MN-Lang	70.5	--	83.7	--	69.7	--	86.9	--	83.0	--	73.5	--	77.9	--
MN- Rothsay	79.2	74.1	93.2	88.1	75.9	69.1	89.1	85.6	93.7	93.0	78.4	91.1	84.9	83.5
MN-Torgy	79.5	70.1	86.6	85.5	73.4	69.4	94.9	83.9	92.6	94.6	70.2	83.9	82.9	81.2
Mott	--	--	87.9	--	68.8	--	.	.	91.9	--	67.7	--	79.0	--
MS Charger	81.0	77.2	92.2	92.4	71.1	70.5	92.5	88.3	92.7	97.3	79.2	97.8	84.8	87.2
MS Cobra	75.9	70.7	81.4	87.3	61.9	63.7	91.0	84.1	93.5	90.0	70.3	89.3	79.0	80.9
MS Nova	**69.3**	**--**	**79.1**	**--**	**68.4**	**--**	**84.2**	**--**	**92.9**	**--**	**76.7**	**87.1**	**78.4**	**87.1**
MT Carlson	75.3	--	87.4	--	51.5	--	74.7	--	97.5	--	64.7	81.5	75.2	81.5
ND Frohberg	69.9	69.0	80.1	82.7	62.9	59.0	80.9	77.2	92.2	90.6	68.6	84.7	75.8	77.2
ND Heron	69.9	64.9	78.9	79.1	70.1	64.6	85.1	80.0	90.8	88.9	71.5	79.7	77.7	76.2
ND Horizon	**80.7**	**75.1**	**93.5**	**96.3**	**74.1**	**71.3**	**89.4**	**85.1**	**101.0**	**98.6**	**90.4**	**93.2**	**88.2**	**86.6**
ND Roughrider	**83.5**	**86.8**	**96.3**	**93.2**	**69.7**	**73.6**	**88.1**	**87.7**	**99.5**	**104.3**	**85.8**	**102.6**	**87.1**	**91.4**
ND Stampede	**81.6**	**79.0**	**90.8**	**86.9**	**73.2**	**71.2**	**85.6**	**85.5**	**98.5**	**97.0**	**84.5**	**103.3**	**85.7**	**87.2**
ND Thresher	75.4	71.0	91.8	86.6	65.8	63.3	96.1	81.6	93.3	92.3	72.1	90.5	82.4	80.9
PFS Muffins	**82.1**	**--**	**83.3**	**--**	**64.8**	**--**	**95.8**	**--**	**93.6**	**--**	**81.1**	**--**	**83.4**	**--**
PFS Rolls	**75.7**	**--**	**86.5**	**--**	**58.6**	**--**	**85.7**	**--**	**100.8**	**--**	**75.3**	**86.5**	**80.4**	**86.5**
PG Predator	**73.1**	**--**	**89.6**	**--**	**69.1**	**--**	**88.3**	**--**	**95.3**	**--**	**79.5**	**--**	**82.5**	**--**
Shelly	71.7	68.8	80.5	83.5	74.3	70.7	88.2	88.3	98.3	95.5	76.4	--	81.6	81.3
SY 611CL2	79.1	75.1	84.6	86.7	70.9	67.1	87.3	85.3	92.5	93.7	75.8	91.6	81.7	83.2
SY Ingmar	71.2	69.1	86.0	85.4	62.7	63.2	84.9	76.8	90.1	89.3	72.7	86.2	77.9	78.3
SY Valda	77.1	75.6	89.3	92.0	67.9	71.2	89.0	85.0	90.8	97.4	86.4	96.5	83.4	86.3
TCG-Badlands	**79.8**	**--**	**87.8**	**--**	**61.8**	**--**	**82.5**	**--**	**93.5**	**--**	**69.6**	**89.6**	**79.2**	**89.6**
TCG-Wildcat	78.7	77.5	88.4	89.6	60.4	59.8	85.5	82.9	97.5	98.2	85.7	94.8	82.7	83.8
TCG-Zelda	**82.5**	**--**	**87.8**	**--**	**68.4**	**--**	**90.3**	**--**	**102.9**	**--**	**78.6**	**96.5**	**85.1**	**96.5**
TW Olympic	**75.2**	**--**	**93.0**	**--**	**73.0**	**--**	**96.3**	**--**	**99.6**	**--**	**75.0**	**--**	**85.3**	**--**
TW Trailfire	**72.3**	**--**	**84.4**	**--**	**66.6**	**--**	**81.9**	**--**	**84.5**	**--**	**74.1**	**--**	**77.3**	**--**
WB9590	66.5	67.7	80.4	82.3	68.6	63.7	84.7	82.5	99.9	97.3	76.0	89.1	79.3	80.4
Mean	76.9	73.5	87.7	87.9	68.0	67.2	89.0	84.1	95.0	94.5	76.3	91.1	82.0	84.1
CV%	5.4	--	3.6	--	4.2	--	4.2	--	6.4	--	6.5	--	5.0	--
LSD 0.10	4.8	--	4.2	--	3.9	--	4.0	--	6.4	--	8.6	--	4.0	--

Table 3. Yield of hard red spring wheat varieties grown at five locations in western North Dakota 2023-2025.

	Dickinson		Hettinger		Mandan		Minot		Williston[1]		Average	
Variety	2025	3 Yr.	2025	3 Yr.	2025	3 Yr.	2025	3 Yr.	2025	3 Yr.	2025	3 Yr.
						(bu/a)						
AAC Hockley	--	--	64.3	--	55.6	--	58.8	--	42.0	--	55.2	--
AAC Hodge	--	--	69.6	--	56.5	--	66.5	--	43.5	--	59.0	--
AP Dagr	80.4	--	64.5	--	58.7	--	65.3	--	38.4	--	61.5	--
AP Elevate	80.7	--	67.8	--	59.8	--	67.2	--	32.5	--	61.6	--
AP Gunsmoke CL2	83.2	67.7	65.2	70.5	50.0	53.9	64.1	61.0	42.2	51.4	60.9	60.9
AP Iconic	79.2	--	70.6	--	56.0	--	66.4	--	39.3	--	62.3	--
AP Murdock	74.2	61.7	63.2	65.0	54.6	58.6	60.5	63.9	32.1	43.2	56.9	58.5
AP Smith	77.2	62.6	64.8	66.7	52.6	54.2	62.3	60.6	34.9	41.6	58.4	57.1
Ascend-SD	86.7	67.2	68.8	70.8	57.3	62.7	72.1	66.0	38.8	45.3	64.7	62.4
Brawn-SD	86.6	67.8	71.8	75.0	65.1	61.0	75.4	70.5	41.9	45.5	68.2	63.9
CP3678	88.9	--	69.0	--	54.6	--	67.6	--	45.0	--	65.0	--
Dagmar	82.3	--	67.9	--	52.9	--	71.3	--	46.0	--	64.1	--
Driver	84.0	66.1	66.9	71.8	62.3	62.2	66.2	57.8	44.6	51.3	64.8	61.9
Enhance-SD	76.5	--	70.1	--	57.7	--	65.0	--	36.2	--	61.1	--
Faller	85.6	68.7	71.2	--	57.1	--	78.0	--	38.8	--	66.1	68.7
LCS Ascent	94.1	73.8	70.9	69.6	55.0	56.6	77.1	70.2	39.1	52.1	67.2	64.5
LCS Cannon	76.1	67.0	68.3	67.2	56.6	56.0	67.3	60.6	42.6	46.9	62.2	59.5
LCS Rimfire	83.2	--	67.4	--	56.9	--	71.9	--	43.8	--	64.6	--
MN-Lang	79.7	--	64.4	--	53.6	--	64.0	--	35.3	--	59.4	--
MN- Rothsay	88.0	67.5	68.9	69.8	58.0	59.7	67.6	65.6	38.5	43.8	64.2	61.3
MN-Torgy	83.5	67.7	68.8	71.4	62.3	64.8	68.5	66.6	43.3	49.0	65.3	63.9
Mott	--	--	--	--	--	--	--	--	--	--	--	--
MS Charger	91.4	67.7	67.8	72.0	57.3	56.1	78.7	63.8	43.2	51.3	67.7	62.2
MS Cobra	84.4	67.1	63.8	66.9	55.7	58.5	70.8	66.3	35.9	44.6	62.1	60.7
MS Nova	86.3	--	67.4	--	56.8	--	68.1	--	47.1	--	65.2	--
MT Carlson	80.4	--	66.4	--	50.8	--	72.1	--	37.2	--	61.4	--
ND Frohberg	79.2	64.8	63.7	66.1	58.2	55.5	66.2	60.2	34.2	42.7	60.3	57.9
ND Heron	75.9	62.1	65.8	65.3	55.0	54.0	66.7	58.6	43.8	48.9	61.4	57.8
ND Horizon	82.0	64.1	64.9	69.5	61.6	62.3	81.0	65.4	43.5	--	66.6	65.3
ND Roughrider	92.7	69.2	75.7	76.2	68.4	68.1	81.0	71.4	41.6	--	71.9	71.2
ND Stampede	86.1	65.6	67.2	70.3	61.5	59.4	78.5	68.3	35.6	--	65.8	65.9
ND Thresher	77.8	60.7	61.4	67.2	45.1	52.3	64.2	56.7	36.9	39.2	57.1	55.2
PFS Muffins	91.9	--	68.4	--	58.5	--	79.8	--	38.7	--	67.5	--
PFS Rolls	91.7	--	70.1	--	54.3	--	74.3	--	33.8	--	64.8	--
PG Predator	82.0	--	67.6	--	58.8	--	71.1	--	33.8	--	62.7	--
Shelly	88.8	69.0	65.0	69.9	57.9	59.1	78.0	68.9	40.2	44.5	66.0	62.3
SY 611CL2	80.7	66.6	68.0	69.2	56.0	61.0	68.4	61.4	42.2	49.9	63.1	61.6
SY Ingmar	77.5	64.1	63.9	62.9	52.0	55.2	64.8	58.4	38.0	--	59.2	60.1
SY Valda	85.5	68.1	66.2	69.7	58.0	61.5	69.5	61.3	42.7	--	64.4	65.1
TCG-Badlands	87.5	--	66.4	--	57.6	--	73.7	--	30.1	--	63.1	--
TCG-Wildcat	83.0	67.5	66.2	67.4	58.8	59.9	63.0	66.2	33.9	45.1	61.0	61.2
TCG-Zelda	89.1	--	69.6	--	61.5	--	72.3	--	43.6	--	67.2	--
TW Olympic	88.7	--	70.3	--	59.1	--	68.0	--	36.6	--	64.5	--
TW Trailfire	76.0	--	59.8	--	44.7	--	71.1	--	45.3	--	59.4	--
WB9590	79.0	64.5	69.7	68.5	56.2	55.4	71.1	65.7	35.8	--	62.4	63.5
Mean	83.9	66.4	67.6	69.5	56.0	58.5	70.4	--	39.5	46.5	63.1	62.1
CV%	6.2	--	4.5	--	8.2	--	7.2	--	6.7	--	5.9	--
LSD 0.10	4.8	--	2.8	--	4.2	--	6.8	--	6.2	--	3.9	--

[1]Williston site damaged by a hailstorm which was estimated to reduce small grain yields by 40%. Assuming 40% loss, trial average yield potential was 55.3 bu/ ac.

Table 4. Protein at 12% moisture of hard red spring wheat varieties across 11 locations in North Dakota, 2025.

Variety	Carrington	Casselton	Forman	Langdon	Prosper	Thompson	Dickinson	Hettinger	Mandan	Minot	Williston	State Avg.
						---(%)---						
AAC Hockley	**15.6**	**15.0**	**15.6**	**14.1**	**13.7**	**13.9**	**--**	**12.4**	**13.9**	**14.1**	**17.8**	**14.6**
AAC Hodge	**15.4**	**14.5**	**15.9**	**15.2**	**14.5**	**14.1**	**--**	**13.3**	**14.7**	**14.4**	**17.3**	**14.9**
AP Dagr	**14.0**	**13.4**	**14.3**	**13.4**	**13.2**	**12.6**	**13.8**	**11.4**	**13.0**	**12.5**	**16.6**	**13.5**
AP Elevate	**14.8**	**14.3**	**15.2**	**14.4**	**13.6**	**13.0**	**14.4**	**13.1**	**14.3**	**15.0**	**16.8**	**14.4**
AP Gunsmoke CL2	15.5	14.8	15.5	14.7	14.9	14.9	14.3	11.8	13.5	15.0	17.3	14.7
AP Iconic	**14.2**	**13.8**	**14.6**	**14.0**	**13.4**	**12.8**	**14.3**	**12.5**	**14.0**	**13.1**	**16.2**	**13.9**
AP Murdock	14.5	14.3	15.3	14.0	13.6	12.8	14.0	12.3	13.7	15.0	16.3	14.1
AP Smith	15.1	14.4	15.2	14.7	13.7	13.7	14.5	13.3	14.5	14.3	16.1	14.5
Ascend-SD	15.1	14.7	15.6	15.2	14.1	14.4	14.3	12.5	13.2	14.7	16.3	14.6
Brawn-SD	13.7	14.3	14.6	13.3	13.0	12.7	13.1	12.0	12.4	14.2	15.2	13.5
CP3678	**15.1**	**14.9**	**16.1**	**14.5**	**14.4**	**14.5**	**14.7**	**12.7**	**14.1**	**15.1**	**16.4**	**14.8**
Dagmar	14.7	15.3	16.4	15.2	14.1	14.5	15.0	12.4	14.4	16.0	16.7	15.0
Driver	14.4	14.6	15.4	14.1	13.9	13.7	13.9	13.1	13.5	15.3	15.2	14.3
Enhance-SD	**15.1**	**14.8**	**16.0**	**15.0**	**13.7**	**14.1**	**14.0**	**13.2**	**13.7**	**14.8**	**16.4**	**14.6**
Faller	13.5	14.1	15.4	13.7	13.2	13.1	13.6	12.3	13.5	14.2	14.7	13.8
LCS Ascent	13.4	13.9	15.1	14.1	12.7	12.1	13.3	11.8	12.9	13.8	15.9	13.5
LCS Cannon	14.6	14.9	15.5	14.0	12.8	12.8	14.0	12.7	12.9	14.8	15.8	14.1
LCS Rimfire	**13.9**	**14.7**	**15.7**	**14.6**	**13.2**	**13.5**	**14.0**	**12.5**	**13.9**	**15.3**	**15.1**	**14.2**
MN-Lang	14.9	15.0	16.4	15.2	14.4	14.6	14.6	13.2	15.1	15.7	15.7	15.0
MN- Rothsay	14.9	14.2	15.4	14.4	13.4	13.4	13.8	13.2	13.7	15.0	16.2	14.3
MN-Torgy	14.9	14.5	16.1	14.5	14.1	14.5	14.1	12.5	14.2	15.1	16.4	14.6
Mott	--	14.4	15.9	--	13.5	13.6	--	--	--	--	--	14.3
MS Charger	13.4	13.0	14.0	12.6	12.2	11.9	12.6	11.5	12.5	13.2	14.3	12.8
MS Cobra	14.8	14.5	16.0	14.8	13.7	13.5	14.0	12.7	13.9	15.3	15.7	14.4
MS Nova	**15.0**	**14.7**	**15.8**	**14.5**	**13.7**	**13.3**	**13.8**	**12.7**	**13.5**	**14.5**	**16.2**	**14.3**
MT Carlson	14.1	14.4	15.5	14.1	13.0	12.8	13.5	12.1	13.3	13.8	15.0	13.8
ND Frohberg	15.4	14.4	15.4	14.5	13.4	13.3	14.8	12.5	14.3	15.3	16.1	14.5
ND Heron	15.0	15.1	16.0	15.0	14.2	13.8	14.5	13.2	14.0	14.6	17.0	14.8
ND Horizon	**15.5**	**15.0**	**15.9**	**15.6**	**14.1**	**13.7**	**14.6**	**13.0**	**13.8**	**14.9**	**16.5**	**14.8**
ND Roughrider	**14.5**	**14.1**	**14.8**	**14.4**	**14.3**	**13.9**	**13.3**	**11.9**	**13.7**	**14.0**	**16.9**	**14.2**
ND Stampede	**14.4**	**15.1**	**15.8**	**15.2**	**13.8**	**14.0**	**14.3**	**12.4**	**13.8**	**16.1**	**17.2**	**14.7**
ND Thresher	14.5	14.7	15.6	14.8	13.8	14.1	14.3	12.9	15.6	15.4	16.0	14.7
PFS Muffins	**14.0**	**14.4**	**15.4**	**14.3**	**13.7**	**13.2**	**13.7**	**11.9**	**13.6**	**15.2**	**15.8**	**14.1**
PFS Rolls	**15.0**	**14.3**	**15.7**	**14.6**	**13.3**	**13.2**	**13.5**	**12.2**	**13.6**	**14.0**	**15.7**	**14.1**
PG Predator	**14.6**	**14.3**	**15.3**	**14.7**	**13.7**	**13.1**	**14.5**	**13.0**	**14.4**	**14.6**	**16.3**	**14.4**
Shelly	14.7	14.1	15.9	14.5	13.3	13.5	13.6	11.7	13.5	14.6	14.3	14.0
SY 611CL2	14.6	14.5	15.5	14.7	14.0	13.7	14.6	12.2	14.0	14.6	16.3	14.4
SY Ingmar	15.3	14.6	15.1	14.8	14.0	13.9	14.7	13.0	14.8	15.0	16.7	14.7
SY Valda	14.9	14.0	14.8	14.2	13.6	13.2	13.8	12.1	13.1	14.5	15.9	14.0
TCG-Badlands	**14.5**	**14.3**	**15.1**	**14.3**	**13.2**	**13.3**	**13.9**	**12.2**	**13.4**	**14.5**	**16.2**	**14.1**
TCG-Wildcat	14.3	15.0	15.6	15.1	13.9	13.9	14.3	13.1	14.1	15.4	17.0	14.7
TCG-Zelda	**14.3**	**14.8**	**15.1**	**14.2**	**13.6**	**13.8**	**14.0**	**12.6**	**13.6**	**14.8**	**16.4**	**14.3**
TW Olympic	**14.1**	**14.8**	**15.7**	**14.2**	**14.2**	**13.8**	**13.7**	**12.5**	**13.7**	**15.4**	**16.0**	**14.4**
TW Trailfire	**14.5**	**15.3**	**16.0**	**14.8**	**13.0**	**13.2**	**14.3**	**12.4**	**13.4**	**15.3**	**16.1**	**14.4**
WB9590	15.5	15.3	15.9	14.7	13.9	13.8	14.7	13.0	13.9	14.5	17.1	14.8
Mean	14.5	14.5	15.5	14.3	13.7	13.5	14.1	12.5	13.7	14.5	16.1	14.3
CV%	3.8	1.2	0.3	2.2	4.1	1.9	2.9	4.1	2.6	4.8	3.1	2.8
LSD 0.10	0.6	0.3	0.3	0.4	0.4	0.4	0.4	0.5	0.3	0.9	1.2	0.3

Table 5. Test weight of hard red spring wheat varieties grown at 11 locations in North Dakota, 2025.

Variety	Carrington	Casselton	Forman	Langdon	Prosper	Thompson	Dickinson	Hettinger	Mandan	Minot	Williston	State Avg.
						(lb/bu)						
AAC Hockley	**63.9**	**61.7**	**60.3**	**59.8**	**60.8**	**59.6**	**--**	**61.7**	**58.2**	**64.0**	**55.2**	**60.5**
AAC Hodge	**63.6**	**61.4**	**59.7**	**58.6**	**60.3**	**59.6**	**--**	**61.5**	**57.7**	**63.8**	**55.0**	**60.1**
AP Dagr	**61.0**	**59.8**	**56.7**	**58.0**	**56.9**	**55.3**	**60.2**	**59.3**	**56.6**	**62.5**	**53.1**	**58.1**
AP Elevate	**61.5**	**61.1**	**58.9**	**58.4**	**58.9**	**58.3**	**61.4**	**60.5**	**57.1**	**63.0**	**54.6**	**59.4**
AP Gunsmoke CL2	62.1	60.3	59.3	58.1	58.2	58.9	61.1	59.9	56.9	63.1	54.5	59.3
AP Iconic	**62.8**	**61.3**	**58.6**	**58.9**	**58.8**	**58.0**	**61.1**	**60.4**	**56.8**	**63.7**	**54.8**	**59.6**
AP Murdock	61.7	60.5	58.3	56.2	59.3	59.1	60.6	60.4	56.7	62.3	54.0	59.0
AP Smith	62.1	60.9	58.6	58.8	58.6	57.4	61.5	60.9	56.5	63.6	54.7	59.4
Ascend-SD	63.4	61.2	59.8	55.3	59.9	59.6	61.8	61.4	58.2	63.3	54.5	59.9
Brawn-SD	64.0	62.1	58.9	61.6	61.5	60.2	62.8	61.9	58.9	64.8	56.8	61.2
CP3678	**62.3**	**60.9**	**58.0**	**58.4**	**59.4**	**57.2**	**61.4**	**61.0**	**56.4**	**63.3**	**55.9**	**59.5**
Dagmar	63.0	60.6	57.7	59.0	59.7	58.7	60.9	61.1	56.9	62.9	54.8	59.6
Driver	63.4	61.8	59.1	60.5	60.5	59.7	62.1	61.9	58.9	64.2	56.6	60.8
Enhance-SD	**62.7**	**60.3**	**57.5**	**57.8**	**59.7**	**58.5**	**60.8**	**60.9**	**57.0**	**62.7**	**55.1**	**59.4**
Faller	62.9	60.7	58.0	59.6	58.6	58.9	61.0	60.3	56.8	63.2	54.3	59.5
LCS Ascent	63.0	60.9	59.7	54.9	60.2	59.5	62.0	61.5	57.5	63.5	55.8	59.9
LCS Cannon	63.8	61.8	60.2	60.2	60.9	60.1	62.8	61.4	58.9	64.1	56.4	61.0
LCS Rimfire	**62.7**	**60.4**	**57.4**	**55.7**	**59.0**	**57.6**	**61.1**	**60.5**	**56.9**	**62.6**	**55.1**	**59.0**
MN-Lang	63.5	61.4	60.5	60.5	61.2	60.5	62.2	61.6	57.7	63.4	55.2	60.7
MN- Rothsay	63.0	61.3	58.5	57.9	59.8	58.7	61.7	61.2	57.0	63.2	56.2	59.8
MN-Torgy	63.1	61.1	60.5	58.6	60.4	59.3	61.6	61.7	58.3	63.1	55.6	60.3
Mott	--	61.0	58.1	--	60.0	59.4	--	--	--	--	--	59.6
MS Charger	62.4	60.5	58.4	59.3	58.1	57.6	60.7	60.1	57.3	62.8	56.2	59.4
MS Cobra	62.8	61.1	57.2	57.8	59.9	59.1	61.4	60.7	57.7	62.7	56.7	59.7
MS Nova	**62.4**	**61.0**	**57.9**	**58.2**	**59.4**	**58.9**	**61.6**	**60.8**	**57.8**	**63.2**	**54.8**	**59.6**
MT Carlson	62.0	60.2	53.3	52.3	59.5	56.8	60.8	59.7	56.6	62.9	54.8	58.1
ND Frohberg	63.5	61.4	56.8	59.2	60.0	58.8	62.2	61.2	58.3	63.6	55.6	60.1
ND Heron	64.0	61.4	60.2	59.5	61.0	59.6	62.4	61.3	58.7	63.2	55.7	60.6
ND Horizon	**62.9**	**61.8**	**58.8**	**56.9**	**59.1**	**60.2**	**61.1**	**58.0**	**57.3**	**63.4**	**55.2**	**59.5**
ND Roughrider	**61.7**	**60.2**	**56.3**	**57.8**	**58.1**	**57.9**	**60.7**	**59.7**	**56.9**	**63.0**	**52.2**	**58.6**
ND Stampede	**62.6**	**61.1**	**58.2**	**60.5**	**58.9**	**58.4**	**61.4**	**59.9**	**56.8**	**63.0**	**54.0**	**59.5**
ND Thresher	61.6	60.3	58.4	55.7	59.1	58.1	60.1	59.1	55.2	62.3	53.3	58.5
PFS Muffins	**62.2**	**60.8**	**56.8**	**56.3**	**58.1**	**57.3**	**61.0**	**59.9**	**56.7**	**62.9**	**54.7**	**58.8**
PFS Rolls	**62.3**	**60.9**	**56.8**	**56.4**	**60.0**	**58.4**	**60.8**	**60.4**	**56.0**	**63.2**	**55.0**	**59.1**
PG Predator	**61.6**	**60.5**	**59.4**	**58.2**	**58.2**	**57.8**	**61.3**	**60.2**	**56.7**	**62.7**	**55.7**	**59.3**
Shelly	62.7	61.1	58.5	58.2	60.0	53.1	61.9	60.7	57.8	63.5	57.0	59.5
SY 611CL2	62.9	61.6	59.3	58.6	59.4	58.6	62.6	60.8	58.1	63.1	55.5	60.0
SY Ingmar	63.1	61.7	59.5	59.3	58.9	58.8	62.0	61.1	57.5	63.6	56.0	60.1
SY Valda	63.1	61.4	60.0	60.5	59.0	59.3	61.6	60.8	57.6	63.4	55.6	60.2
TCG-Badlands	**62.5**	**60.5**	**56.0**	**55.3**	**59.6**	**58.2**	**61.1**	**60.6**	**55.9**	**62.6**	**55.1**	**58.9**
TCG-Wildcat	63.5	61.1	55.5	59.0	59.3	59.9	62.3	60.5	57.9	63.8	55.4	59.8
TCG-Zelda	**62.9**	**61.3**	**58.2**	**57.5**	**59.0**	**58.0**	**61.3**	**60.4**	**56.3**	**63.2**	**55.4**	**59.4**
TW Olympic	**63.1**	**61.3**	**59.4**	**60.3**	**58.9**	**58.8**	**62.2**	**61.2**	**58.5**	**63.3**	**56.2**	**60.3**
TW Trailfire	**62.8**	**60.7**	**58.9**	**56.9**	**59.1**	**57.5**	**60.8**	**60.1**	**57.2**	**62.6**	**54.9**	**59.2**
WB9590	62.5	60.8	57.0	56.8	59.7	57.9	61.0	60.6	56.8	63.3	53.8	59.1
Mean	62.6	61.0	58.3	58.0	59.4	58.5	61.4	60.6	57.2	63.2	55.1	59.6
CV%	0.7	0.4	1.0	0.5	3.4	3.6	0.6	0.9	1.3	0.5	1.2	1.7
LSD 0.10	0.5	0.3	0.8	0.8	0.7	0.7	0.3	0.5	0.7	0.4	1.5	0.7

Table 6. Quality data from 2022-2024. The Wheat Quality Index (WQI) is a weighted average developed to summarize the relative milling and baking quality of lines in the trial. Data from across years are from 2022-2024 for all varieties which were tested in a minimum of two years (and four locations per year) across North Dakota.

Variety	Test Weight[1]	Vitreous Kernels[2]	Wheat Protein[3]	Farinograph Absorption[4]	Flour Extraction[5]	Farinograph Stability[6]	Loaf Volume[7]	WQI RANK[8]
	lb/bu	**%**	**12% m.b.**	**%**	**%**	**min**	**cm^3**	
ND Frohberg	61.6	69.1	14.3	67.7	67.3	13.7	982.1	1
MS Cobra	61.1	79.9	14.5	67.1	68.0	11.0	1052.4	2
ND Thresher	59.6	68.5	14.8	66.3	68.9	11.9	999.7	3
ND Horizon	61.1	73.7	14.6	68.0	67.6	9.5	995.3	4
ND Stampede	60.7	71.8	14.3	68.0	66.5	12.4	975.4	5
SY Ingmar	61.3	73.4	14.8	64.7	67.9	12.5	990.5	6
AP Smith	60.5	71.8	14.5	64.6	67.1	14.9	952.2	7
Ascend-SD	61.3	83.4	14.4	66.5	67.2	10.8	952.2	8
WB9590	61.0	72.1	14.5	65.3	66.8	14.0	940.2	9
SY 611CL2	61.6	68.8	14.4	69.7	66.3	10.2	958.8	10
Faller	60.5	65.3	13.9	65.5	69.4	11.2	965.4	11
LCS Cannon	62.4	53.7	14.3	65.2	69.2	12.5	943.9	12
ND Heron	62.0	68.1	15.1	73.4	65.6	8.7	970.9	13
MN Rothsay	60.7	58.7	14.2	63.0	68.5	15.4	935.5	14
LCS Ascent	61.7	40.5	13.7	65.0	67.6	15.6	930.7	15
TCG-Wildcat	61.5	71.7	14.6	65.5	67.5	10.8	925.0	16
AP Murdock	60.1	59.9	14.0	65.4	67.3	13.2	927.1	17
Brawn-SD	62.3	62.2	13.5	63.7	67.8	16.1	899.0	18
Shelly	61.2	60.7	13.7	62.6	69.1	14.5	902.1	19
MN Torgy	61.2	65.2	14.5	63.8	67.0	11.8	911.8	20
ND Roughrider	59.6	72.5	13.7	66.6	67.2	9.4	909.6	21
SY Valda	60.7	71.8	14.1	64.7	67.9	8.9	919.3	22
AP Gunsmoke CL2	60.3	66.4	14.8	63.0	66.6	13.4	890.2	23
MS Charger	60.7	53.6	12.8	65.7	67.7	10.7	896.8	24
Driver	61.3	61.8	14.1	61.9	68.0	12.3	891.6	25
Mean	**60.8**	**68.3**	**14.2**	**65.4**	**67.6**	**12.8**	**943.4**	

[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 US No. 1.

[2]Vitreous kernels - Percentage seeds having a vitreous-colored endosperm, a high percentage is desirable. US No. 1 DNS requires > 75% vitreous kernels.

[3]Wheat Protein - Measured by NIR at a 12% moisture basis. A high protein is desirable for baking quality.

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

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

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

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

[8]Standardized means were used to calculate the Wheat Quality Index (WQI). The WQI is a weighted index calculated as: Test Weight (5%); Vitreous kernel (5%); Wheat Protein (10%); Flour Extraction (10%); Farinograph Absorption (23.3%); Farinograph Stability (23.3%) and Loaf Volume (23.3%). Adjusted means across locations were calculated for each trait using a mixed model. These means were standardized (mean=0 and standard deviation=1) to remove the effect of scale, which varies between traits.

Table 7. Quality Data from 2024 from four locations across North Dakota. The Wheat Quality Index (WQI) is a weighted average developed to summarize relative milling and baking quality of the varieties tested. Data below are from varieties tested in 2024 at Hettinger, Williston, Minot, and Thompson (Grand Forks Co.) ND. These data are always presented from the previous year due to the amount of time it takes to test the samples.

Variety	Test Weight[1]	Vitreous Kernels[2]	Wheat Protein[3]	Farinograph Absorption[4]	Flour Extraction[5]	Farinograph Stability[6]	Loaf Volume[7]	WQI Rank[8]
	lb/bu	%	12% m.b.	%	%	min	cm^3	
ND Horizon	61.5	80.2	14.4	70.2	68.2	10.1	982.1	1
MS Cobra	61.4	82.8	14.0	68.8	67.9	11.7	1039.6	2
ND Frohberg	61.8	79.2	14.0	69.0	67.6	13.0	960.0	3
AP Smith	60.8	81.1	14.3	66.7	67.2	18.9	956.9	4
ND Thresher	59.9	75.7	14.6	67.9	68.5	11.8	977.1	5
AP Elevate	60.9	75.8	14.2	68.2	67.4	12.5	979.1	6
SY Ingmar	61.5	76.9	14.6	66.9	67.2	13.1	987.2	7
Ascend-SD	61.5	89.1	14.4	69.3	67.8	11.3	949.9	8
ND Stampede	60.8	80.0	14.0	69.6	67.7	12.3	953.9	9
LCS Cannon	62.6	62.9	14.2	67.4	68.9	14.1	945.8	10
SY 611CL2	61.8	70.0	14.0	70.3	66.6	12.0	969.0	11
MN Rothsay	61.0	64.0	13.9	64.9	68.5	16.1	958.9	12
WB9590	61.1	74.4	14.0	66.7	66.8	16.4	930.7	13
TCG-Zelda	61.4	77.3	14.0	67.7	67.0	13.6	937.8	14
MS Nova	61.2	71.7	13.8	65.7	66.3	15.8	977.1	15
TCG-Badlands	60.9	78.3	13.8	66.7	67.5	11.6	962.0	16
PFS Rolls	61.0	73.3	13.9	64.1	68.6	19.7	922.7	17
TCG-Wildcat	61.6	79.9	14.3	67.0	67.3	12.3	920.6	18
Faller	60.8	68.8	13.7	66.5	69.1	11.4	956.9	19
LCS Ascent	61.9	41.5	13.5	66.8	67.1	17.1	921.6	20
MT Carlson	61.1	65.4	13.6	66.9	66.0	12.3	996.3	21
AP Gunsmoke CL2	60.4	73.3	14.5	65.6	67.6	15.9	888.4	22
AP Murdock	60.7	64.8	13.9	67.5	67.6	14.9	880.3	23
MN Torgy	61.4	67.5	14.2	65.7	66.7	13.2	945.8	24
Brawn-SD	62.6	69.2	13.3	66.3	67.6	15.8	891.4	25
ND Heron	62.1	75.2	14.8	73.9	65.1	9.3	926.7	26
Driver	61.1	66.4	13.9	63.5	68.2	13.9	920.6	27
Shelly	61.2	66.1	13.5	64.1	68.5	13.9	909.5	28
ND Roughrider	59.6	79.2	13.6	68.3	67.2	10.4	877.3	29
SY Valda	60.9	78.9	14.0	66.1	67.9	9.6	894.4	30
MS Charger	60.4	56.0	12.4	67.0	68.5	11.4	862.2	31
Mean	**60.9**	**73.6**	**13.9**	**67.0**	**67.6**	**13.6**	**938.9**	

[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 US No. 1.

[2]Vitreous kernels - Percentage of seeds having a vitreous-colored endosperm, a high percentage is desirable. US No. 1 DNS requires > 75% vitreous kernels.

[3]Wheat Protein - Measured by NIR at a 12% moisture basis. A high protein is desirable for baking quality.

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

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

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

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

[8]Standardized means were used to calculate the Wheat Quality Index (WQI). The WQI is a weighted index calculated as: Test Weight (5%); Vitreous kernel (5%); Wheat Protein (10%); Flour Extraction (10%); Farinograph Absorption (23.3%); Farinograph Stability (23.3%) and Loaf Volume (23.3%). Adjusted means across locations were calculated for each trait using a mixed model. These means were standardized (mean=0 and standard deviation=1) to remove the effect of scale, which varies between traits.

Table 8. Data from the hard red spring wheat variety x fungicide trials conducted at Prosper (Cass County) and Thompson (Grand Forks County) in 2025. These trials are funded by the ND Wheat Commission and provide an opportunity to collect data on the yield response of spring wheat varieties included in the statewide NDSU trials under varying levels of disease pressure. The fungicide used was Prosaro @ 8.2 fl oz/ ac applied at early flowering. In most years, multiple dates of fungicide application are used to coincide with early flowering of each variety. In 2025, due to relatively late planting and a shortened flowering window, one date of fungicide application ocurred at Prosper and Thompson: July 2.

	Prosper 2025						Thompson 2025					
	No fungicide			Yes fungicide			No fungicide			Yes fungicide		
Variety	Yield	Test wgt	Protein	Yield	Test wgt	Protein	Yield	Test wgt	Protein	Yield	Test wgt	Protein
	bu/a	lbs/bu	%	bu/a	lbs/bu	%	bu/a	lbs/bu	%	bu/a	lbs/bu	%
AAC Hockley	85.8	60.8	13.7	88.0	61.0	14.1	65.7	59.6	13.9	64.2	60.2	13.8
AAC Hodge	91.6	60.3	14.5	93.9	60.2	14.4	72.0	59.6	14.1	73.9	59.2	14.0
AP Dagr	93.0	56.9	13.2	98.9	58.4	12.9	77.0	55.3	12.6	84.1	57.3	12.4
AP Elevate	99.5	58.9	13.6	101.8	59.6	13.2	79.6	58.3	13.0	86.3	58.9	13.3
AP Gunsmoke CL2	89.1	58.2	14.9	97.0	59.1	14.8	80.1	58.9	14.9	82.1	59.0	14.9
AP Iconic	99.0	58.8	13.4	102.3	59.4	13.0	80.1	58.0	12.8	93.8	59.9	12.7
AP Murdock	99.9	59.3	13.6	100.8	60.0	13.4	81.3	59.1	12.8	85.5	59.3	12.8
AP Smith	87.5	58.6	13.7	95.0	59.2	13.5	74.4	57.4	13.7	78.1	58.9	13.8
Ascend-SD	94.0	59.9	14.1	105.2	60.3	14.5	79.0	59.6	14.4	88.3	60.4	14.2
Brawn-SD	104.9	61.5	13.0	101.9	61.7	13.3	76.0	60.2	12.7	90.2	61.2	12.8
CP3678	89.9	59.4	14.4	93.5	59.5	14.6	64.4	57.2	14.5	67.7	57.9	14.2
Dagmar	96.9	59.7	14.1	105.9	60.1	13.9	80.0	58.7	14.5	85.1	59.5	14.0
Driver	93.4	60.5	13.9	96.2	60.6	13.6	72.5	59.7	13.7	73.1	60.5	13.7
Enhance-SD	103.4	59.7	13.7	109.0	59.9	13.5	78.5	58.5	14.1	86.8	59.0	13.9
Faller	100.0	58.6	13.2	101.7	59.1	13.3	81.3	58.9	13.1	86.6	59.4	13.0
LCS Ascent	100.2	60.2	12.7	102.7	60.8	12.9	80.0	59.5	12.1	85.2	60.1	12.1
LCS Cannon	96.8	60.9	12.8	100.0	61.0	13.0	82.3	60.1	12.8	85.5	60.8	12.8
LCS Rimfire	97.7	59.0	13.2	94.5	59.4	13.6	70.3	57.6	13.5	72.1	57.3	13.4
MN-Lang	83.0	61.2	14.4	87.9	50.1	14.1	73.5	60.5	14.6	77.5	61.3	14.1
MN- Rothsay	93.7	59.8	13.4	100.2	59.8	13.4	78.4	58.7	13.4	83.3	59.3	13.1
MN-Torgy	92.6	60.4	14.1	96.9	60.4	13.7	70.2	59.3	14.5	74.1	60.0	13.8
Mott	91.9	60.0	13.5	97.2	60.3	13.3	67.7	59.4	13.6	78.6	60.1	12.9
MS Charger	92.7	58.1	12.2	105.9	58.2	12.4	79.2	57.6	11.9	84.8	58.3	11.8
MS Cobra	93.5	59.9	13.7	92.1	60.8	13.7	70.3	59.1	13.5	76.8	59.7	13.2
MS Nova	92.9	59.4	13.7	92.6	59.8	13.5	76.7	58.9	13.3	82.9	59.8	13.1
MT Carlson	97.5	59.5	13.0	101.7	59.8	13.1	64.7	56.8	12.8	73.8	58.6	12.6
ND Frohberg	92.2	60.0	13.4	97.7	60.5	13.5	68.6	58.8	13.3	76.8	59.7	13.0
ND Heron	90.8	61.0	14.2	94.7	61.1	13.8	71.5	59.6	13.8	77.4	59.5	13.8
ND Horizon	101.0	59.1	14.1	100.3	59.8	14.0	90.4	60.2	13.7	85.7	60.7	13.6
ND Roughrider	99.5	58.1	14.3	104.9	58.4	13.9	85.8	57.9	13.9	93.4	58.8	13.4
ND Stampede	98.5	58.9	13.8	101.9	59.1	14.2	84.5	58.4	14.0	94.4	60.0	13.5
ND Thresher	93.3	59.1	13.8	92.7	59.2	13.9	72.1	58.1	14.1	84.1	59.5	13.6
PFS Muffins	93.6	58.1	13.7	100.1	58.8	13.7	81.1	57.3	13.2	88.6	58.6	13.0
PFS Rolls	100.8	60.0	13.3	104.4	60.2	13.5	75.3	58.4	13.2	76.7	58.9	13.3
PG Predator	95.3	58.2	13.7	99.7	59.2	13.5	79.5	57.8	13.1	86.4	58.9	12.8
Shelly	98.3	60.0	13.3	101.0	60.0	13.1	76.4	53.1	13.5	78.0	59.5	13.1
SY 611CL2	92.5	59.4	14.0	95.6	59.6	13.5	75.8	58.6	13.7	84.6	59.8	13.9
SY Ingmar	90.1	58.9	14.0	94.6	59.5	13.8	72.7	58.8	13.9	80.1	60.0	13.9
SY Valda	90.8	59.0	13.6	99.5	59.8	13.4	86.4	59.3	13.2	90.0	59.8	13.2
TCG-Badlands	93.5	59.6	13.2	100.5	60.4	13.0	69.6	58.2	13.3	83.5	59.7	13.1
TCG-Wildcat	97.5	59.3	13.9	103.6	59.7	13.9	85.7	59.9	13.9	89.1	60.2	14.0
TCG-Zelda	102.9	59.0	13.6	101.5	59.7	13.5	78.6	58.0	13.8	86.5	58.4	13.3
TW Olympic	99.6	58.9	14.2	105.5	59.3	14.1	75.0	58.8	13.8	83.1	59.6	13.6
TW Trailfire	84.5	59.1	13.0	94.1	59.7	12.7	74.1	57.5	13.2	80.6	53.2	13.2
WB9590	99.9	59.7	13.9	107.4	60.4	13.6	76.0	57.9	13.8	77.1	59.2	13.3
Mean	**95.0**	**59.5**	**13.7**	**99.3**	**59.7**	**13.6**	**76.3**	**58.6**	**13.5**	**82.1**	**59.3**	**13.3**
*Higher value p<0.1			*	*	NS				*	*	*	

NS = not significantly different at p<0.1

NDSU EXTENSION

North Dakota Hard Red Winter Wheat

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During the 2024-25 growing season, 100,000 acres of winter wheat were planted and 85,000 acres were harvested. While no statewide winter wheat yield estimate was available at the time of writing this publication, winter wheat yield was extremely variable across the state. Many acres of winter wheat were abandoned early in 2025 after an exceptionally warm and dry fall in 2024 inhibited germination and emergence. Much of the crop failed to emerge before snowfall and many fields suffered winter kill. For those fields surviving the winter and harvested for grain, yield varied from typical ranges of 50-60 bushels per acre (bu/a) to exceptionally high, for example, 90 plus bu/a, in areas that received abundant spring precipitation.

ND Noreen, a 2020 release from NDSU, was reported as the most commonly planted winter wheat variety in the state at 16.6% of acres. In second place was Ideal, a 2011 release from SDSU, reported on 10.8% of acres. Other varieties not named in the survey comprised 72.6% of winter wheat acres.

Characteristics of hard red winter wheat varieties adapted for production in North Dakota are described in Table 1. Information on the agronomic and quality performance of selected varieties is summarized in subsequent tables. Yields are expressed on a 13.5% moisture basis and protein on a 12% basis, which are the industry standards.

Successful winter wheat production depends on numerous production practices, including selecting the right variety for a particular area. The information included in this publication is meant to help growers choose that variety or group of varieties. Characteristics to consider when selecting a variety are winter hardiness, yield potential in your area, test weight, protein content when grown with proper fertility, straw strength, plant height, reaction to important diseases and maturity.

The recommended seeding dates for winter wheat are Sept. 1-15 north of North Dakota Highway 200 and Sept. 15-30 in southern regions. Planting after the recommended dates reduces winter survival and grain yield potential. Planting prior to the recommended date may deplete soil moisture reserves unnecessarily. It also increases the risk of wheat streak mosaic virus and may reduce winter survival.

Winter wheat should be seeded at a rate of 1 million to 1.2 million pure live seeds per acre. The higher seeding rates of this recommended range should be used for late seeding or with poor seedbed conditions. Producers should consider only the most winter-hardy varieties available when growing winter wheat in North Dakota. Relative ratings for winter hardiness are found in Table 1.

Phosphorus aids winter survival by stimulating root growth and fall tillering. The secondary root system that develops during tillering is essential for a healthy, deep-rooted plant capable of withstanding stress. If winter wheat is planted on bare soil or following fallow, an application of phosphorus is recommended if soil phosphorous levels are low. While important, the contribution of phosphorus to winter survival is secondary to varietal hardiness.

Data from several years and locations should be used when selecting varieties. The idea that data from a single location nearest your farm will indicate which variety will perform the best for you next year is incorrect. You should select varieties that, on average, perform the best at multiple trial locations near your farm across several years.

List of Tables

Table 1. 2025 North Dakota hard red winter wheat variety descriptions and agronomic traits.

			Reaction to Disease[1]								
Variety	Agent or Origin[2]	Year	Stripe Rust	Leaf Rust	Stem Rust	Scab	Tan Spot	Days to Heading[3]	Straw Strength[4]	Height[5] (inches)	Winter[6] Hardiness
AAC Coldfront	AAFC	2022	4	4	4	5	NA	0	2	33	4
AAC Goldrush	AAFC	2021	5	3	5	5	NA	1	4	33	4
AAC Overdrive	AAFC	2022	3	4	3	4	NA	0	4	30	3
AAC Vortex	Meridian	2021	4	4	4	4	8	0	3	33	2
AAC Wildfire	AAFC	2015	1	5	8	4	6	4	4	33	2
AC Emerson	Meridian	2011	1	6	1	3	5	1	3	35	5
CS Bridger CLP	**Circle S**	**2024**	**NA**	**NA**	**NA**	**NA**	**NA**	**-1**	**4**	**28**	**NA**
Jerry	ND	2001	8	3	1	8	8	0	6	38	3
LCS Steel AX	Limagrain	2022	7	7	9	8	4	-1	4	32	5
MS Maverick	Meridian	2020	2	6	5	8	4	-3	5	29	4
ND Allison	ND	2023	7	5	4	4	NA	1	4	34	4
ND Noreen	ND	2020	3	3	1	3	4	0	4	35	3
Northern	MT	2015	1	8	1	8	6	2	4	32	4
SD Andes	SD	2020	2	8	NA	5	6	-1	4	32	2
SD Midland	SD	2021	1	8	7	6	8	-2	4	33	4
SD Pheasant	SD	2023	NA	NA	NA	5	NA	-2	5	32	4
SY Monument	Agripro	2014	3	3	1	8	8	-3	4	30	4
WB 4422	WB	2022	8	6	6	8	5	-4	3	31	4
WB 4540	**WB**	**2024**	**NA**	**NA**	**NA**	**NA**	**NA**	**-5**	**3**	**31**	**NA**
Winner	SD	2019	5	NA	3	4	5	-4	4	31	4

[1]Disease reaction scores from 1-9, with 1 = resistant and 9 = very susceptible, NA = not available.
[2]MT = Montana State University; ND = North Dakota State University; SD = South Dakota State University;
WB = WestBred; AAFC = Agriculture and Agri-Food Canada; Meridian = Meridian Seeds; Circle S = Circle S Seeds (Montana).
[3]Days to heading relative to Jerry.
[4]Straw strength: 1 = strongest, 9 = weakest. Based on field observations from limited sites.
[5]Based on the average of several environments and should be used for comparing varieties. The environment can impact the height of varieties.
[6]Relative winter hardiness rating: 1 = excellent, 10 = no survival. These values are subject to change as additional information becomes available.
Bold varieties are those recently released or the first time tested, so data are limited and rating values may change.

Table 2. Yield of winter wheat varieties grown at 4 locations in North Dakota in 2025, with three-year averages (2023-25).

Variety	Langdon 2025	Langdon 3-Yr. Avg.	Minot 2025	Minot 3-Yr. Avg.	Dickinson 2025	Dickinson 3-Yr. Avg.	Hettinger 2025	Hettinger 3-Yr. Avg.	Avg. N.D. 2025	Avg. N.D. 3-Yr. Avg.
	- bu/a -									
AAC Coldfront	136.5	--	84.3	--	102.3	--	57.7	--	95.2	--
AAC Goldrush	120.4	90.2	75.2	58.4	93.0	70.3	52.2	58.4	85.2	69.3
AAC Overdrive	122.7	--	78.8	--	95.3	--	55.6	--	88.1	--
AAC Vortex	127.4	97.7	67.0	58.6	99.2	72.7	51.9	59.3	86.4	72.1
AAC Wildfire	119.1	90.8	56.8	58.0	100.5	75.7	49.2	60.4	81.4	71.2
AC Emerson	120.1	87.7	78.1	62.8	88.8	64.1	51.4	53.4	84.6	67.0
CS Bridger CLP	127.1	--	71.0	--	85.7	--	53.9	--	84.4	--
Jerry	99.7	81.0	71.8	60.3	92.6	63.2	48.3	51.3	78.1	64.0
LCS Steel AX	134.4	--	71.8	--	97.4	--	61.8	--	91.3	--
MS Maverick	118.9	88.4	61.4	54.8	75.7	62.3	61.6	56.4	79.4	65.5
ND Allison	126.6	97.9	71.5	59.6	98.7	78.5	57.6	58.4	88.6	73.6
ND Noreen	123.1	94.3	65.4	63.0	100.5	68.8	54.0	58.6	85.7	71.2
Northern	125.6	94.0	72.1	62.8	91.2	77.8	57.7	62.4	86.6	74.3
SD Andes	131.0	97.9	71.5	65.8	96.1	84.0	60.6	63.6	89.8	77.8
SD Midland	132.8	99.5	71.5	59.7	98.5	77.8	60.5	62.9	90.8	75.0
SD Pheasant	119.8	89.0	73.0	--	106.8	71.7	64.7	59.5	91.1	73.4
SY Monument	124.0	88.3	68.5	55.1	97.3	64.7	63.0	55.2	88.2	65.8
WB 4422	132.7	--	84.9	--	94.1	--	60.9	--	93.2	--
WB 4540	127.7	--	77.0	--	96.7	--	64.6	--	90.5	--
Winner	125.5	94.1	76.8	--	90.9	70.4	64.5	59.2	89.4	74.6
Mean	124.9	92.2	72.7	59.9	96.1	71.6	57.7	57.1	87.8	71.0
CV (%)	5.1	--	7.5	--	6.0	--	5.0	--	6.7	--
LSD 0.10	4.4	--	7.5	--	5.4	--	2.7	--	6.9	--

Note: the 2025 winter wheat trials at Casselton, Carrington, and Williston were lost to winter kill.

Table 3. Test weight of winter wheat varieties grown at 4 locations in North Dakota in 2025.

Variety	Langdon	Minot	Dickinson	Hettinger	Average
	………………………...……...(lb/bu)…………………...………………				
AAC Coldfront	62.2	62.8	62.1	54.1	60.3
AAC Goldrush	60.2	62.2	60.1	52.5	58.8
AAC Overdrive	58.3	59.6	58.6	50.8	56.8
AAC Vortex	60.6	61.5	61.2	51.8	58.8
AAC Wildfire	60.9	61.6	60.5	49.1	58.0
AC Emerson	60.8	62.3	61.7	52.7	59.4
CS Bridger CLP	58.8	60.7	57.0	51.7	57.1
Jerry	58.8	60.8	60.2	52.5	58.1
LCS Steel AX	60.8	62.0	59.4	54.5	59.2
MS Maverick	61.1	61.9	59.7	55.4	59.5
ND Allison	60.9	62.3	61.1	54.1	59.6
ND Noreen	61.6	62.8	62.9	55.3	60.7
Northern	58.5	61.0	58.2	53.1	57.7
SD Andes	61.7	62.8	61.5	55.0	60.3
SD Midland	60.9	62.0	61.5	54.3	59.7
SD Pheasant	59.7	61.6	60.9	54.4	59.2
SY Monument	59.2	60.0	58.6	52.1	57.5
WB 4422	61.2	61.9	60.2	55.0	59.6
WB 4540	59.6	60.1	58.7	54.6	58.3
Winner	60.3	61.9	59.9	55.2	59.3
Mean	60.1	61.4	60.1	53.6	58.9
CV (%)	1.1	1.2	0.8	1.5	1.5
LSD 0.10	0.6	1.0	0.4	0.8	1.0

Note: 58.0 lb/bu test weight is required for US No. 1 grade Hard Red Winter Wheat

Table 4. Grain protein content at 12% moisture of winter wheat varieties grown at 4 locations in North Dakota in 2025.

Variety	Langdon	Minot	Dickinson	Hettinger	Average
			(%)		
AAC Coldfront	11.9	12.5	11.7	12.5	12.2
AAC Goldrush	13.1	12.8	12.4	13.7	13.0
AAC Overdrive	13.1	12.4	12.5	13.8	13.0
AAC Vortex	13.3	13.4	12.6	13.8	13.3
AAC Wildfire	12.9	12.8	12.4	14.5	13.2
AC Emerson	13.3	13.2	12.9	13.6	13.3
CS Bridger CLP	12.3	12.4	12.6	13.8	12.8
Jerry	13.2	13.4	12.7	13.8	13.3
LCS Steel AX	11.8	11.4	11.3	12.6	11.8
MS Maverick	13.1	13.3	12.8	12.9	13.0
ND Allison	11.6	12.3	11.6	12.1	11.9
ND Noreen	13.1	13.6	12.7	13.5	13.2
Northern	12.8	13.0	12.5	13.0	12.8
SD Andes	12.4	12.6	12.2	13.4	12.7
SD Midland	12.4	11.9	11.8	13.5	12.4
SD Pheasant	12.9	13.2	12.7	13.6	13.1
SY Monument	12.6	11.9	11.8	12.9	12.3
WB 4422	12.6	13	12.5	12.8	12.7
WB 4540	12.1	12.5	11.9	12.5	12.3
Winner	12.6	12.5	12.4	12.2	12.4
Mean	12.7	12.7	12.3	13.2	12.7
CV (%)	1.9	3.4	2.5	4.9	3.0
LSD 0.10	0.2	0.7	0.3	0.6	0.5

Table 5. Analytical milling and baking characteristics of selected varieties evaluated at Casseltonand Hettinger, North Dakota in 2024.

	Kernel			Flour			Farinograph				Loaf	
Variety	Test Weight[1]	1,000 Kernel Weight[2]	Whole Wheat Protein 12 MB[3]	Flour Protein 14 MB	Flour Ash 14 MB	Milling Extraction[5]	Abs[6]	Peak Time	Stability[7]	Mixing Tolerance Index	Loaf Volume[8]	Crumb Color
	(lb/bu)	(gram)	(%)	(%)	(%)	(%)	(%)	(min)	(min)	(BU)	(cc)	(1-10)[9]
Jerry	61.3	25.5	11.7	10.8	0.5	74.0	60.7	6.6	13.0	21	851	8
SD Andes	63.6	31.6	10.3	9.4	0.5	76.0	57.4	7.0	13.0	22	811	8
ND Noreen	63.7	29.7	11.9	11.0	0.5	74.2	59.9	8.7	17.4	21	876	8
Keldin	62.6	35.2	10.1	9.2	0.5	73.7	58.8	4.5	14.4	18	767	8
AC Emerson	63.0	22.5	12.3	11.1	0.4	74.7	57.9	16.5	34.5	13	925	9
Northern	61.1	33.6	10.7	9.9	0.5	75.5	61.4	3.9	9.6	26	869	8
Mean	62.5	29.7	11.2	10.2	0.5	74.7	59.3	7.9	17.0	20	850	8

[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]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.

[3]Wheat Protein - Measured by NIR at a 12% moisture basis. A high protein is desirable for baking quality.

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

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

[7]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.

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

[9]Scale 1-10, with 1 being low and 10 being superior.

North Dakota Durum

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Durum was planted on 1.2 million acres in North Dakota in 2025, up slightly from 1.1 million acres seeded in 2024. The average yield was 44 bushels per acre (bu/a), down slightly from the record-high 47 bu/a last year. The 2025 growing season started early with some farmers being able to plant in late March or early April. Mid-May brought a lot of precipitation to the state, especially in the central region, with some counties reporting record-high rainfall totals for the month. Fields not planted prior to these rains experienced delays while producers waited for fields to dry out enough to seed. This division of planting dates, for those fields planted in April or early May and those planted in late May or June, resulted in a staggered crop with early-planted fields ready to harvest in August and later-planted fields not ready to harvest until mid-September or later.

The top five durum varieties in 2025 and the percent of the acreage they occupied according to survey data were ND Riveland (48.1%), AAC Stronghold (9.7%), ND Stanley (9.7%), Divide (7.7%), and VT Peak (5.2%). ND Riveland, ND Stanley, and Divide are releases from the NDSU durum breeding program, AAC Stronghold and VT Peak are Agriculture and Agri-Food Canada (SeCan) varieties.

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 trials 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 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 90% confidence (LSD probability 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 at that location.

The abbreviation NS is used to indicate no significant difference for that trait among any of the varieties at the 90% level of confidence. The CV is a measure of variability in the trial. CV stands for coefficient of variation and is expressed as a percentage. Large CVs (> 10%) mean a large amount of variation in the trial could not be attributed to differences among 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 or online at https://vt.ag.ndsu.edu/. Ideally, you should use data from multiple locations and years when selecting a variety for your operation.

List of Tables

Table 1. Descriptions and agronomic traits of durum wheat varieties grown in North Dakota, 2025.

						Reaction to Disease[5]				
	Agent or Origin[1]	Year Released	Height (inches)[2]	Straw Strength[3]	Days to Heading[4]	Stem Rust	Leaf Rust	Foliar Disease	Bact. Leaf Streak	Head Scab
AAC Schrader	**Can.**	**2024**	**37**	**4**	**60**	**NA**	**NA**	**NA**	**NA**	**NA**
AAC Spitfire	**Can.**	**2017**	**35**	**4**	**63**	**NA**	**NA**	**NA**	**NA**	**NA**
AAC Stronghold[7]	Can.	2016	34	3	62	NA	NA	NA	NA	NA
Alkabo	ND	2005	34	3	62	1	1	5	7	6
Carpio	ND	2012	35	5	64	1	1	5	6	5
CDC Defy	Can.	2019	37	3	61	NA	NA	NA	NA	NA
Divide	ND	2005	35	5	63	1	1	5	7	5
Joppa	ND	2013	35	5	63	1	1	5	7	5
Maier	ND	1998	34	4	62	1	1	5	NA	8
Mountrail	ND	1998	35	4	63	1	1	5	7	8
MT Blackbeard[6]	**MT**	**2022**	**39**	**6**	**63**	**1**	**1**	**5**	**NA**	**6**
ND Grano[6]	ND	2017	35	5	63	1	1	8	7	6
ND Riveland[6]	ND	2017	37	4	63	1	1	5	6	5
ND Stanley[6]	ND	2021	35	3	63	1	1	5	6	5
Strongfield[6]	Can.	2004	34	5	63	1	1	6	NA	8
TCG Bright	**21st Cent Gen**	**2022**	**32**	**4**	**67**	**NA**	**NA**	**NA**	**NA**	**NA**
TCG Ranger	**21st Cent Gen**	**2024**	**35**	**4**	**58**	**NA**	**NA**	**NA**	**NA**	**NA**

[1]Refers to agent or developer: Can. = Agriculture and Agri-Food Canada, ND = North Dakota State University. MT = Montana State University. 21st Cent Gen = Twenty-first Century Genetics (TCG)

Bold varieties are those recently released or new to NDSU testing, so data are limited and ratings may change.

[2]Plant height was obtained from the average of six locations in 2025.

[3]Straw Strength = 1-9 scale, with 1 the strongest and 9 the weakest. Ratings based on recent data, 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 six locations in 2025.

[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.

[7]Solid stem variety to reduce wheat stem sawfly damage.

Table 2. Yield of durum wheat varieties at six Research Extension Centers in North Dakota, 2023-2025.

	Carrington		Langdon		Dickinson		Hettinger		Minot		Williston[1]		Average	
Variety	**2025**	**3 Yr.**	**2025**	**3 Yr.**	**2025**	**3 Yr.**	**2025**	**3 Yr.**	**2025**	**3 Yr.**	**2025**	**3 Yr.**	**2025**	**3 Yr.**
	(bu/a)													
AAC Schrader	**68.4**	**--**	**81.8**	**--**	**--**	**--**	**59.5**	**--**	**45.6**	**--**	**--**	**--**	**63.8**	**--**
AAC Spitfire	**71.6**	**--**	**70.3**	**--**	**77.8**	**--**	**61.9**	**--**	**--**	**--**	**--**	**--**	**70.4**	**--**
AAC Stronghold	73.9	--	71.2	--	77.7	--	57.3	61.4	63.8	47.4	34.0	--	63.0	54.4
Alkabo	71.9	62.4	73.6	73.2	80.4	65.3	55.8	62.8	49.1	49.1	35.3	44.9	61.0	59.6
Carpio	69.2	61.2	79.7	75.8	81.2	66.2	54.2	63.0	55.9	46.8	28.0	39.3	61.4	58.7
CDC Defy	75.6	66.5	81.2	--	83.8	--	56.5	66.3	62.2	50.4	--	--	71.8	61.1
Divide	65.0	62.1	77.2	73.3	73.8	62.4	54.6	61.3	40.4	35.7	29.4	37.4	56.7	55.4
Joppa	75.1	63.1	78.4	76.1	80.0	62.9	56.0	64.7	55.4	46.1	31.3	43.1	62.7	59.3
Maier	62.6	55.8	73.0	71.6	72.1	61.3	55.5	59.4	41.0	36.6	32.0	38.6	56.0	53.9
Mountrail	69.2	60.9	70.0	76.4	77.8	67.2	56.0	63.1	52.9	46.9	32.2	39.6	59.7	59.0
MT Blackbeard	**68.4**	**--**	**72.4**	**--**	**79.3**	**61.7**	**63.1**	**67.1**	**56.9**	**--**	**--**	**--**	**68.0**	**--**
ND Grano	69.2	62.1	72.7	76.1	77.4	65.3	54.3	62.3	48.4	46.5	31.5	41.1	58.9	58.9
ND Riveland	73.4	66.6	87.8	80.0	77.9	61.5	58.1	61.6	48.7	46.6	30.8	41.4	62.8	59.6
ND Stanley	77.0	64.8	79.7	77.1	78.4	64.7	56.9	63.3	67.4	53.9	32.9	41.6	65.4	60.9
Strongfield	65.7	57.9	67.5	67.9	78.3	61.1	53.1	61.3	53.3	40.0	30.8	40.8	58.1	54.8
TCG Bright	**--**	**--**	**--**	**--**	**80.7**	**--**	**55.2**	**--**	**50.1**	**43.3**	**--**	**--**	**62.0**	**--**
TCG Ranger	**66.2**	**--**	**85.3**	**--**	**--**	**--**	**59.6**	**--**	**52.8**	**--**	**--**	**--**	**66.0**	**--**
Mean	68.7	61.7	78.2	74.8	78.6	63.6	57.4	63.2	52.9	--	31.9	40.8	62.8	58.0
CV %	7.8	--	6.1	--	6.1	--	4.1	--	6.9	--	6.0	--	6.8	--
LSD 0.10	6.3	--	5.6	--	4.4	--	2.2	--	4.9	--	4.5	--	4.1	--

[1]Williston site damaged by hail; yield reduction estimated 30-40%; estimated trial average yield had hail not occurred is 43 bu/a.

Table 3. Test weight and protein of durum wheat varieties at six Research Extension Centers in North Dakota, 2025.

Variety	Carrington		Langdon[1]		Dickinson		Hettinger		Minot		Williston[2]		Average	
	Test Wt.	Protein	Test Wt.	Protein	Test Wt.	Protein	Test Wt.	Protein	Test Wt.	Protein	Test Wt.	Protein	Test Wt.	Protein
	lb/bu	%	lb/bu	%	lb/bu	%	lb/bu	%	lb/bu	%	lb/bu	%	lb/bu	%
AAC Schrader	**60.0**	**12.6**	**51.9**	**15.0**	**--**	**--**	**60.5**	**11.8**	**60.9**	**13.6**	**--**	**--**	**58.3**	**13.2**
AAC Spitfire	**58.9**	**12.3**	**48.0**	**15.2**	**59.5**	**13.8**	**59.4**	**11.8**	**--**	**--**	**--**	**--**	**56.4**	**13.3**
AAC Stronghold	59.6	12.4	50.8	14.7	61.1	14.4	60.5	11.8	62.2	14.4	57.1	18.0	58.5	14.3
Alkabo	60.0	11.9	52.9	13.5	61.1	13.0	59.5	11.0	61.7	12.9	55.7	16.4	58.5	13.1
Carpio	60.7	12.5	53.0	13.8	61.9	13.2	59.1	10.8	60.3	14.6	55.0	16.9	58.3	13.6
CDC Defy	60.7	11.8	52.2	14.3	61.6	13.5	59.7	11.1	62.9	13.7	--	--	59.4	12.9
Divide	58.8	12.9	51.3	14.4	61.1	13.0	59.7	11.1	60.3	13.6	56.0	17.6	57.9	13.8
Joppa	59.9	11.6	53.2	13.5	61.1	12.6	58.8	10.4	61.5	13.0	56.2	16.8	58.4	13.0
Maier	58.9	12.7	51.5	14.7	60.9	13.5	59.9	10.6	60.8	13.9	55.3	18.2	57.9	13.9
Mountrail	58.5	12.0	50.6	13.8	60.6	12.7	58.3	10.8	61.5	12.8	54.9	17.4	57.4	13.3
MT Blackbeard	**60.0**	**12.4**	**50.7**	**14.6**	**61.2**	**14.1**	**60.3**	**11.5**	**61.7**	**14.5**	**--**	**--**	**58.8**	**13.4**
ND Grano	59.8	12.3	51.3	14.2	61.3	13.7	59.5	11.4	61.5	13.9	55.5	17.6	58.1	13.8
ND Riveland	60.9	11.9	53.2	13.5	60.8	13.2	59.8	11.3	61.1	13.7	56.0	17.6	58.6	13.5
ND Stanley	61.2	12.4	53.7	14.3	61.5	13.7	60.1	11.1	62.3	13.5	56.8	17.3	59.3	13.7
Strongfield	58.4	12.8	48.0	15.2	60.9	14.2	59.2	11.3	60.0	14.9	55.6	18.4	57.0	14.5
TCG Bright	**--**	**--**	**--**	**--**	**60.8**	**13.2**	**59.8**	**10.8**	**61.7**	**13.4**	**--**	**--**	**60.8**	**12.5**
TCG Ranger	**60.0**	**10.9**	**52.7**	**12.6**	**--**	**--**	**59.9**	**10.4**	**62.6**	**12.4**	**--**	**--**	**58.8**	**11.6**
Mean	60.0	12.3	52.3	14.2	61.1	13.6	59.8	11.3	61.4	14.1	55.9	17.5	58.4	13.4
CV %	0.8	3.1	1.5	2.4	0.5	3.8	1.0	5.1	1.3	5.2	1.0	1.8	1.3	2.5
LSD 0.10	0.6	0.5	0.9	0.4	0.3	0.5	0.5	0.5	1.1	1.0	1.3	0.7	0.7	0.3

[1]Harvest at Langdon was delayed by two weeks due to rain. Low test weights are assumed to be a result of excessive moisture on the ripe grain.

[2]Williston site received 1.5 in of rain in the week prior to harvest. Low test weights are assumed to be a result of excessive moisture on the ripe grain.

Table 4. Durum wheat variety quality descriptions, milling and processing data averaged for five years (2020-2024) from drill strips (26 locations/years).

Variety	Test Weight	Vitreous Kernels	1000 kerenel wt	Large Kernels	Falling Number	Wheat Protein[1]	Semolina Extraction	Gluten Index[2]	Pasta b-value[3]	Overall Quality [4]
	(lb/bu)	(%)	(g)	(%)	(sec)	(%)	(%)			
Alkabo	61.4	85	41.9	54	455	14.0	58.4	57	23.8	good
Carpio	61.6	83	42.5	64	536	14.2	58.3	94	23.5	good
Divide	60.9	88	40.8	53	527	14.2	58.4	83	23.4	good
Joppa	61.5	91	42.1	49	512	14.1	59.4	89	24.3	good
Maier	61.0	92	40.9	53	491	15.2	58.7	60	24.0	good
Mountrail	60.6	92	40.2	45	497	14.4	58.5	29	23.5	fair
ND Grano	61.9	90	41.5	55	522	14.6	58.7	73	24.3	good
ND Riveland	61.4	93	43.8	61	543	14.3	55.4	89	24.0	good
ND Stanley	62.3	87	42.9	62	530	14.5	59.2	80	23.9	good
Strongfield	66.7	93	40.3	58	542	15.1	57.4	74	23.7	good
Average	61.9	90	41.7	55	515	14.5	58.2	73	23.8	

For all numbered footnotes, refer to bottom of Table 5.

Table 5. Durum wheat variety quality descriptions, milling and processing data for 2023 at five locations from drill strips.

Variety	Test Weight	1000 kerenel wt	Large Kernels	Falling Number	Wheat Protein[1]	Semolina Extraction	Gluten Index[2]	Pasta b-value[3]	Overall Quality[4]
	(lb/bu)	(g)	(%)	(sec)	(%)	(%)			
Alkabo	61.8	42.3	60.6	440	13.5	60.2	66	21.6	good
Carpio	62.3	44.4	68.8	545	13.7	60.9	99	21.6	good
Divide	61.6	41.3	56.4	548	14.3	60.5	87	22.5	good
Joppa	62.1	43.0	54.1	501	13.6	61.7	96	22.4	good
Maier	61.5	42.7	62.1	488	14.4	61.4	64	22.7	good
Mountrail	61.0	42.8	55.7	479	13.9	60.5	28	22.7	fair
ND Grano	62.7	42.4	60.9	518	13.6	61.5	83	22.5	good
ND Riveland	62.0	45.4	70.3	492	13.8	58.3	93	22.8	good
ND Stanley	63.1	46.1	69.0	509	13.5	61.4	85	22.2	good
Strongfield	61.8	42.4	62.2	499	14.1	61.3	78	22.2	good
Average	62.0	43.3	62.0	502	13.8	60.8	78	22.3	

[1]Wheat protein is reported on a 12% moisture basis.

[2]Gluten index is unitless. Numbers less than 15 = very weak and greater than 80 = very strong gluten proteins.

[3]Pasta b-value: based on the Hunter color scale. Values >23.0 indicate acceptable pasta color; values >24.0 indicate good pasta color.

[4]Overall Quality is determined based on agronomic, milling and spaghetti processing performance.

NOTES

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