NORTHARVEST
BeanGrower

INSIDE
2022 Dry Bean Research Reports

NORTHARVEST BeanGrower

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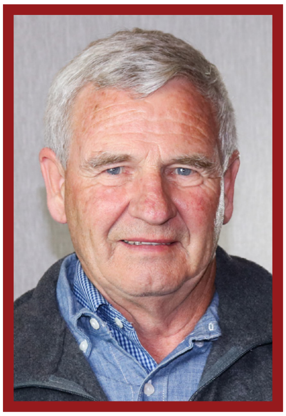
VOLUME 28 ISSUE 2

STARTING POINT

RESEARCH IS ROADMAP TO OUR FUTURE



The Northarvest Bean Growers Association has always emphasized the importance of research. That's evident with the investment we've made in our research priorities. This research serves as a roadmap to our future. With the information gathered in research plots and laboratories, provide a strategic path for our industry. Ultimately, this information helps us reach our agronomic goals.

In the Northarvest region, we have a tremendous team of university researchers and Extension specialists. You heard from many of those experts during the recent Bean Day program. Take time to go through their reports in this edition of the *BeanGrower* magazine. This information is a priority.

Spring will be here soon. With the current commodity prices, it will be interesting to see what happens with the acreage mix. Dry beans obviously have a story to tell when making plans for the '22 growing season. It'll be interesting to see what Mother Nature has in store for us in the months ahead. Regardless, keep your fingers crossed for good weather and a great crop.

Thanks,

Norm Kraus, Chair
Research Committee
Northarvest Bean Growers Association

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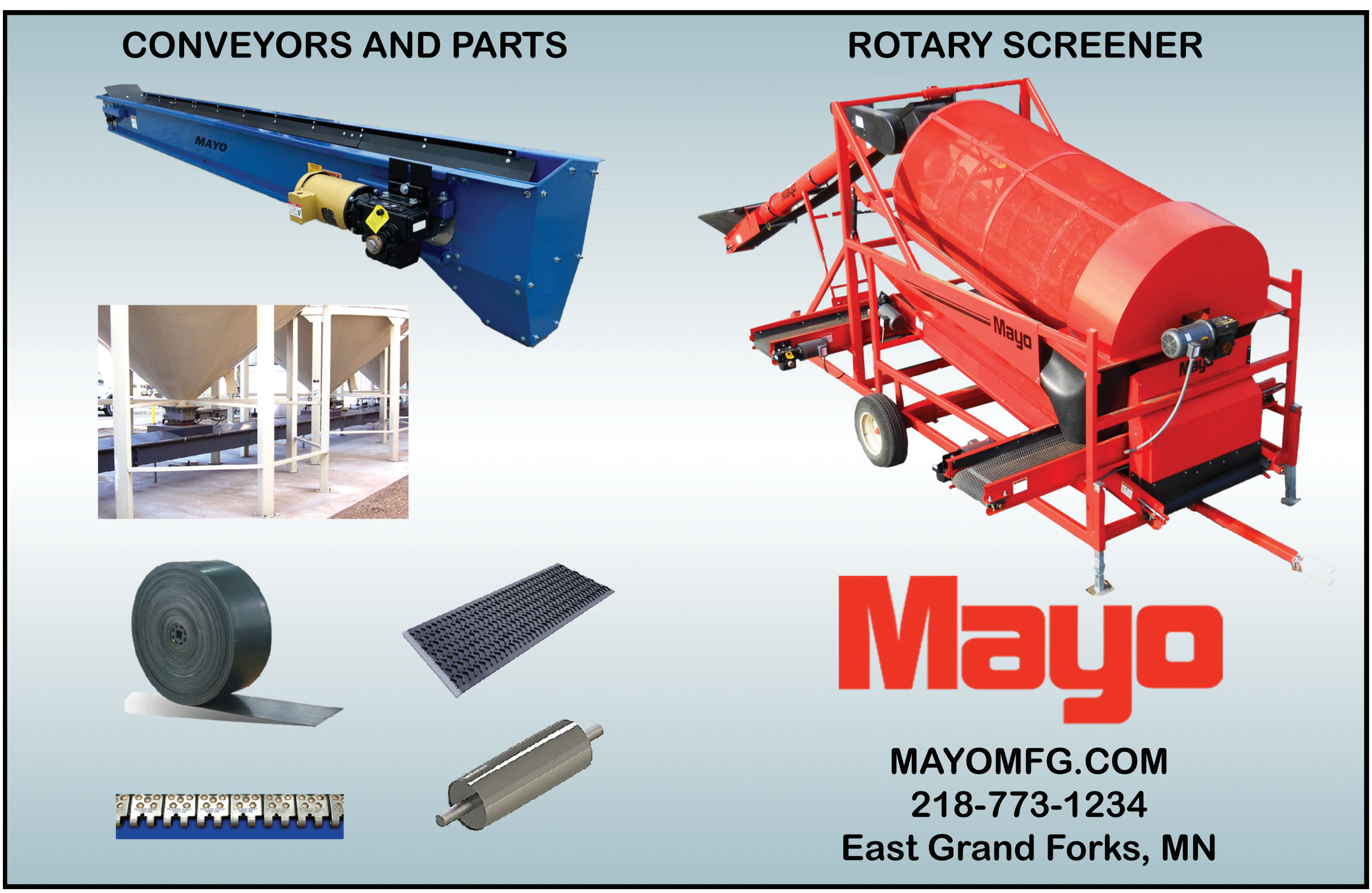


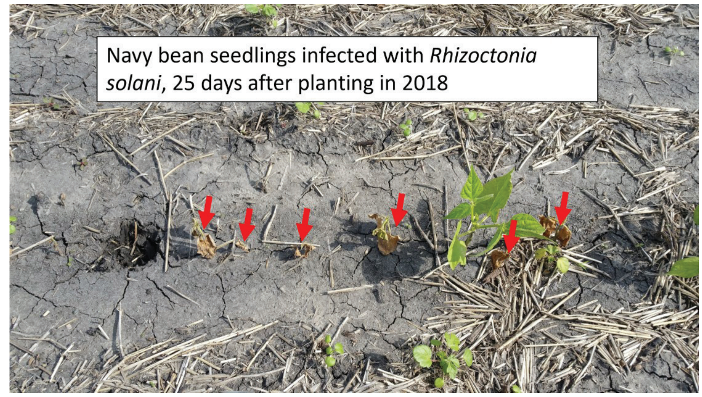
Impact of Drainage and Fungicide Treatment on Rhizoctonia Root Rot in Navy Bean in 2021

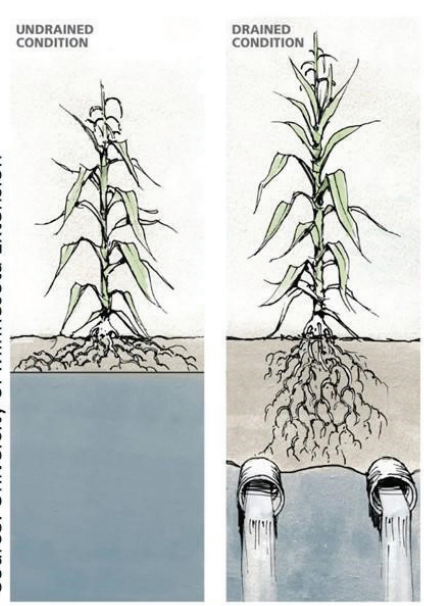
Principal Investigators: Jeff Strock, Ph.D., project leader and Soil Scientist; Lindsay Pease, Ph.D. co-investigator and Extension Specialist in Nutrient and Water Management; Ashok Chanda, Ph.D. co-investigator and Extension Sugarbeet Pathologist, University of Minnesota.

Background: In parts of northwest Minnesota and eastern North Dakota, high clay content soils mean that root systems can become waterlogged for several hours to days during periods of high rainfall due to slow internal drainage. The impact of excess water on plant growth and yield is influenced by plant type, soil characteristics, duration of excess water or flooding, initial soil water content, soil and air temperature and growth phase for row crops. Dry beans are particularly sensitive to waterlogging, dying after only one day under water. Although there are a number of potential options for reducing crop damage, disease incidence, and yield loss caused by waterlogging, such as genetic tolerance and cover cropping, this project was aimed at evaluating artificial drainage, specifically drain spacing.

The goal of agricultural drainage is to provide an optimal balance of water and air in the soil in order to create a hospitable environment for plant growth. For crop producers, frequently the differences between poor, average and record yields is attributed to the amount and timing of precipitation and available soil water. A well-designed drainage system may result in a number of benefits including: better soil aeration, timely field operations, less flooding in low areas, higher soil temperatures, less surface runoff, better soil structure, better root development, improved host plant resistance, higher yields and improved crop quality.

Excess water stress to plants may not only result in lost productivity but it can also increase their disease susceptibility. Both directly and indirectly, this stress makes them vulnerable to damage by pathogens, especially in the early stages of plant development. Excess water is often associated with development of root diseases. Root rot caused by Rhizoctonia solani in dry beans tends to be favored by low soil temperature and moderate to high soil moisture. Cool, wet soils are not only optimal for some soil pathogens, but also delay emergence and plant development. Infected plants may die as seedlings, survive in a weakened, lower-yielding state, or outgrow the initial infection if the conditions are favorable later in the growing season.


Navy bean seedlings infected with *Rhizoctonia solani*, 25 days after planting in 2018



Source: University of Minnesota Extension

Despite the connection between soil moisture and root disease, the interactions between subsurface drainage spacing and traditional disease management options have never been studied in the Red River Basin. Without this information, growers cannot fully evaluate the costs of subsurface drainage systems against its potential benefits for crop production. This information is essential as only about 10.4% NHBGA-reported acres were tile-drained as of 2019.

Objectives: The overall goal of this project is to develop and evaluate management approaches (e.g. drain spacing and fungicide application) in a corn-bean-wheat-sugar beet cropping system. Two of our objectives were to measure:

1. The effect of drain spacing and Rhizoctonia solani on navy bean yield,

disease incidence and severity, and affiliated interactions.

2. The performance of seed treatment versus in-furrow fungicide application against Rhizoctonia solani AG 2-2.

Plant tolerance to waterlogging and anaerobic conditions vary; therefore, plant growth and yield are expected to improve under progressively more intensive (narrower) drain spacings. Disease severity and incidence are also expected to decline under narrower drain spacings.

Field Trial Methods: This plot-scale research project was carried out at the Northwest Research and Outreach Center in Crookston, MN. The soil at the site was classified as a Hegne silty clay loam. The plot area consisted of five drain spacings: 15, 25, 40 and 60 ft. plus a control which represented an undrained condition.

The research site is approximately four acres. Agronomic practices, including variety selection, weed control, tillage and fertility followed Extension recommendations. A Rhizoctonia inoculum source consisting of whole barley grain infested with R. solani AG 2-2 was spread across the trial area at 35 lb/A on May 26 and worked into the top 4 inches of soil with a field cultivator. Immediately following, a susceptible navy bean cultivar T9905 with Allegiance base seed treatment (0.75 fl oz/cwt) was sown in 22 inch rows across the trial area. Data was collected for emergence and stand establishment. Infected plants were confirmed in the lab for infection by R. solani by planting in water cultures. At harvest, data were collected for root rot rating severity and incidence and yield. Fungicide treatments included: 1) untreated, inoculated, 2) inoculated, seed treatment with Vibrance (0.16 fl oz/cwt seed), and 3) inoculated, with in-furrow fungicide Quadris (9.5 fl oz/A). Starter fertilizer (10-34-0) was used at a rate of 1 gal/A.

2021 Results:

Weather -- Persistent drought conditions existed throughout the growing season during 2021. The four-month period between April and July was particularly dry (Table 1). Monthly precipitation was 36% below the 30-year average and 38% below the 10-year average for this four month period. A lack of adequate rainfall would be expected to negatively affect stand establishment and crop yield. Dry conditions throughout the season may also have affected the incidence and severity of root rot caused by Rhizoctonia, which thrives under cool and moderate to high soil moisture conditions.

Plant Populations == Analysis of variance showed that there were no statistically significant differences for the effect of fungicide treatment on plant population 28 days after planting (DAP). In contrast, the same analysis at 43 and 78 DAP did indicate statistically significant differences for the effect of fungicide treatment on plant population. Plant population data at 43 DAP indicated that the no-fungicide treatment had significantly lower stands compared to Vibrance seed treatment or Quadris in-furrow (Table 2). At 78 DAP the data indicated that there was no statistically significant difference in plant population between either of the fungicide treatments. However, seed treatment had slightly lower stands, which was statistically not significant from the untreated control. The poor fungicide treatment separation for yield observed across the different fungicide treatments was likely the result of the drought conditions at the site during the 2021 growing

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Table 1. Monthly precipitation at Crookston, MN during 2021.

Month	Rainfall (inches)	% of 10 year mean rainfall	% of 30 year mean rainfall
April	0.67	56	56
May	0.95	40	34
June	1.65	44	42
July	0.32	11	10
August	2.3	105	82
September	2.4	108	106

Table 2. Effect of fungicide treatment on plant population and yield of navy bean at Crookston, MN.

Fungicide treatment	Plant population x 1000/ac			Yield
	28 DAP	43 DAP	78 DAP	bu/ac
Untreated control	91 a	93 b	91 b	14 a
Vibrance (S)	96 a	101 a	98 ab	16 a
Quadris (IF)	92 a	106 a	101 a	14 a

DAP = days after planting; S = Seed applied; IF = in-furrow applied.

Table 3. Plant population and yield of navy bean by drain spacing treatment at Crookston, MN.

Drain spacing	Plant population x 1000/ac			Yield
ft.	28 DAP	43 DAP	78 DAP	bu/ac
undrained	100 a	104 a	104 a	13 b
15	70 b	89 b	91 b	11 b
25	100 a	101 a	89 b	15 ab
40	102 a	105 a	96 a	19 a
60	94 a	102 a	102 a	15 ab

DAP = days after planting.

season. Plots were hand harvested on October 7 with an Echo adjustable hedge trimmer by cutting the beans at the soil level.

Drain spacing == Analysis of variance revealed that drain spacing had a statistically significant effect on plant population at 28 and 43 DAP and that the response was similar (Table 3). The data showed that the plant population at the narrowest drain spacing, 15 ft., was different and smaller, on average by 29,000 plants per acre, than the other treatments. This result suggests that under the drought conditions that existed during 2021, the narrowest drain spacing lowered soil moisture in the profile between Fall 2020 and Spring 2021. This resulted in a drier soil profile for this treatment compared to the others. The drier conditions likely resulted in poor stand establishment. By 78 DAP plant populations were significantly smaller for the 15 ft. and 25 ft. drain spacings. The data also suggest that plant populations at the widest drain spacing, 60 ft., and in the undrained zone were more stable than the 15 ft. and 25 ft. spacings. Although numerically smaller, the plant population at 40 ft. was not statistically different from the 60 ft. or the undrained zone. Maximum bean yield, 19 bu/ac, occurred at the 40 ft. drain spacing although the yields at 25 ft., 40 ft., and 60 ft. were not statistically different from one another (Table 3). Minimum bean yield, 11 bu/ac, occurred at the 15 ft. drain spacing although the yields at 25 ft., 60 ft., and the undrained zone were not statistically different from one another.

Even though 2021 was a drought year, the data are useful in understanding the behavior of dry beans to fungicide treatments and drain spacing under dry conditions.

Acknowledgements

Funding from Northarvest Bean Growers Association made this research possible. Research team members (Austin Lien, Jeff Nielsen, and Heidi Reitmeier) and student helpers (James Deleon, Luke Noah, Donny Wu, Kenan McQueen, Cameron Fleisher, Ethan Erdman, and Peyton Loss) were critical contributors to the execution of this research. Thanks to Andry Ranaivoson for assistance with the statistical analysis.

2022 NORTHARVEST DIRECTORS ELECTED

The Northarvest Bean Growers Association board of directors certified the 2022 mail ballot election results at the 47th annual Bean Day Conference on Friday, January 21st held at the Holiday Inn of Fargo, ND. Northarvest district directors elected included:

Dexter Cronquist of Gilby, ND (District 2). Dexter was recently a board member for the Farmers Elevator Company of Forest River. He enjoyed the board opportunity providing ideas for the company and felt the board experience has served him well in his own endeavors, including serving on the Gilby Fire & Rescue. The Cronquist farm raises Black Beans, Wheat, Soybeans, Corn, Sugar Beets, and Sunflowers.

Joseph Mauch of Hankinson, ND (District 5). Joseph has previously served the Northarvest Bean Growers Association (NBGA) as Board President, Vice President, and Treasurer since 2007. Joseph has interest in the bean checkoff dollars being allocated most effectively and enjoys being involved in new usage research as well as improving varieties. He has also served as a past delegate to the U.S. Dry Bean Council and is a member of the North Dakota Corn & Soybean Growers Associations. The Mauch farm raises Navy Beans, Black Beans, Soybeans, Corn, and Sugarbeets.

Cordell Huebsch of New York Mills, MN (District 8). Cordell plans to continue to work on directing checkoff dollars to positive return on investment projects and promotions. Cordell has served on the board of Northarvest Bean Growers Association (NBGA) since 2019, and is active on the Legislative, Promotion, and Communication Committees. Cordell is an alumni of the Minnesota Agriculture & Rural Leadership (MARL) program. He also serves on the Central Minnesota Irrigation and Minnesota Irrigation Association. The Huebsch farm raises Dark Red Kidneys, Corn, Strawberries, and Pumpkins.

Dry Bean Trials on the Sand Plains of Minnesota

By: Hannah Barrett

This was the second consecutive year of receiving an award from Northarvest. This year the CLC Ag and Energy Center again worked with Juan Osorno, NDSU Dry Bean Breeder, to establish irrigated kidney bean trials at Staples, MN. The collaboration between NDSU and the CLC Ag and Energy Center began about three years ago when NDSU's trials could not be planted at their regular locations. Collaboration with Juan Osorno and his team has also been instrumental in providing insight in additional grants that we have successfully obtained related to kidney bean projects at CLC. There continues to be interest in edible bean research on irrigated sands as expressed by Northarvest Dry Bean Growers Association leading to the following collaborative field trials that were conducted during the 2021 growing season.

The kidney variety trial (KVT) had 41 lines that consisted of dark red, light red, and white kidneys (and few cranberry entries) of either commercial or breeding/experimental lines from both public and private programs. The second trial was the miscellaneous variety trial (MVT) that had 12 lines of black, navy, and pinto entries. Results from these trials (released varieties only) were published in the annual NDSU Extension bulletin A-654 that reports all the dry bean variety trials throughout the region (www.ndsu.edu/agriculture/sites/default/files/2021-12/a654_dry_bean_2021.pdf)

The next two trials were breeding trials. The first was a kidney preliminary yield trial (KPYT), which included 17 entries of dark red kidney, 13 entries of light red kidney, and 21 white kidney breeding lines from the NDSU dry bean breeding program at final stages of testing and selection. The second breeding trial was the F6 plant rows trial. Since these lines have not yet been released as public cultivars, both seed and results from these trials are returned to the NDSU dry bean breeding program for internal use only.

All the trials were planted June 3. One of the challenges that we faced this year was drought. Water had to be applied through overhead irrigation before and after planting for seed germination to initiate as there was no natural moisture. With the overhead irrigation applied, the dry bean trials flourished as the dryer conditions led to less disease pressure. In conversation with Juan Osorno, it was noted that the seed yields from these trials were very high in spite of the drought conditions.

The CLC staff planted the trials, managed in-season maintenance, in-season observations, note taking, and harvest. In some instances, note taking was made along with Juan Osorno, John Posch, and the entire crew that works with the NDSU dry bean breeding program. This provided a great opportunity for learning and discussion for all the CLC staff.

The NDSU Dry Bean staff originally planned to come and harvest the plot when 80-90 percent of the varieties were matured and dried. When harvest time came, CLC staff was asked to step in as NDSU was operating with a smaller crew than anticipated due to staffing changes. Harvest was completed by CLC staff with a PMC-10 Almaco plot combine. After harvest of the samples, CLC staff also cleaned the samples before shipping them to NDSU for further data analysis.

We hope to continue this collaboration in the upcoming 2022 growing season with NDSU in establishing trials.

I appreciate the hard work of my coworkers here at the CLC Ag and Energy Center in assisting to manage the trials including Keith Olander, Cory Detloff, Ron Nelson, Todd Pollema, Bruce Berg, John Hlatkey, Taylor Thompson, Noah Boelter, Crystal Halbersma, Katie Benson, Maddie Smith, and Greta Rick.

Dry Bean Improvement for the Northern Plains

Principal Investigators: Juan M. Osorno, Ph.D., Project Leader; Research Specialists: A. Jody Vander Wal and John Posch (resigned Aug. 2021); Research Assistants: Kristin Simons Ph.D.; and Graduate Students: Oscar Rodriguez, Maria Mazala, and Jose C. Figueroa-Cerna.

Long-Term Breeding Objectives -- The objective of the dry bean breeding program at NDSU is to develop high yielding, high quality dry bean cultivars adapted to the northern Great Plains using genetics and breeding. This involves many characteristics of dry beans and different disciplines of research (e.g. genetics/breeding, pathology, physiology, soils, nutrition, etc.). The main priority is to improve pinto, navy, black, and kidney market classes, but also great northern, red and pink. Crosses involve adapted cultivars grown in the Northern Plains, breeding lines developed at NDSU, and germplasm possessing desirable traits from other breeding programs. Each year, the breeding program evaluates material from around the world as possible sources of resistance/tolerance to both biotic and abiotic stresses. New crosses and parental combinations are made each year so there is a continuous feeding of new genetic material through the breeding pipeline. As new material enters into the breeding program, testing and selection (both phenotypic and genotypic) allows keeping the superior material while eliminating lines with undesirable traits/characteristics. All this process involves a combination of multiple disciplines besides breeding/genetics such as genomics/bioinformatics, production agronomy, pathology, plant physiology, and food science, among others.

Target Traits: The MIN-DAK region is the largest dry bean producing region but is also a very unique environment. Therefore, we focus our effort in developing improved varieties that are well adapted to these growing conditions. Breeding efforts are focused on: high seed yield and overall productivity, upright plant architecture, acceptable maturity and drydown, seed visual (size, shape, color, canning/cooking) and nutritional quality, resistance/tolerance to abiotic stress (waterlogging and intermittent drought), resistance/tolerance to diseases such as white mold, rust, root rots, anthracnose, bean common mosaic virus, bacterial blights, and soybean cyst nematode, among others. Many of these traits are part of the NHBGA research priorities list, making the breeding program highly relevant and impactful for the region.

2021 Milestones:

- Based on the 2020 annual dry bean grower's survey in the Northarvest region, NDSU dry bean varieties represented ~48%, ~50%, and ~15% of the area grown with black, great northern, and pinto beans, respectively. When translated to farm gate value of

2021 ND Dry Bean Variety Trial Results Now Available

Dry edible beans have been a significant crop in eastern and east-central North Dakota during the past decades. Dry edible bean production for 2021 is estimated at 1,820 pounds per acre, up 420 pounds from 2020.

The Northarvest Bean Growers Association funds dry edible bean variety trials at the NDSU Research Extension Centers in Minot, Williston, Langdon, Carrington, Oakes and Hettinger.

This work provides unbiased, science-based variety comparisons for pinto, navy, black and miscellaneous bean classes. Each trial consists of approximately 20 varieties, including experimental lines selected by North Dakota State University dry bean breeder Juan Osorno. The trials utilize conventional tillage at Langdon and Carrington, no-till at Minot and Hettinger and irrigated conventional tillage at Oakes and Williston.

Information about dry bean variety performance can be accessed on the web at www.ag.ndsu.edu/varietytrials.

production (assuming an average price of $45 per hundredweight across market classes), it shows that just with the 2020 harvest, NDSU dry bean varieties contributed to generate approximately $133 million USD to dry bean growers in the region. This represents a net return of ~$887 USD per every dollar invested in the NDSU dry bean breeding program. Additional economic impact is also made to the rest of the food chain (elevators, wholesale buyers/brokers, packers, processors, etc.).

- A new navy bean variety has been released for 2022: ND Polar offers higher seed yield than other navy bean varieties commonly grown in the region. In addition, it offers a good agronomic package for the rest of the traits.
- ND Twilight black bean was released in early 2020 and in 2021, it continued to show either superior or similar performance when compared with other common black bean cultivars such as Eclipse or Zorro. In addition, ND Twilight is resistant to bean common mosaic virus and rust (race 20-3) and has intermediate resistance to soybean cyst nematode.
- Other varieties released by NDSU such as ND Falcon pinto, ND Pegasus great northern, and ND Whitetail white kidney continued showing either competitive or superior seed yields in 2021. These varieties also offer interesting disease resistance packages such as rust (ND Falcon), white mold (ND Pegasus and ND Whitetail), soybean cyst nematode (ND Falcon), bacterial blights (ND Whitetail), and root rots (ND Whitetail). These are all important traits included in the current list of "areas of interest" developed by Northarvest Bean Growers Association.
- NDSU Foundation seedstocks reported that for 2021, seed of almost all varieties mentioned above was classified as "sold out". This is a good indication of the interest that the bean industry has in utilizing the varieties released by the NDSU dry bean breeding program and its economic impact in the region.
- Recent research results are showing that in addition to the visual seed quality aspects of slow darkening pintos, this newer sub-market class also offer faster cooking time as well as higher iron bioavailability. This is a great case for added value on a product already being grown in ~35-40% of the pinto acreage in North Dakota.

Growing Season: Across all our 8 field testing locations, the beginning of the growing season started with normal conditions during planting, emergence and early crop establishment. However, the heavy rainfalls experienced in June caused major flooding problems in our nurseries at Hatton variety trials. This location also suffered Dicamba drift damage during the beginning of flowering, which caused the loss of ~50% of our trials. Dicamba drift issues also occurred at Carrington at the end of the season, so this nursery could not be harvested because most plants never dried down. Forest River variety trial suffered from soil compaction issues that was also conducive to the appearing of Fusarium wilt. Damage was so severe that this location was only scored for their reaction to the Fusarium wilt disease (some plots/varieties had more dead plants than others), but not harvested for seed yield data. Then the increased drought conditions during the rest

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of the growing season across the region caused significant seed yield reduction across all trials and locations. Prosper suffered significant leafhopper damage; however, seed yield was not significantly affected. Fortunately, at the end of the season, our nurseries at Prosper and Johnstown in North Dakota, as well as Staples and Perham in Minnesota were very uniform and allowed us to obtain high-quality data for selections. Besides a very mild pressure of common bacterial blight and white mold (at some locations), there was no pressure from other common diseases such as white mold and rust. Root rot pressure at our nurseries in Minnesota allowed the identification of superior kidney genotypes, especially in the case of resistance to Fusarium solani. A second location in Minnesota was grown in collaboration with the Central Lakes College Ag. and Energy Center (Hannah Barrett) at Staples that included a variety trial and a trial with our preliminary kidney breeding lines.

Performance of Newly Released Varieties: During the 2021 growing season, the varieties released by NDSU continued to show either similar or superior performance compared with other varieties commonly grown in the region. A new navy bean variety (ND Polar) was released in early 2022 and it has shown superior performance when compared with other varieties commonly grown in the region.

2021 Research Activities: Variety testing is made in collaboration with the NDSU Research and Extension Centers (REC) across the state. Results of these variety trials can be found in the NDSU-Extension publication A-654. These trials are grown at more than 8 locations in North Dakota (including several RECs) and two in Minnesota includes all the public and private varieties plus few breeding lines at final stages of testing. This is a great decision tool not only for growers but also for public and private breeding programs when deciding about potential variety releases. Given the dry conditions experience during the 2021 growing season (among other factors), several trials were either lost or were not published due to highly variable data (high CV%). The NDSU dry bean breeding program continues to test and screen every year thousands of early generation genotypes, hundreds of preliminary and advanced breeding lines, commercial cultivars, and other germplasm. This breeding pipeline is grown in field experiments across the Northarvest region. On average, every year the NDSU dry bean breeding program grows field trials and nurseries accounting for ~8,000 plots across all 8 locations that when combined, are equivalent to ~35 acres. Consequently, this is the largest public dry bean breeding program in the USA. In addition, the aid of winter nurseries that were made at Puerto Rico (~1800 rows each year), and New Zealand (~300 rows plus breeder seed increases), help to speed up the breeding process, especially at the early generations.

Breeding activities vary throughout the year but in general, it follows a similar cycle across years: cross, test/evaluate across multiple locations, and select the best lines for the next breeding cycle. Daily activities mainly involve crosses in the greenhouse, selection at early generations, yield testing of preliminary and advanced breeding lines, marker-assisted selection for specific disease-resistance genes, disease screening in the greenhouse, and some genetic/agronomic studies. Greenhouse activities complement the field work by doing disease screening (bean rust, common bacterial blight, BCMV, anthracnose, white mold, among others), crossings, and seed increases. Inoculum for disease screening is provided by the Plant Pathology Dept. Each year, the crossing block in the greenhouse facilities involves approximately 250 new parental combinations. Greenhouse screening

Juan Osorno, NDSU Dry Bean Breeder

for disease resistance have allowed the identification of some genotypes with improved resistance to some of the most important pathogens in the area, especially for bean rust, white mold, common bacterial blight, and anthracnose.

Additional research conducted by graduate students and postdoctoral scientists focuses on seed coat slow darkening, upright plant architecture, nutritional traits, multiple disease resistance (common bacterial blight, anthracnose, rust, white mold, and bean common mosaic virus), as well as genetic resistance to root rots in large-seeded types (kidney). New potential sources of resistance have been identified for waterlogging tolerance, slow darkening, root rots, halo blight, common bacterial blight, white mold, and anthracnose through some of these studies. Additional research is also underway (in collaboration with Dr. G. Yan) on genetic resistance to soybean cyst nematode. In collaboration with Dr. P. McClean, studies are focused on the development and use/application of molecular markers to improve the efficiency of selection within the breeding program such as Genome-Wide Association Mapping (GWAS) and Genotyping by Sequencing (GBS) methods, among others.

Acknowledgements: The support from Northarvest bean growers association (trough the checkoff system), NDSU, and the North Dakota Dry Edible Bean Seed Growers Association (NDDEBSGA), has been fundamental for the long-term success of the dry bean breeding program at NDSU and the growers of the Northarvest region. Other funding agencies include USDA-ARS, USDA-NIFA, USDA-AMS, ND Department of Agriculture, and USAID.

We want to thank the following growers for allowing us to do research trials in their farms: Mark Dombeck (Perham-MN), Jim and Dylan Karley (Johnstown-ND), Brian Shanilec (Forest River-ND), Tim Skjoiton (Hatton-ND), and Mark and Jim Sleeten (Hatton-ND).

Additional collaborators and partners: Plant Pathology: Dimitri Fonseka, Robin Lamppa, etc. Bean Genomics: Phil McClean, Rian Lee, Atena Oladzad. Breeding Pipeline Managmt.: Ana M. Morales-Heilman. Extension: Hans Kandel, Sam Markell, Greg Endres, and Janet Knodel. Summer interns/workers and Industry partners.

2021 Dry Edible Bean Disease Research Report

Principle investigators: Upinder Gill, Rust Pathologist, Sam Markell, Extension Plant Pathologist, Jack Rasmussen, Plant Pathologist & Department Head; North Dakota State University, Fargo Campus

Background: Multiple diseases and pests significantly impact dry bean yields in the Northarvest region. The success of dry bean growers relies on the effective management of diseases that cause economic yield losses. For the past several years, the plant pathology group at North Dakota State University (NDSU) has been actively developing, testing, and recommending disease management strategies for the dry bean growers. Among dry bean diseases, rust, common bacterial blight (CBB), white mold, root rot, brown spot, halo blight and anthracnose are some of the frequently occurring diseases that impact dry bean cultivation in the region. Our goal is to minimize the crop losses by conducting disease surveys in the region, understanding the pathogen diversity, studying the fungicide treatments and resistant cultivars on total yield, and supporting the breeding program in their disease screening efforts for the development of resistant cultivars. The continued research at NDSU is focused on the following objectives:

1. Monitor dry bean diseases in the Northarvest region.
2. Support NDSU dry bean breeding program to identity/select resistant germplasm to economically significant diseases in the Northarvest region.
3. Field evaluation of dry bean cultivars and breeding lines containing Ur-11 for rust resistance and yield advantage under disease pressure.
4. Characterize regional rust isolates by race typing and studying the population diversity in relation to North & South American isolates.

We believe these activities are essential to improve dry bean production and productivity in the region.

Monitor dry bean diseases in the Northarvest region. Annual disease surveys were conducted by visiting 41 dry bean fields in 10 North Dakota counties (Benson, Cass, Foster, Grand Forks, Nelson, Pembina, Steele, Trail, Walsh, and Wells) between August 17 to 25 in 2021 (Table 1). Pinto, navy, black, great northern, pink, and kidney fields were visually inspected for foliar diseases and the samples were collected for laboratory evaluations. Similar to the past several years, common bacterial blight (CBB) was observed in 100% of the fields evaluated. In 2018 and 2019, CBB was reported in nearly 95% of the survey fields. Besides CBB, brown spot and halo blight were observed at low frequency in only two and one field(s) located in Grand Forks and Steele counties, respectively. No white mold, rust, and anthracnose were observed in any of the surveyed fields. Low

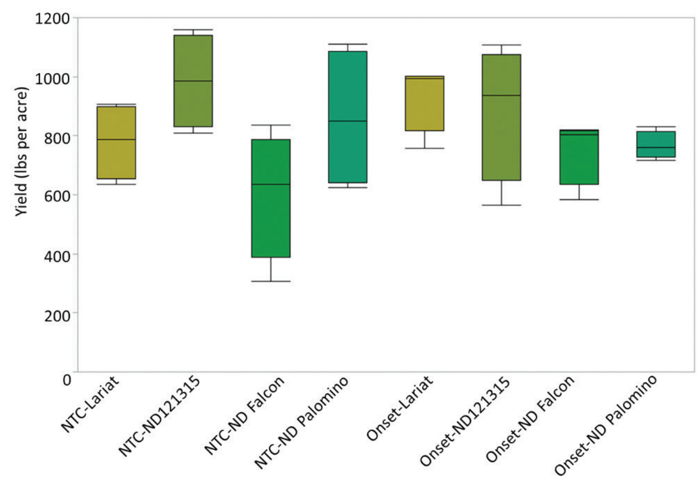

Figure 1: Dry bean yield (means of four replications) estimates of four lines in Fargo, ND trial.

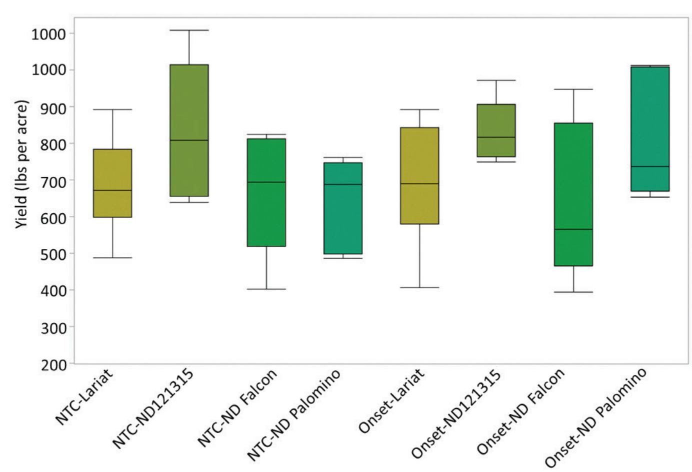

Figure 2. Dry bean yield (means of six replications) estimates of four lines in Casselton, ND trial.

disease incidence of those diseases was likely related to drought conditions that occurred in the growing season. Drought conditions resulted in poor canopy formation resulting in more air-flow and reduced leaf wetness periods and an unfavorable microclimate for many diseases.

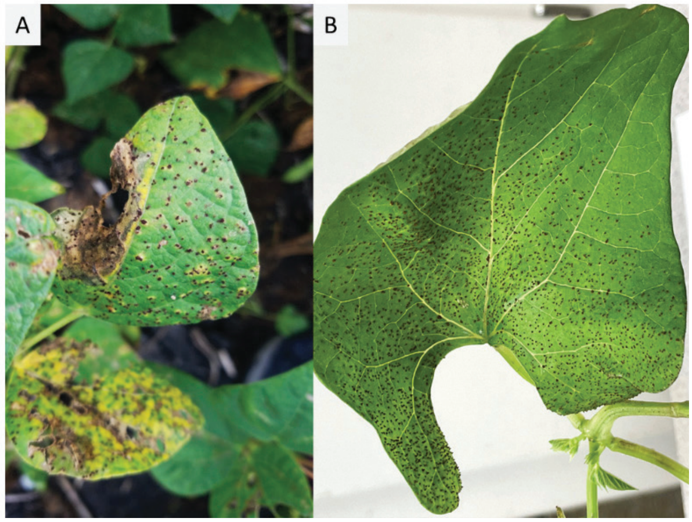

Figure 3. Symptoms of rust on dry bean leaves in the field (A) and greenhouse (B) trials.

Support NDSU dry bean breeding program to identity/select resistant germplasm to economically significant diseases in the Northarvest region. Breeding high-yielding and disease-resistant varieties is critical for dry bean production. In our efforts to support NDSU dry bean breeding program, pathogen isolates were increased and provided for screening breeding germplasm for reactions to anthracnose, rust, and CBB. These pathogens included highly virulent pathogen races such as race 73 of the anthracnose pathogen and race 20-3 of the rust pathogen. These efforts aim to support the selection and release of superior dry bean cultivars with a good disease resistance package. The dry bean pathology group will continue to support the NDSU dry bean breeding projects by working with Dr. Juan Osorno and his team to evaluate advanced breeding lines and germplasm against CBB, root rot, anthracnose, and rust.

Field evaluation of dry bean cultivars and breeding lines containing Ur-11 for rust resistance and yield advantage under disease pressure. Rust is a significant threat to dry bean production in the Northarvest region. Cultivating resistant bean varieties in combination with fungicide applications is generally used to manage this disease. In this effort, new bean varieties (ND Falcon) and breeding lines are being developed by the NDSU dry bean breeding program. These lines contain the Ur-11 resistance gene which is effective against a highly damaging race (20-3) of the bean rust pathogen in the region. The use of resistant varieties provides yield protection against rust diseases and increases economic return in the form of reduced cost of fungicide applications.

Field trials were conducted in 2021 at two locations (Fargo and Casselton) for yield analysis of rust resistant lines (ND Falcon and ND121315) and susceptible controls (Lariat and ND Palomino). Fungicide treatments included no fungicide and a single application of 20 gallons of Onset (tebuconazole, FRAC 3) spray solution per acre at first sign of rust occurrence. The experiment was inoculated with regional rust isolates and weekly disease severity data was recorded for four weeks. Plots were harvested at maturity to estimate the total yield. No significant differences were observed between fungicide and no fungicide applications at both locations **(Figure 1 and 2)**. Disease severity was high enough to observe differences among varieties, with Falcon being more resistant than the other three lines **(Table 2; Figure 3a)**. Further, a fungicide application

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reduced disease severity numerically on all varieties, although it was only statistically different on Lariat and Palomino. It is worth mentioning that the 2021 year was extremely dry with low rainfall resulting in poor crop growth, which likely reduced both yield and disease development. Therefore, these trials will be repeated in 2022 by including more bean lines from the breeding program to get an accurate estimate of yield advantage using of resistant varieties.

Table 1. Incidence of diseases observed in dry bean fields surveyed in 2021.

County	Number of fields	White Mold	Bacterial blight (All)	CBB	BS	HB	Rust	Anthracnose
Grand Forks	7	0	7	7	1	1	0	0
Wells	7	0	7	7	1	0	0	0
Benson	2	0	2	2	0	0	0	0
Trail	7	0	7	7	0	0	0	0
Steele	3	0	3	3	1	0	0	0
Walsh	6	0	6	6	0	0	0	0
Pembina	6	0	6	6	0	0	0	0
Nelson	1	0	1	1	0	0	0	0
Foster	1	0	1	1	0	0	0	0
Cass	1	0	1	1	0	0	0	0
Total	41	0	41	41	2	1	0	0

Survey conducted from 8/17 to 8/25/2021

Characterize regional rust isolates by race typing and studying the population diversity in relation to North & South American isolates: Rust isolates collected in the past from Northarvest regions have displayed a high level of population diversity with more than 18 reported races. We continued our rust surveillance efforts this year too. As indicated above, the rust isolates were not identified from the surveyed fields in 2021. Therefore, we used our collection of unique rust isolates from North Dakota and other regions to study the changes in rust populations at the genomic level. This work is continuing and involve isolates revival, DNA isolation, and sequencing. So far, we have revived 27 rust races from our old stocks **(Figure 3B)**. These races, along with other races, will be characterized to understand the differences among them at the DNA level. This study will help us understand the pathogen movement and the origin of new pathogen populations that are damaging to bean varieties in the region.

As in the past, our research team in the Department of Plant Pathology at NDSU strives to keep the dry bean diseases at bay to support our growers. In these efforts, NDSU has recruited a new Pulse Pathologist, Dr. Malaika Ebert, to support the dry bean pathology research program.

Thank you: Once again, we thank our grower partners, the Northarvest Bean Growers Association, the North Dakota Department of Agriculture, and our private industry partners for their continued support to our research programs. We also thank research specialists Jessica Halvorson, Bryan Hansen, Scott Meyer, Robin Lamppa, and Matthew Breiland; postdoctoral fellow Sarah Rodriguez and graduate student Jatinder Singh for working on these projects. Thank you to our collaborator Juan Osorno and his dry bean breeding team Kristin Simons, Albert (Jody) Vander Wal, and John Posch.

Table 2. Impact of genetic resistance on rust disease severity over the period of trial. Note: AUDPC is a relative measure of rust severity, with higher AUDPC values indicating higher rust severity.

Plant Genotypes	Rate	AUDPC (Fargo)	AUDPC (Casselton)
Lariat	NTC	1,279abc	1,490a
Falcon	NTC	600c	507cd
ND Palomino	NTC	1,479abc	1,300a
ND121315	NTC	1,905a	1,510a
Lariat	4 fl oz/A Onset	1,448abc	691bc
ND Falcon	4 fl oz/A Onset	651bc	204d
ND Palomino	4 fl oz/A Onset	1,545abc	738bc
ND121315	4 fl oz/A Onset	1,672ab	1,058ab

NTC = Non-treated control
AUDPC = area under the disease progress curve

Improving White Mold Management in Dry Beans

Principal investigator: Michael Wunsch, plant pathologist, NDSU Carrington Research Extension Center. **Co-PI:** Kelly Cooper, agronomist / NDSU Robert Titus Irrigation Research Site'

Optimizing fungicide application timing for improved management of white mold in dry beans: Field studies were conducted at the NDSU Carrington Research Extension Center and at the NDSU Robert Titus Irrigation Research Farm in Oakes in 2017, 2020 and 2021 to identify the fungicide application timing that optimizes white mold management in pinto, dark-red kidney, navy and black beans. Overhead irrigation was applied as needed to facilitate disease pressure. The goal of this project was to identify when fungicides should be applied when risk of white mold is elevated as dry beans enter bloom.

Testing was conducted on dry beans seeded to 14-inch or 28-inch rows at 90,000 viable seeds/ac (pinto and kidney beans) or 100,000 viable seeds/ac (navy and black beans). Testing was conducted on 'Laz Paz' (2017), 'Lariat' (Carrington, 2020), and 'Palomino' pinto beans (Oakes, 2020 and 2021; Carrington, 2021); 'Avalanche' (Carrington, 2017), 'T9905' (Carrington, 2020) or 'HMS Medalist' navy beans (Carrington, 2020); 'Eclipse' (Oakes and Carrington, 2017) and 'Black Bear' (Carrington, 2020) black beans; and 'Dynasty' dark-red kidney beans. Fungicides were applied with a hand-held 56-inch, 4-nozzle boom. When canopy closure averaged less than 90%, applications were made with TeeJet DG11015 nozzles at 30 psi (medium droplets); when canopy closure averaged 90-95%, applications were made with TeeJet AIXR11015 nozzles at 60 psi (medium-coarse droplets); and when canopy closure was >95%, applications were made with TeeJet AIXR11015 nozzles at 50 psi (coarse droplets). Testing was conducted with a single application of Topsin (30 fl oz/ac in 2017 and 2020; 40 fl oz/ac in 2021) and with sequential applications of Topsin followed by Endura (8 oz/ac) 8 to 14 days later. Studies were conducted with 6 to 14 replicates, with a large number of replicates utilized so as to mitigate spatial differences in Sclerotinia disease pressure.

The best predictors of optimum fungicide application timing were percent canopy closure and the percent of plants with one or more initial pods.

- Pinto beans: When the canopy was at or near closure (average ≥ 95% of the ground covered) when the first pin-shaped pods were developing, white mold management and pinto bean yield were optimized when fungicides were applied when approx. 15% of plants had initial pin-shaped pods

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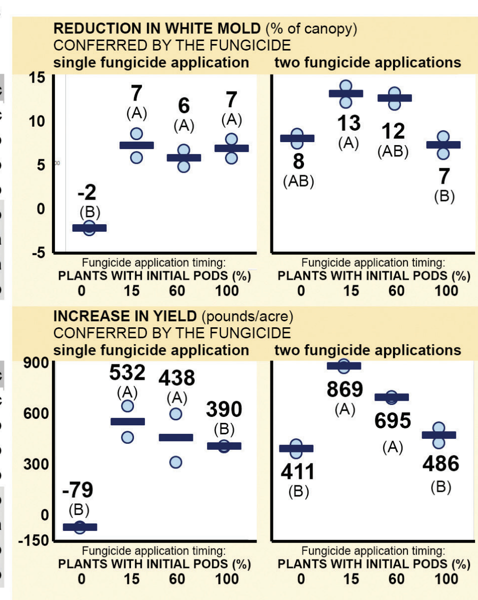
Figure 1. Impact of fungicide application timing on white mold management in pinto beans; Carrington, ND (2017). Treatment means followed by different letters are significantly different (P < 0.05).

PINTO BEANS: studies with canopy at / near closure (≥ 95% closed) when 10-20% of plants had initial pods

	plants with an open blossom	plants with initial pods	canopy closure	COMBINED ANALYSIS two studies WHITE MOLD % of canopy	
Non-treated control				84	c
Application A	80%	0%	70-90%	87	c
Applic. B: 2 days after A	100%	15%	95-99%	78	b
Applic. C: 3 days after B	100%	60%	98-100%	79	b
Applic. D: 2days after C	100%	100%	100%	78	b
Applic. A + 10 or 14 days later				77	b
Applic. B + 10 or 14 days later				72	a
Applic. C + 10 or 14 days later				72	a
Applic. D + 10 or 14 days later				77	b
				CV: 1.3	

	plants with an open blossom	plants with initial pods	canopy closure	YIELD pounds/acre	
Non-treated control				1291	c
Application A	80%	0%	70-90%	1212	c
Applic. B: 2 days after A	100%	15%	95-99%	1823	b
Applic. C: 3 days after B	100%	60%	98-100%	1729	b
Applic. D: 2days after C	100%	100%	100%	1681	b
Applic. A + 10 or 14 days later				1703	b
Applic. B + 10 or 14 days later				2161	a
Applic. C + 10 or 14 days later				1986	ab
Applic. D + 10 or 14 days later				1777	b
				CV: 4.7	



(Figure 1). When the canopy was open (average < 95% of the ground covered) when the first pin-shaped pods were developing, white mold management and dry bean yield were optimized when fungicide applications were delayed until 50% of the plants had initial pin-shaped pods **(Figure 2)**. The growth stage which optimized fungicide performance was the same irrespective of whether one fungicide application or two sequential applications were made.

- Black beans and navy beans: When the canopy was open (average < 95% closure) when the first pin-shaped pods were developing, the response to fungicides was very similar irrespective of whether applications were made at the first appearance of pin-shaped pods or delayed until 30-50% of plants had initial pods **(Figures 3 and 4)**.
- Dark-red kidney beans: When the canopy was open (average < 95% closure) when the first pin-shaped pods were developing, the efficacy of a single fungicide application appeared to be optimized by delaying the application until more than half of the plants had initial pin-shaped pods **(Figure 5)**. When two sequential fungicide applications were made, making applications at the first appearance of initial pods appeared to perform equivalently or better than delaying.

Follow-up research is needed to confirm these findings. The number of field studies conducted for each market class was relatively small, and statistical separation was often not achieved. Final conclusions are anticipated after a fourth year of field trials in 2022.

Optimizing fungicide spray droplet size for improved management of white mold in dry beans

Field studies were conducted at the NDSU Carrington Research Extension Center and at the NDSU Robert Titus Irrigation Research Farm in Oakes in 2021 to assess the impact of calibrating fungicide droplet size relative to canopy characteristics at each of two sequential fungicide applications targeting white mold in dry beans.

Testing was conducted with a tractor-mounted sprayer equipped with a pulse-width modulation system (Capstan AG; Topeka, KS). In Carrington, spray volume was 15 gal/ac, and driving speed was 10.5 mph. Fine droplets were applied with TeeJet XR11005 nozzles at 60 psi, medium droplets were

Figure 2. Impact of fungicide application timing on white mold management in pinto beans; Carrington and Oakes, ND (2020 and 2021). Treatment means followed by different letters are significantly different (P < 0.05).

PINTO BEANS: Studies where canopy was open (< 95% closure) **when 10-20% of plants had initial pods**

	plants with an open blossom	plants with initial pods	canopy closure	COMBINED ANALYSIS four studies WHITE MOLD % of canopy	
Non-treated control				44	c
Application A	34-63%	0%	40-79%	38	bc
Applic. B: 1 to 4 days after A	55-89%	11-17%	45-91%	36	abc
Applic. C: 2 to 4 days after B	83-97%	53-64%	53-93%	29	abc
Applic. D: 2 to 3 days after C	88-100%	73-84%	67-93%	30	abc
Applic. A + 8 to 14 days later				25	ab
Applic. B + 8 to 14 days later				27	ab
Applic. C + 8 to 14 days later				21	a
Applic. D + 8 to 14 days later				23	ab
				CV: 21.9	

	plants with an open blossom	plants with initial pods	canopy closure	YIELD pounds/acre	
Non-treated control				2470	c
Application A	34-63%	0%	40-79%	2622	bc
Applic. B: 1 to 4 days after A	55-89%	11-17%	45-91%	2624	bc
Applic. C: 2 to 4 days after B	83-97%	53-64%	53-93%	2770	bc
Applic. D: 2 to 3 days after C	88-100%	73-84%	67-93%	2822	abc
Applic. A + 8 to 14 days later				2887	ab
Applic. B + 8 to 14 days later				2890	ab
Applic. C + 8 to 14 days later				3003	ab
Applic. D + 8 to 14 days later				3056	a
				CV: 5.9	

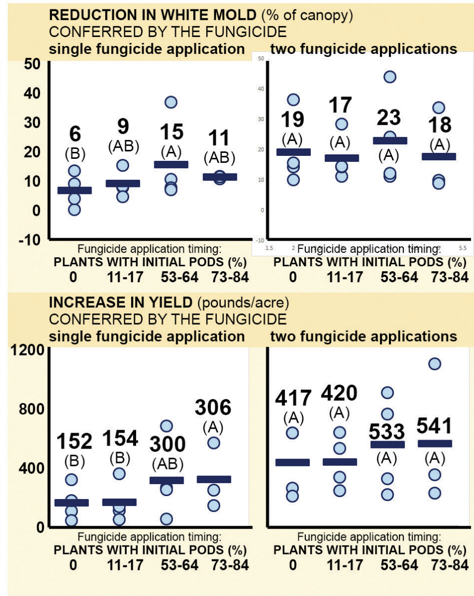
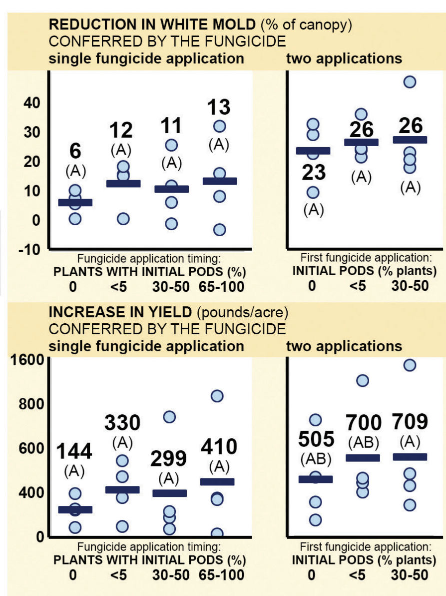


Figure 3. Impact of fungicide application timing on white mold management in black beans; Carrington and Oakes, ND (2017 and 2020). Treatment means followed by different letters are significantly different (P < 0.05).

BLACK BEANS: Studies where canopy was open (< 95% closure) **when 10-20% of plants had initial pods**

	plants with an open blossom	plants with initial pods	canopy closure	COMBINED ANALYSIS four studies WHITE MOLD % of canopy	
Non-treated control				56	c
Application A	11-60%	0%	40-85%	50	c
Applic. B: 2 or 3 days after A	50-100%	< 5%	60-88%	44	abc
Applic. C: 2 or 4 days after B	75-100%	30-50%	80-92%	46	bc
Applic. D: 2 days after C	85-100%	65-100%	70-100%	43	abc
Applic. A + 10 or 12 days later				33	ab
Applic. B + 10 or 12 days later				31	a
Applic. C + 10 or 12 days later				30	a
				CV: 14.6	

	plants with an open blossom	plants with initial pods	canopy closure	YIELD pounds/acre	
Non-treated control				2419	b
Application A	11-60%	0%	40-85%	2563	b
Applic. B: 2 or 3 days after A	50-100%	< 5%	60-88%	2749	ab
Applic. C: 2 or 4 days after B	75-100%	30-50%	80-92%	2718	ab
Applic. D: 2 days after C	85-100%	65-100%	70-100%	2829	ab
Applic. A + 10 or 12 days later				2924	ab
Applic. B + 10 or 12 days later				3119	a
Applic. C + 10 or 12 days later				3128	a
				CV: 8.1	



applied with XR11006 nozzles at 35 psi, and coarse droplets were applied with XR11010 nozzles at 30 psi. In Oakes, spray volume was 15 gal/ac, and driving speed was 6.0 mph. Fine droplets were applied with TeeJet XR11004 nozzles at 60 psi, medium droplets were applied with XR11006 nozzles at 35 psi, and coarse droplets were applied with XR11010 nozzles at 30 psi. At both study locations, pulse width was modified as needed to maintain a constant driving speed and constant spray volume across nozzles differing in spray output, with pulse width manually set based on the measured spray output. Calibration was conducted in the field immediately before spraying treatments; calibration was also conducted with the fungicide in the tank. Testing was conducted with Topsin (40 fl oz/ac) + NIS (Preference, 0.25% v/v) applied at early bloom and Endura (8 oz/ac) applied 12 days later (Carrington) or 14 days later (Oakes). Dry beans were seeded to rows 14 or 15 inches apart at a seeding rate of 90,000 viable seeds/ac ('Palomino' pinto, 'Pink Panther' light-red kidney beans, 'Dynasty' dark-red kidney beans) or 100,000 viable seeds/ac ('Medalist' navy and 'Black Bear' black beans). The studies in Carrington were conducted under conventional tillage. In Oakes, the studies were repeated three times: (1) direct-seeded into fallow ground, (2) seeded into winter rye that terminated 14 days before planting, and (3) seeded winter rye that terminated within 24 hours of planting. The rye treatments were utilized to facilitate testing in dry beans that differed in canopy closure at early bloom. Studies were conducted with six to twelve replicates. Within each experimental replicate, each fungicide treatment was applied to a block of

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all of the dry bean market classes and varieties planted back-to-back, resulting in all varieties being sprayed concurrently with the exact same fungicide mix and sprayer calibration. The sprayer was turned on or off in a non-harvested filler plot established before, between, and after treatment blocks.

White mold management and dry bean yield were optimized by calibrating spray droplet size relative to canopy closure at each application timing.

- PINTO BEANS: When the canopy was open (<80% of the ground covered) at the first fungicide application and near closure (average 91-95% of the ground covered) at the second fungicide application, pinto bean yield under white mold pressure was optimized by applying fungicides with medium droplets in the first application and coarse droplets in the second application **(Figure 6)**.
- DARK-RED AND LIGHT-RED KIDNEY BEANS: When the canopy was near closure (87-94% of the ground covered) at the first fungicide application and at or near closure (91-100% of the ground covered) at the second fungicide application, kidney bean yield under white mold pressure was optimized by applying fungicides with medium droplets in the first application and coarse droplets in the second application **(Figure 7)**.
- When the canopy was open (< 85% of the

Figure 4. Impact of fungicide application timing on white mold management in navy beans; Carrington and Oakes, ND (2017, 2020, 2021). Treatment means followed by different letters are significantly different (P < 0.05).

NAVY BEANS: Studies in which canopy was open (< 95% closure) **when 10-20% of plants had initial pods**

	plants with an open blossom	plants with initial pods	canopy closure	COMBINED ANALYSIS four studies WHITE MOLD % of canopy	
Non-treated control				42	d
Application A	10-50%	0%	50-87%	44	d
Applic. B: 2 or 3 days after A	22-69%	< 5%	60-87%	41	cd
Applic. C: 2 or 4 days after B	83-88%	23-50%	70-92%	38	bcd
Applic. D: 2 days after C	75-95%	65-95%	75-95%	37	bcd
Applic. A + 10 or 12 days later				31	abc
Applic. B + 10 or 12 days later				28	ab
Applic. C + 10 or 12 days later				25	a
				CV: 11.7	

	plants with an open blossom	plants with initial pods	canopy closure	YIELD pounds/acre	
Non-treated control				2583	c
Application A	10-50%	0%	50-87%	2683	c
Applic. B: 2 or 3 days after A	22-69%	< 5%	60-87%	2722	c
Applic. C: 2 or 4 days after B	83-88%	23-50%	70-92%	2773	bc
Applic. D: 2 days after C	75-95%	65-95%	75-95%	2694	c
Applic. A + 10 or 12 days later				3006	ab
Applic. B + 10 or 12 days later				3101	a
Applic. C + 10 or 12 days later				3066	a
				CV: 3.9	

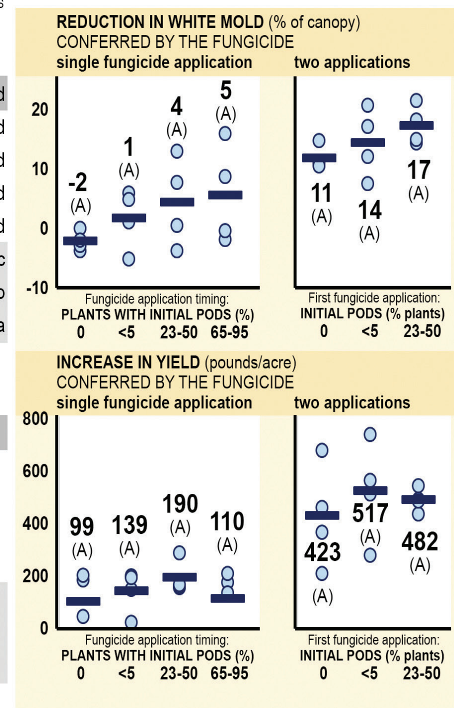
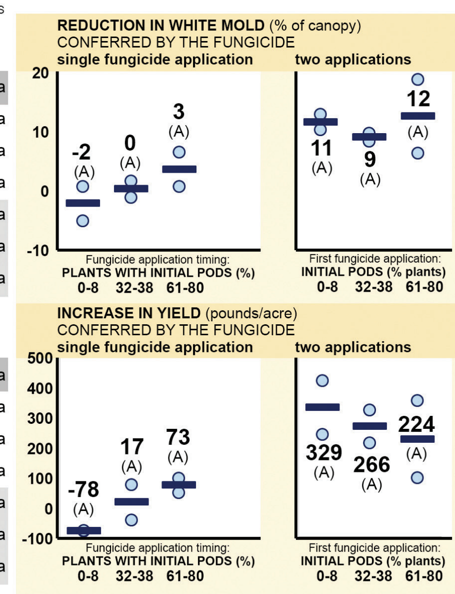


Figure 5. Impact of fungicide application timing on white mold management in dark-red kidney beans; Carrington, ND (2020 and 2021). Treatment means followed by different letters are significantly different (P < 0.05).

KIDNEY BEANS: Studies where canopy was open (< 95% closure) **when 10-20% of plants had initial pods**

	plants with an open blossom	plants with initial pods	canopy closure	COMBINED ANALYSIS two studies WHITE MOLD % of canopy	
Non-treated control				33	a
Application A	46-65%	0-8%	79-80%	35	a
Applic. B: 2 or 3 days after A	64-90%	32-38%	87-90%	32	a
Applic. C: 2 or 4 days after B	86-96%	61-80%	91-93%	29	a
Applic. A + 10 or 12 days later				21	a
Applic. B + 10 or 12 days later				24	a
Applic. C + 10 or 12 days later				20	a
				CV: 14.9	

	plants with an open blossom	plants with initial pods	canopy closure	YIELD pounds/acre	
Non-treated control				2849	a
Application A	46-65%	0-8%	79-80%	2771	a
Applic. B: 2 or 3 days after A	64-90%	32-38%	87-90%	2866	a
Applic. C: 2 or 4 days after B	86-96%	61-80%	91-93%	2922	a
Applic. A + 10 or 12 days later				3178	a
Applic. B + 10 or 12 days later				3115	a
Applic. C + 10 or 12 days later				3073	a
				CV: 3.0	



ground covered) at both applications, applying fungicides with fine droplets both times appeared to optimize fungicide performance **(pinto beans, Table 1)**. Statistical separation was not achieved in this study, and follow-up research is needed to confirm these findings.

- When the canopy closed (average 98% of the ground covered) at both applications, applying fungicides with coarse droplets both times appeared to optimize fungicide performance (kidney beans, Table 1). Statistical separation was not achieved in this study, and follow-up research is needed to confirm these findings.
- Similar relationships between canopy closure and optimal droplet size were also observed in navy and black beans (Table 1). Only a single study was conducted with each of these market classes, and follow-up research is needed to confirm these findings.

Continued research on optimizing fungicide spray droplet size for white mold in dry beans is planned for 2022.

Figure 6. Impact of calibrating fungicide spray droplet size relative to canopy closure in pinto beans; Carrington and Oakes, ND (2021). Treatment means followed by different letters are significantly different (P < 0.05, bar graphs; P < 0.10, scatter plot).

	Carrington 2021 no cover crop		Oakes 2021 rye, late term.		Oakes 2021 rye, early term.		Combined Analysis 3 studies	
variety	'Palomino'		'Palomino'		'Palomino'			
CANOPY CLOSURE when fungicides were applied								
application #1	40-60% **(52%)**		45-85% **(64%)**		45-90% **(76%)**		40-90% **(64%)**	
application #2	80-100% **(95%)**		50-100% **(91%)**		75-100% **(92%)**		50-100% **(93%)**	
WHITE MOLD (% of canopy)								
Non-treated	55	a	12	a	27	b	31	b
Fine / Fine	46	a	8	a	12	a	22	a
Fine / Medium	45	a	9	a	14	a	23	a
Fine / Coarse	47	a	10	a	16	a	25	a
Medium / Medium	48	a	10	a	14	a	24	a
Medium / Coarse	43	a	7	a	14	a	21	a
Coarse / Coarse	42	a	7	a	15	a	21	a
	CV: 13.2		CV: 48.4		CV: 34.1		CV: 8.9	
YIELD (pounds/acre)								
Non-treated	2161	a	3363	a	2944	b	2822	b
Fine / Fine	2642	a	3382	a	3282	ab	3102	ab
Fine / Medium	2529	a	3416	a	3337	a	3094	ab
Fine / Coarse	2605	a	3445	a	3573	a	3208	a
Medium / Medium	2522	a	3523	a	3230	ab	3092	ab
Medium / Coarse	2829	a	3536	a	3510	a	3292	a
Coarse / Coarse	2716	a	3473	a	3509	a	3233	a
	CV: 9.8		CV: 7.4		CV: 8.1		CV: 3.7	

Fungicide droplet size: 1st application / 2nd application

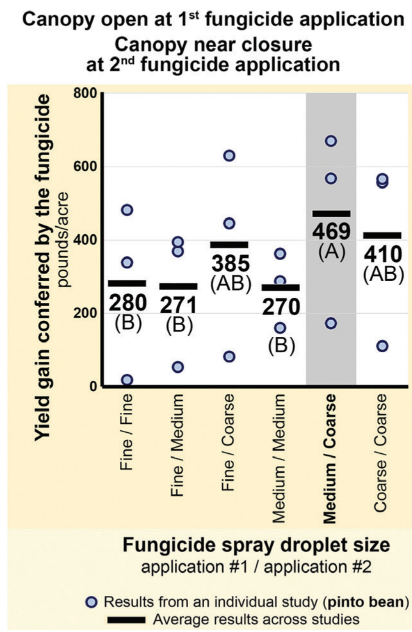
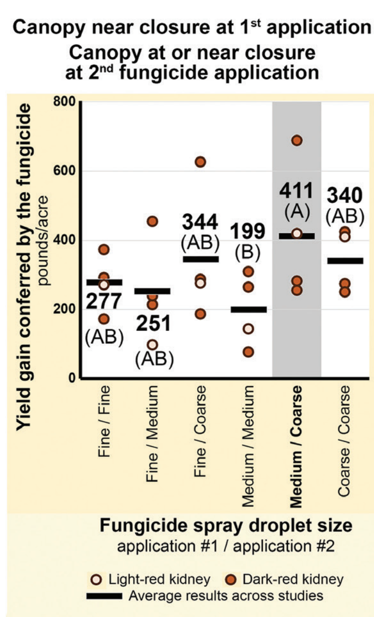


Figure 7. Impact of calibrating fungicide spray droplet size relative to canopy closure in light-red and dark-red kidney beans; Carrington and Oakes, ND (2021). Treatment means followed by different letters are significantly different (P < 0.05, bar graphs; P < 0.10, scatter plot).

	Oakes 2021 no cover crop		Oakes 2021 rye, late term.		Carrington 2021 no cover crop		Carrington 2021 no cover crop		Combined Analysis 4 studies	
variety	'Dynasty'		'Dynasty'		'Dynasty'		'Pink Panther'			
CANOPY CLOSURE when fungicides were applied										
application #1	80-100% **(94%)**		75-100% **(94%)**		60-100% **(87%)**		75-100% **(91%)**		60-100% **(92%)**	
application #2	60-100% **(91%)**		95-100% **(99%)**		100% **(100%)**		90-100% **(99%)**		60-100% **(97%)**	
WHITE MOLD (% of canopy)										
Non-treated	50	a	30	a	56	b	53	a	47	b
Fine/Fine	45	a	30	a	46	a	46	a	42	ab
Fine/Med.	41	a	27	a	51	ab	52	a	43	ab
Fine./Coarse	42	a	28	a	50	ab	49	a	42	ab
Med./Med.	49	a	29	a	49	ab	48	a	44	ab
Med./Coarse	36	a	26	a	50	ab	42	a	39	a
Coarse/Coarse	38	a	25	a	47	a	46	a	39	a
	CV: 26.8		CV: 34.1		CV: 13.7		CV: 23.9		CV: 6.5	
YIELD (pounds/acre)										
Non-treated	2934	a	3189	a	2431	b	2659	b	2803	b
Fine/Fine	3307	a	3361	a	2723	ab	2931	ab	3080	a
Fine/Med.	3387	a	3429	a	2645	ab	2757	ab	3054	a
Fine./Coarse	3560	a	3470	a	2619	ab	2941	ab	3148	a
Med./Med.	3199	a	3266	a	2740	a	2804	ab	3002	ab
Med./Coarse	3622	a	3470	a	2686	ab	3078	a	3214	a
Coarse/Coarse	3354	a	3439	a	2706	ab	3074	a	3143	a
	CV: 11.7		CV: 6.9		CV: 9.1		CV: 11.4		CV: 3.2	



Optimizing fungicide spray volume for improved management of white mold in dry beans

Field studies evaluating the impact of fungicide spray volume were conducted at the NDSU Carrington Research Extension Center in 2020 and 2021.

Testing was conducted with a tractor-mounted sprayer equipped with a pulse-width modulation system (Capstan AG; Topeka, KS). Testing was conducted with medium droplets delivered with TeeJet XR11006 nozzles at 35 psi, and driving speed was 6.0 mph. Pulse width was modified as needed to achieve the target spray volume while maintaining a constant driving speed and the same nozzles and

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pressure across all treatments. Calibration was conducted in the field immediately before spraying treatments; calibration was also conducted with the fungicide in the tank. Testing was conducted with Topsin (40 fl oz/ac) + NIS (Preference, 0.25% v/v) applied at early bloom and Endura (8 oz/ac) applied 12 days later (Carrington) or 14 days later (Oakes). Dry beans were seeded to rows 14 inches apart at a seeding rate of 90,000 viable seeds/ac ('Palomino' pinto, 'Pink Panther' light-red kidney beans, 'Dynasty' dark-red kidney beans) or 100,000 viable seeds/ac ('T9905' navy and 'Eclipse' black beans). Studies were conducted with eight replicates in 2021 and thirteen replicates in 2020.

Increasing spray volume from 10 to 25 gal/ac had no impact on white mold severity or dry bean yield **(Figure 8)**. A weak trend of increased yield was observed as spray volume increased from 20 to 25 gal/ac in the study conducted on navy beans in 2020 and on dark-red kidney beans in 2021, but the differences were not statistically significant and this trend was not observed in the other studies.

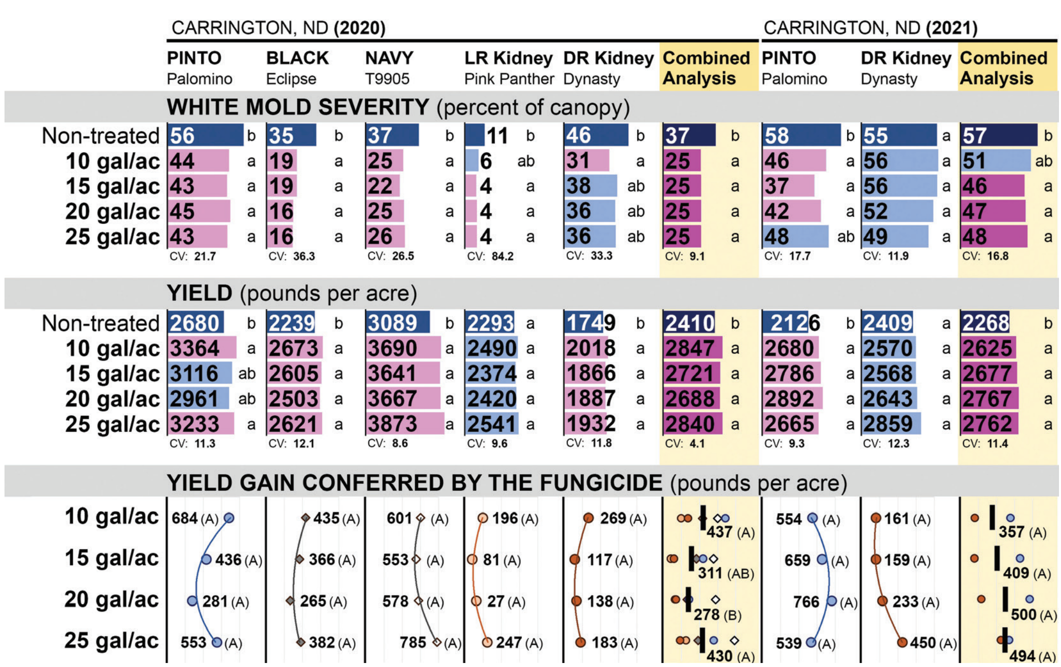
Continued research on optimizing fungicide spray volume for white mold in dry beans is planned for 2022.

Table 1. Impact of calibrating fungicide spray droplet size relative to canopy closure in pinto, kidney, black and navy beans; Carrington and Oakes, ND (2021). Treatment means followed by different letters are significantly different (P < 0.05).

	Canopy **closed** at both applications	Canopy **open** at both applications	Canopy **open** at first application / Canopy **closed** at second application	
	DARK RED KIDNEY	**PINTO**	**NAVY**	**BLACK BEAN**
variety:	Dynasty	Palomino	Medalist	Black Bear
study location (year):	Oakes (2021)	Oakes (2021)	Carrington (2021)	Carrington (2021)
cover crop:	early-terminated rye	no cover crop	no cover crop	no cover crop
CANOPY CLOSURE				
1st application:	90-100% (ave. 98%)	45-95% (ave. 68%)	30-75% (ave. 57%)	50-85% (ave. 68%)
2nd application:	90-100% (ave. 98%)	40-100% (ave. 82%)	95-100% (ave. 99.7%)	90-100% (ave. 99%)
WHITE MOLD (% of canopy)				
Non-treated control	**30** a*	**29** b*	**61** b*	**70** b*
Fine / Fine	**26** a	**16** ab	**50** ab	**54** a
Fine / Medium	**26** a	**10** a	**52** ab	**53** a
Fine / Coarse	**33** a	**14** ab	**45** a	**57** a
Medium / Medium	**23** a	**21** ab	**52** ab	**54** a
Medium / Coarse	**31** a	**16** ab	**50** ab	**54** a
Coarse/ Coarse	**30** a	**16** ab	**45** a	**46** a
CV:	42.3	45.4	17.5	16.2
YIELD (pounds/acre)				
Non-treated control	**3174** a*	**2912** a*	**2242** b*	**1894** b*
Fine / Fine	**3494** a	**3407** a	**2841** a	**2434** a
Fine / Medium	**3587** a	**3336** a	**2673** a	**2495** a
Fine / Coarse	**3418** a	**3208** a	**2884** a	**2394** a
Medium / Medium	**3455** a	**3060** a	**2770** a	**2588** a
Medium / Coarse	**3433** a	**3186** a	**2739** a	**2557** a
Coarse/ Coarse	**3625** a	**3173** a	**2888** a	**2640** a
CV:	8.9	13.6	10.6	14.4

* Within-column means followed by different letters are significantly different (P < 0.05; Tukey comparison procedure).

Figure 8: Impact of fungicide spray volume on white mold management and dry bean yield; Carrington, ND (2020, 2021). Within-column means followed by different letters are significantly different (P < 0.05).



Evaluation of Selected Plant Establishment Factors and Nutrition Inputs in Pinto Bean

Principal Investigator: Greg Endres, Extension cropping systems specialist, NDSU Carrington Research Extension Center (CREC). Co-Investigators: Mike Ostlie, research agronomist, CREC and Bryan Hanson, research agronomist, Langdon Research Extension Center (LREC)

Background: Field studies continued with pinto bean by North Dakota State University (NDSU) in 2021 to examine response to selected fertilizer treatments; winter rye as a cover crop; and response to row spacing plus plant populations.

Fertilizer Treatments: The CREC has been conducting research since 2009 to examine pinto bean performance primarily with starter phosphorus fertilizer and application methods. Results have been published in the NDSU Extension circular A1883 'Pinto bean response to phosphorus starter fertilizer in east-central ND'. Yearly trial reports are available at the website: www.ag.ndsu.edu/carringtonrec/archive/agronomy/production-management.

The 2021 trial was conducted at the CREC to examine pinto bean response with selected zinc (Zn) and sulfur (S) fertilizer treatments. The dryland trial was established on a conventional-tilled loam soil with 3.9% organic matter, 7.6 pH, 5 ppm (Olsen test; low) P, and 0.66 ppm (low) Zn. Preplant (PP) fertilizer was applied and incorporated on May 26. 'ND Palomino' was planted in 30-inch rows on May 28. Starter fertilizer was in-furrow (IF) applied at planting. Foliar fertilizer treatments were applied on July 9 at the V5 to bud growth stages. Treatments included:

- untreated check
- IF 10-34-0 (fertilizer check)
- PP incorporated granular Zn and S
- IF 10-34-0 plus chelated Zn (Ammend; CHS)
- IF 10-34-0 followed by foliar Zn

The trial was not harvested for seed yield due to adverse growing conditions including marginal topsoil moisture for plant establishment (resulting in low and non-uniform plant density) and high air temperatures during plant development.

Multi-year results show limited yield response to IF-applied specialty fertilizers, and foliar Zn and S. The research will continue in 2022 to build substantial databases for selected fertilizer treatments for reference by farmers and crop advisers.

Winter Rye as a Preplant Cover Crop: A study was initiated at the CREC during fall 2016 with winter (cereal) rye as a cover crop preceding dry bean production. Expected advantages with winter rye, established ahead of pinto bean and timely termination, include reduction in soil erosion, supplement for managing weeds, manage excess soil moisture, and efficiency with direct harvest of bean seed. The study was completed in 2021, providing a 5-year database on the production strategy.

'ND Dylan' winter rye was direct-seeded into small grain or soybean residue at 60-75 lb/A during mid-September to early October of 2016-2020. Standard treatments in the study based on rye termination and pinto bean planting dates:

1) Fall and/or spring tillage followed by preplant (PP) or preemergence (PRE) glyphosate and PRE Spartan Charge or Spartan Elite (conventional check).
2) PP glyphosate 4-5 weeks before bean planting.
3) PP glyphosate 4-5 weeks before bean planting plus PRE herbicide.
4) PP glyphosate 2-3 weeks before bean planting.
5) PP or PRE glyphosate near bean planting.
6) PRE glyphosate about 1-2 weeks after bean planting.

'Lariat' or 'ND Palomino' pinto bean were direct planted into rye residue (except tilled plots) or living rye ('green planted') in 30-inch rows during late May to early June. Selected post-emergence herbicides were applied across the trial for general weed control.

Averaged over four years (2018-21), pinto bean seed yield with rye terminated 4-5 weeks prior to bean planting ranged from 17.9-18.7 cwt/acre compared to the conventional check with 17.6 cwt/acre. The highest numeric yield of 18.7 cwt/acre was with rye terminated 4-5 weeks prior to bean planting plus use of PRE herbicide. Seed yield averaged 16.9 cwt/acre with delaying rye termination 2-3 weeks before

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planting. Seed yield averaged 13.8 cwt/acre with delaying rye termination until near bean planting ('green planted').

During each year of bean production (20017-21), topsoil moisture in the trials was depleted by delaying rye termination until or after bean planting. In addition, rainfall to replenish soil moisture was often not timely. Averaged over four years, topsoil moisture levels, measured within a week of bean planting, were greater with the conventional check and PP rye termination compared to moisture with rye termination at or after bean planting. Bean plant development (emergence, flowering and maturity) was extended 3-10 days with delaying rye termination until or after bean planting. Also, bean plant canopy closure was reduced 16-27% with the extended delay in rye termination.

Grass (primarily green and yellow foxtail) and broadleaf (e.g. kochia and common lambsquarters) weeds generally had similar control with use of PRE herbicides and when rye termination was delayed until or after bean planting. Weed control generally was reduced with early rye termination as the lack of live rye and residue allowed weed presence earlier in the growing season.

In summary, pinto bean seed yield with PP terminated rye was similar to yield with the conventional check. Delay in terminating rye until near or after dry bean planting allowed the rye to deplete topsoil moisture that was needed to timely establish bean plants, and negatively impacted bean plant development, canopy closure and yield. Dry topsoil conditions during early bean plant establishment throughout years of the study indicate rye termination at least 2 weeks before bean planting is suggested. The delay in rye termination did provide benefits of increase ground cover during the crop season and weed control similar as achieved with the PRE herbicide.

Row Spacing and Planting Rate: In 2018, a study at the CREC was initiated to examine pinto bean response among intermediate-spaced (21 inches) vs. wide rows (28 inches) and targeted stands of 50,000, 70,000, and 90,000 plants/A. In 2019, paired rows (7-inch pairs centered at 28 inches) were added to the study. In 2020-21, the LREC contributed to the study using slightly different row spacings (30-, 18- and 6-inch pairs).

Averaged over 10 site-years (including trials conducted before 2018) and plant populations, pinto bean seed yield averaged 22.9 cwt/A with intermediate (15- to 22-inch) vs. 19.1 cwt/A with wide (28- to 30-inch) rows. Averaged across 5 site-years, yield with paired rows was similar to 18- to 21-inch rows, and 2.7 cwt/A greater than 28- to 30-inch rows.

Averaged across 3 site-years and row spacings, plant populations of 87,000 plants/A increased yield by 5% (0.9 cwt/A) compared to yield with 70,000 plants/A.

Four site-years of data indicates the combination of intermediate row spacing (18 or 21 inches) and an early season plant population over 80,000 plants/A (83,700 plants/A) increases yield and net revenue compared to wide rows with 64,000 plants/A.

Pinto Bean Crop Tolerance to Preplant, Low-dose Application of Dicamba

Principal Investigator: Greg Endres, Extension cropping systems specialist, NDSU Carrington Research Extension Center (REC). **Co-Investigators:** Joe Ikley, Extension weed specialist; Brian Jenks, weed scientist, North Central REC; and Mike Ostlie, research agronomist, CREC

Background: There are a limited number of preplant (PP) burndown herbicides, available for pinto bean and other broadleaf row crops, that are effective on herbicide-resistant broadleaf weeds, provide initial soil residual, and are low cost. Low rates of dicamba fit this description but waiting periods between dicamba application and row-crop planting generally restrict use of the herbicide, due to potential crop injury. If pinto bean will tolerate a prior low-dose PP application of dicamba with limited waiting period for planting or after a significant rainfall, farmers will have another herbicide option to control herbicide-resistant broadleaf weeds including horseweed (marestail), kochia, pigweed species, plus wild buckwheat.

Objective: Build a North Dakota database that provides a reference for pinto bean growers and crop advisers to make decisions on use of PP low-dose dicamba for burndown and short-term residual weed control while considering potential crop injury.

Materials and methods: The study was conducted at Carrington (irrigated) and North Central (Minot) RECs, and Prosper in 2021. Treatments: 1) untreated and 2) treated (Clarity or generic dicamba applied at 4 fl oz product/A mid-May); pinto bean planted 3) <7 days after dicamba application and before rain or irrigation of 1”, and 4) >14 days after dicamba application and rain or irrigation of 1”.

Dicamba application, and pinto bean planting dates: Carrington - May 13, and May 19 and June 1; Minot - May 7, and May 14 and 27; and Prosper - May 17, and May 19 and June 2. Rain or irrigation

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water (inches) received at first and second planting dates: Carrington - 0.08 and 2.16; Minot - 0 and 0.96; and Prosper - 0 and 0.74.

Results: Visually evaluated plant injury (biomass and stand reduction) of pinto bean grown in dicamba-treated soil with first and second planting dates: Carrington: 28% and <7%; Minot: 91-93% and 24-40%; and Prosper: 50-65% and 30-58%. Early season plant stands (measured) with first and second planting dates compared to untreated checks: Carrington: no reduction; Minot: 73% and 19%; and Prosper: 35% and no reduction.

Seed was harvested at Carrington and yield (cwt/A) was statistically similar among treatments: Untreated check=31.3 and dicamba treated=29.9 with first planting date; and untreated check=30.7 and dicamba treated=30.4 with second planting date.

Summary (across locations): Pinto bean grown in dicamba-treated soil generally had unacceptable plant injury with both planting dates and unacceptable plant stand reduction with first planting date. Seed yield (measured at Carrington) was similar among treatments. The study will continue in 2022.

Herbicide Programs to Control ALS-Resistant Palmer Amaranth and Waterhemp in Dry Beans

Principal Investigator: Joe Ikley, Assistant Professor/Extension Weed Specialist, Department of Plant Sciences

Background: Herbicide-resistant waterhemp (*Amaranthus tuberculatus*) is becoming an increasingly problematic weed to control in dry bean in the Northarvest Bean Growers region. Annual survey results indicate that waterhemp is one of the top three worst weeds in 20% of dry bean acres in the Northarvest region. Waterhemp populations resistant to ALS-inhibiting (Group 2) herbicides are of particular concern due to reliance on using imazamox in many dry bean herbicide programs.

Herbicide-resistant Palmer amaranth (*Amaranthus palmeri*) has been detected in several counties in the Northarvest region. Palmer amaranth will prove as problematic as waterhemp if it becomes established in dry bean acres. Knowing that most Palmer amaranth will be introduced with Group 2 herbicide resistance, more information is needed to see how Palmer will respond to herbicide programs labelled in dry beans.

Objective 1 – Determine optimum rate and tank-mix of PPI and PRE herbicides for residual control: There is currently limited data on the effectiveness of preplant incorporated herbicides for waterhemp and Palmer amaranth control. These pigweeds have longer emergence windows than redroot pigweed or Powell amaranth, so identifying product combinations that provide longer residual control will be beneficial for season-long management. In this objective, we evaluated combinations of EPTC (Eptam), pendimethalin (Prowl), ethalfluralin (Sonalan), and trifluralin (Treflan) for residual control of waterhemp and Palmer amaranth. Preemergence options sulfentrazone (Spartan), metolachlor (Dual), and dimethenamid-P (Outlook) were included

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Objective 1: Herbicide efficacy ratings were collected every 2 weeks after planting. Pigweed biomass was collected and the trials were terminated at 8 weeks after planting.

Treatments:

1) Eptam – 4 pt/A PPI
2) Sonalan – 3 pt/A PPI
3) Treflan – 1.5 pt/A PPI
4) Prowl H2O – 3 pt/A PPI
5) Eptam + Sonalan – 3 + 2 pt/A PPI
6) Eptam + Treflan – 3 + 1.5 pt/A PPI
7) Dual Magnum – 2 pt/A PRE
8) Outlook – 14 fl oz/A PRE
9) Outlook – 21 fl oz/A PRE
10) Spartan Charge – 5 fl oz/A PPI
11) Spartan Charge – 5 fl oz/A PRE
12) Spartan Elite – 25 fl oz/A PPI
13) Spartan Elite – 25 fl oz/A PRE
14) Spartan Charge + Prowl H2O – 4 fl oz + 1.5 pt/A PPI
15) Spartan Charge + Outlook – 4 fl oz + 14 fl oz/A PRE
16) Untreated Check

Objective 2: Eptam + Sonalan at 3 + 2 pt/A were be applied PPI as a base herbicide program in plots. Postemergence programs were applied when waterhemp and Palmer amaranth were 1 to 2 inches in height. Sequential applications were made 7 days after initial postemergence application. MSO at 1% v/v + AMS at 8.5 lb/100 gallon were included with each postemergence treatment. Herbicide efficacy and crop injury ratings were collected 1, 2, and 4 weeks after initial postemergence application. Pigweed biomass was collected at 4 weeks after initial biomass application. Yields were collected at the Fargo location for the waterhemp trial.

Treatments:

1) No POST Herbicide (check)
2) Basagran 5L – 1.6 pt/A
3) Basagran 5L – 0.8 pt/A followed 7 days later by Basagran 5L at 0.8 pt/A
4) Reflex – 12 fl oz/A
5) Reflex – 6 fl oz/A followed 7 days later by Reflex at 6 fl oz/A
6) Basagran 5L + Raptor – 1.6 pt + 4 fl oz/A
7) Basagran 5L + Raptor – 0.8 pt + 2 fl oz/A followed 7 days later by Basagran 5L at 0.8 pt/A + Raptor at 2 fl oz/A
8) Basagran 5L + Reflex – 1.6 pt + 12 fl oz/A
9) Basagran 5L + Reflex – 0.8 pt + 6 fl oz/A followed 7 days later by Basagran 5L at 0.8 pt/A + Reflex at 6 fl oz/A
10) NDSU Dry bean tank-mix applied once – Basagran 5L + Raptor + Reflex – 0.56 + 2 + 4 fl oz/A
11) NDSU Dry bean tank-mix applied twice – Basagran 5L + Raptor + Reflex – 0.56 + 2 + 4 fl oz/A followed 7 days later by the same treatment
12) Raptor – 4 fl oz/A (ALS-resistance check)

for comparison.

Objective 2 – Determine effective postemergence programs for foliar control: There are few effective postemergence options for control of Group 2-resistant waterhemp and Palmer amaranth. Fomesafen (Reflex) is the most effective product labelled in dry bean. Single applications of full rates, and multiple applications of split rates of bentazon and fomesafen will be evaluated for efficacy on ALS-resistant waterhemp and Palmer amaranth.

Objective 3 – Determine the optimal postemergence timing to apply a layered residual herbicide: The addition of a residual herbicide to postemergence applications is an important component of waterhemp and Palmer amaranth management in many crops, including dry beans. Currently, the only herbicides with effective residual activity on ALS-resistant pigweeds that can be applied over the top of dry beans are fomesafen and dimethenamid-P. If a pigweed population is resistant to PPO-inhibiting herbicides, then dimethenamid-P or S-metalochlor are the only viable options remaining. We applied these residual products at various dry bean growth stages to determine the best timing in order to achieve residual control of late emerging pigweeds until the dry bean crop can canopy.

Objective 3:
Eptam + Sonalan at 3 + 2 pt/A were be applied PPI as a base herbicide program in plots. Postemergence applications were applied with a tank-mix of Varisto (imazamox + bentazon) at 1 pt/A and with MSO at 1% v/v + AMS at 8.5 lb/100 gallon. Postemergence application of layered residual were timed for V1 and V3 dry beans. Herbicide efficacy and crop injury ratings were recorded every two weeks following V3 applications. Yields were collected at the Fargo location for the waterhemp trial.

Treatments:
1) Varisto alone applied at V1
2) Outlook – 10 fl oz/A applied at V1
3) Dual Magnum – 1 pt/A applied at V1
4) Reflex – 12 fl oz/A applied at V1
5) Outlook + Reflex – 10 + 12 fl oz/A applied at V1
6) Dual Magnum + Reflex – 1 pt + 12 fl oz/A applied at V1
7) Varisto alone applied at V3
8) Outlook – 10 fl oz/A applied at V3
9) Dual Magnum – 1 pt/A applied at V3
10) Reflex – 12 fl oz/A applied at V3
11) Outlook + Reflex – 10 + 12 fl oz/A applied at V3
12) Dual Magnum + Reflex – 1 pt + 12 fl oz/A applied at V3

Materials and methods: All field experiments were conducted on a Group 2-resistant waterhemp population in Fargo, ND and on a Group 2-resistant Palmer amaranth population in eastern ND. All field experiments were conventionally tilled and were conducted in a RCBD with four replications. Experiments on waterhemp were established on May 10, 2021 at the Fargo location. Experiments on Palmer amaranth were established on June 2, 2021 at a research location in Barnes county, ND. PPI treatments were applied, then incorporated with a rototiller set to 4 inches. Pinto beans (ND Palomino) were planted at 70,000 seed per acre in 30 inch rows. Preemergence treatments were then applied.

Results Objective 1: Overall field conditions at the Fargo location were dry at trial establishment. There was only 1 inch of rainfall within the first 4 weeks after trial establishment, and waterhemp pressure was light for the first month of the experiment. At 4 weeks after planting, all treatments provided 90% or greater waterhemp control (Table 1). At 8 weeks after planting, PPI treatments generally outperformed preemergence treatments (Table 2). All PPI treatments provided ≥80% waterhemp control, while control from preemer-

Table 1. Preplant incorporated and preemergence waterhemp control at Fargo location 4 weeks after planting.

Treatment	Visible waterhemp control (%)[a]
Eptam – 4 pt/A PPI	97 AB
Sonalan – 3 pt/A PPI	99 A
Treflan – 1.5 pt/A PPI	95 AB
Prowl H2O – 3 pt/A PPI	90 C
Eptam + Sonalan – 3 + 2 pt/A PPI	96 AB
Eptam + Treflan – 3 + 1.5 pt/A PPI	99 A
Dual Magnum – 2 pt/A PRE	96 AB
Outlook – 14 fl oz/A PRE	97 AB
Outlook – 21 fl oz/A PRE	99 A
Spartan Charge – 5 fl oz/A PPI	95 ABC
Spartan Charge – 5 fl oz/A PRE	93 BC
Spartan Elite – 25 fl oz/A PPI	99 A
Spartan Elite – 25 fl oz/A PRE	98 A
Spartan Charge + Prowl H2O – 4 fl oz + 1.5 pt/A PPI	93 BC
Spartan Charge + Outlook – 4 fl oz + 14 fl oz/A PRE	99 A

[a]Numbers followed by similar letters are not different according to treatment separation using Fisher's LSD (0.05).

gence treatments ranged from 48 to 83% control.

Overall field conditions at the Palmer amaranth location were dry at trial establishment. The site did receive some timely rainfall in June, though overall conditions remained dry, and the site had moderate Palmer amaranth pressure. At 4 weeks after planting, Palmer amaranth control ranged from 58 to 97% across all treatments (Table 3). PPI treatments provided 73 to 97% control while preemergence treaments provided to 58 to 84% control. At 8 weeks after planting, PPI treatments provided 60 to 85% control, while preemergence treatments provided 38 to 58% control. Overall the PPI treatments provided better control of Palmer amaranth the preemergence treatments in this trial.

Resullts Objective 2: The blanket PPI application of Eptam + Sonalan provided good control several weeks into the season. This led to light infestations of waterhemp and Palmer amaranth for the targeted postemergence applications in these trials. Overall, the treatments with Reflex provided the best control of both waterhemp (Talbe 5) and Palmer amaranth (Table 6), while any treatment without Reflex did not provide adequate control. Control of waterhemp with treatments

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Table 2. Preplant incorporated and preemergence waterhemp control at Fargo location 8 weeks after planting.

Treatment	Visible waterhemp control (%)[a]
Eptam – 4 pt/A PPI	91 AB
Sonalan – 3 pt/A PPI	94 AB
Treflan – 1.5 pt/A PPI	89 AB
Prowl H2O – 3 pt/A PPI	85 ABC
Eptam + Sonalan – 3 + 2 pt/A PPI	85 ABC
Eptam + Treflan – 3 + 1.5 pt/A PPI	99 A
Dual Magnum – 2 pt/A PRE	81 BC
Outlook – 14 fl oz/A PRE	73 CD
Outlook – 21 fl oz/A PRE	65 D
Spartan Charge – 5 fl oz/A PPI	80 BCD
Spartan Charge – 5 fl oz/A PRE	48 E
Spartan Elite – 25 fl oz/A PPI	94 AB
Spartan Elite – 25 fl oz/A PRE	73 CD
Spartan Charge + Prowl H2O – 4 fl oz + 1.5 pt/A PPI	80 BCD
Spartan Charge + Outlook – 4 fl oz + 14 fl oz/A PRE	83 BC

[a]Numbers followed by similar letters are not different according to treatment separation using Fisher's LSD (0.05).

Table 3. Preplant incorporated and preemergence Palmer amaranth control at Barnes county location 4 weeks after planting.

Treatment	Visible Palmer amaranth control (%)[a]
Eptam – 4 pt/A PPI	92 AB
Sonalan – 3 pt/A PPI	92 AB
Treflan – 1.5 pt/A PPI	78 ABCD
Prowl H2O – 3 pt/A PPI	88 ABC
Eptam + Sonalan – 3 + 2 pt/A PPI	97 A
Eptam + Treflan – 3 + 1.5 pt/A PPI	91 ABC
Dual Magnum – 2 pt/A PRE	58 D
Outlook – 14 fl oz/A PRE	74 BCD
Outlook – 21 fl oz/A PRE	75 BCD
Spartan Charge – 5 fl oz/A PPI	79 ABCD
Spartan Charge – 5 fl oz/A PRE	80 ABC
Spartan Elite – 25 fl oz/A PPI	96 A
Spartan Elite – 25 fl oz/A PRE	71 CD
Spartan Charge + Prowl H2O – 4 fl oz + 1.5 pt/A PPI	73 BCD
Spartan Charge + Outlook – 4 fl oz + 14 fl oz/A PRE	84 ABC

[a]Numbers followed by similar letters are not different according to treatment separation using Fisher's LSD (0.05).

Table 4. Preplant incorporated and preemergence Palmer amaranth control at Barnes county location 8 weeks after planting.

Treatment	Visible Palmer amaranth control (%)[a]
Eptam – 4 pt/A PPI	70 ABC
Sonalan – 3 pt/A PPI	74 AB
Treflan – 1.5 pt/A PPI	51 BCDE
Prowl H2O – 3 pt/A PPI	68 ABCD
Eptam + Sonalan – 3 + 2 pt/A PPI	85 A
Eptam + Treflan – 3 + 1.5 pt/A PPI	55 BCDE
Dual Magnum – 2 pt/A PRE	38 E
Outlook – 14 fl oz/A PRE	44 DE
Outlook – 21 fl oz/A PRE	52 BCDE
Spartan Charge – 5 fl oz/A PPI	48 CDE
Spartan Charge – 5 fl oz/A PRE	58 BCDE
Spartan Elite – 25 fl oz/A PPI	73 ABC
Spartan Elite – 25 fl oz/A PRE	55 BCDE
Spartan Charge + Prowl H2O – 4 fl oz + 1.5 pt/A PPI	60 ABCDE
Spartan Charge + Outlook – 4 fl oz + 14 fl oz/A PRE	55 BCDE

[a]Numbers followed by similar letters are not different according to treatment separation using Fisher's LSD (0.05).

containing Reflex varied between 80 and 98%, while Palmer amaranth control ranged from 50 to 70% with the same treatments.

Results Objective 3: The planned sequential programs all provided at least 85% season-long control of waterhemp at the Fargo location (Table 7). Treatments that utilized Reflex in the postemergence application all provided the greatest control (97 to 100%). There were no differences in yield amongst treatments, though yield was generally poor due to season-long drought (data not shown). The same treatments provided less control of Palmer amaranth at the Barnes county site (Table 8). That trial was terminated 61 days after planting to prevent Palmer amaranth escapes from producing seed. Palmer amaranth control ranged from 61 to 95% control. There were no differences between treatments, in part due to varying Palmer amaranth pressure across the trial.

Summary: These experiments evaluated commercially available PPI, preemergence and postemergence herbicides on control of waterhemp and Palmer amaranth. The results indicate that there are several PPI and preemergence herbicides to provide good to excellent control of both weeds. Postemergence treatments will heavily rely on fomesafen (Reflex) for foliar control of waterhemp and Palmer amaranth. We plan to repeat all these experiments in 2022 to observe all treatments in different environmental conditions than 2021.

Table 5. Postemergence waterhemp control at Fargo location 4 weeks after initial postemergence application.

Treatment[a]	Visible waterhemp control (%)[b]
Basagran 5L at 1.6 pt/A	10 C
Basagran 5L at 0.8 pt/A followed by	
Basagran 5L at 0.8 pt/A	10 C
Reflex at 12 fl oz/A	94 A
Reflex at 6 fl oz/A followed by	
Reflex at 6 fl oz/A	80 B
Basagran 5L + Raptor at 1.6 pt + 4 fl oz/A	10 C
Basagran 5L + Raptor at 0.8 pt + 2 fl oz/A followed by	
Basagran 5L + Raptor at 0.8 pt + 2 fl oz/A	10 C
Basagran 5L + Reflex at 1.6 pt + 12 fl oz/A	95 A
Basagran 5L + Reflex at 0.8 pt + 6 fl oz/A followed by	
Basagran 5L + Reflex at 0.8 pt + 6 fl oz/A	98 A
NDSU Dry bean tank-mix applied once – Basagran 5L + Raptor + Reflex at 0.56 + 2 + 4 fl oz/A	84 B
NDSU Dry bean tank-mix applied twice – Basagran 5L + Raptor + Reflex at 0.56 + 2 + 4 fl oz/A followed by Basagran 5L + Raptor + Reflex at 0.56 + 2 + 4 fl oz/A	94 A
Raptor at 4 fl oz/A	8 C

[a]All postemergence treatments contained MSO at 1% v/v + AMS at 8.5 lb/100 gallon.
[b]Numbers followed by similar letters are not different according to treatment separation using Fisher's LSD (0.05).

Table 6. Postemergence Palmer amaranth control at Barnes county location 4 weeks after initial postemergence application.

Treatment[a]	Visible Palmer amaranth control (%)[b]
Basagran 5L at 1.6 pt/A	0 B
Basagran 5L at 0.8 pt/A followed by Basagran 5L at 0.8 pt/A	3 B
Reflex at 12 fl oz/A	57 A
Reflex at 6 fl oz/A followed by Reflex at 6 fl oz/A	50 A
Basagran 5L + Raptor at 1.6 pt + 4 fl oz/A	10 B
Basagran 5L + Raptor at 0.8 pt + 2 fl oz/A followed by	
Basagran 5L + Raptor at 0.8 pt + 2 fl oz/A	7 B
Basagran 5L + Reflex at 1.6 pt + 12 fl oz/A	53 A
Basagran 5L + Reflex at 0.8 pt + 6 fl oz/A followed by Basagran 5L + Reflex at 0.8 pt + 6 fl oz/A	70 A
NDSU Dry bean tank-mix applied once – Basagran 5L + Raptor + Reflex at 0.56 + 2 + 4 fl oz/A	63 A
NDSU Dry bean tank-mix applied twice – Basagran 5L + Raptor + Reflex at 0.56 + 2 + 4 fl oz/A followed by Basagran 5L + Raptor + Reflex at 0.56 + 2 + 4 fl oz/A	57 A
Raptor at 4 fl oz/A	10 B

[a]All postemergence treatments contained MSO at 1% v/v + AMS at 8.5 lb/100 gallon.
[b]Numbers followed by similar letters are not different according to treatment separation using Fisher's LSD (0.05).

Table 7. End of season (100 days after planting) waterhemp control from planned sequential applications for dry bean herbicides at Fargo location.

Treatment[a]	Visible waterhemp control (%)[b]
Varisto at 1 pt/A applied at V1	89 CD
Varisto + Outlook at 1 pt + 10 fl oz/A applied at V1	85 D
Varisto + Dual Magnum at 1 pt + 1 pt/A applied at V1	92 BCD
Varisto + Reflex at 1 pt + 12 fl oz/A applied at V1	97 AB
Varisto + Outlook + Reflex at 1 pt + 10 fl oz + 12 fl oz/A applied at V1	100 A
Varisto + Dual Magnum + Reflex at 1 pt + 1 pt + 12 fl oz/A applied at V1	100 A
Varisto at 1 pt/A applied at V3	93 ABCD
Varisto + Outlook at 1 pt + 10 fl oz/A applied at V3	94 ABC
Varisto + Dual Magnum at 1 pt + 1 pt/A applied at V3	95 ABC
Varisto + Reflex at 1 pt + 12 fl oz/A applied at V3	99 AB
Varisto + Outlook + Reflex at 1 pt + 10 fl oz + 12 fl oz/A applied at V3	98 AB
Varisto + Dual Magnum + Reflex at 1 pt + 1 pt + 12 fl oz/A applied at V3	100 A

[a]All treatments received a PPI application of Eptam + Sonalan at 3 + 2 pt/A the day of planting; All postemergence treatments contained MSO at 1% v/v + AMS at 8.5 lb/100 gallon.
[b]Numbers followed by similar letters are not different according to treatment separation using Fisher's LSD (0.05).

Table 8. End of season (61 days after planting) Palmer amaranth control from planned sequential applications for dry bean herbicides at Barnes county location.

Treatment[a]	Visible Palmer amaranth control (%)[b]
Varisto at 1 pt/A applied at V1	71 A
Varisto + Outlook at 1 pt + 10 fl oz/A applied at V1	61 A
Varisto + Dual Magnum at 1 pt + 1 pt/A applied at V1	69 A
Varisto + Reflex at 1 pt + 12 fl oz/A applied at V1	81 A
Varisto + Outlook + Reflex at 1 pt + 10 fl oz + 12 fl oz/A applied at V1	80 A
Varisto + Dual Magnum + Reflex at 1 pt + 1 pt + 12 fl oz/A applied at V1	63 A
Varisto at 1 pt/A applied at V3	78 A
Varisto + Outlook at 1 pt + 10 fl oz/A applied at V3	63 A
Varisto + Dual Magnum at 1 pt + 1 pt/A applied at V3	76 A
Varisto + Reflex at 1 pt + 12 fl oz/A applied at V3	84 A
Varisto + Outlook + Reflex at 1 pt + 10 fl oz + 12 fl oz/A applied at V3	89 A
Varisto + Dual Magnum + Reflex at 1 pt + 1 pt + 12 fl oz/A applied at V3	95 A

[a]All treatments received a PPI application of Eptam + Sonalan at 3 + 2 pt/A the day of planting; All postemergence treatments contained MSO at 1% v/v + AMS at 8.5 lb/100 gallon.
[b]Numbers followed by similar letters are not different according to treatment separation using Fisher's LSD (0.05).

Soybean, Dry Bean, and Sunflower Tolerance to Preplant Dicamba (NDSU-Minot)

Principal Investigator: Brian Jenks, NDSU North Central Research Extension Center

Introduction: For decades, glyphosate has been a common effective herbicide used to control weeds prior to planting field crops. However, too frequent use of glyphosate has led to weeds becoming resistant to glyphosate. Farmers are looking for other herbicide options to control weeds prior to planting that are now resistant to glyphosate like kochia and horseweed. Dicamba is an herbicide that historically has controlled kochia, horseweed and others, but dicamba has some soil residual activity that may injure certain sensitive crops if planted soon after application. Dicamba will typically break down over a few weeks, but will break down faster with significant rainfall (>1 inch) and warm temperatures.

Objective: The objective of this study was to evaluate soybean, dry bean, and sunflower tolerance to 4 fl oz of dicamba applied under two scenarios: 1) crops planted 7 days after dicamba application with no rainfall between application and planting (worst-case scenario), and 2) crops planted 14+ days after dicamba application with at least 1 inch of rainfall between application and planting.

Methods: In this study, dicamba was applied May 7, 2021. For scenario 1, the three crops were planted May 14 (7 days after application) with no rain between application and planting. For scenario 2, crops were planted May 27 (20 days after application) with at least one inch of rain between application and planting.

Results: Under scenario 1, dicamba caused severe soybean and dry bean injury (>85%) and reduced crop density (Table 1 and 2). Dicamba caused less visual injury to sunflower (23% injury 1 month after planting), but sunflower density and height did not differ significantly from the non-treated check (Table 3).

For scenario 2, dicamba caused less soybean and dry bean injury compared to scenario 1, but injury (~40%) was still significant one month after planting. Very minimal injury (4%) was observed with sunflower under scenario 2.

Discussion: After one research year, the data certainly indicate that dicamba will significantly injury soybean and dry bean when planted within 7 days after application with no rainfall. Soybean and dry bean were still sensitive when planted about 3 weeks after application with 1 inch of rainfall after application. However, most of that 1 inch of rain fell between 13-17 days after application, which did not provide enough time for breakdown of the herbicide. Scenario 2 was more favorable for sunflower, which exhibited very little crop injury. This study will be repeated in 2022.

Table 1. Soybean tolerance to dicamba

		Injury				Density		Height	
Treatment^{ab}	Planting	18-Jun	24-Jun	1-Jul	19-Jul	10-Jun	8-July	8-Jul	28-Jul
		------------------%------------------				plants/m of row		-------cm-------	
Untreated	7 DAA	0^{b}	---	0^{b}	0^{b}	8.8^{a}	7.9^{a}	15.5^{a}	38.0^{a*}
Treated	7DAA	87^{a}	---	85^{a}	85^{a}	2.8^{b}	3.3^{b}	12.9^{b}	31.2^{a}
Untreated	20 DAA	---	0^{a}	---	0^{a}	8.0^{a}	7.3^{a}	13.8^{a}	32.4^{a}
Treated	20 DAA	---	39^{a}	---	22^{a}	5.8^{b}	6.7^{a}	13.5^{a}	32.6^{a}

Table 2. Dry bean tolerance to dicamba

		Injury				Density		Height	
Treatment^{ab}	Planting	18-Jun	24-Jun	1-Jul	19-Jul	10-Jun	8-July	8-Jul	28-Jul
		------------------%------------------				plants/m of row		-------cm-------	
Untreated	7 DAA	0^{b}	---	0^{b}	0^{b}	5.1^{a}	5.3^{a}	19.8^{a*}	36.4^{a}
Treated	20 DAA	91^{a}	---	93^{a}	93^{a}	1.4^{b}	2.3^{b}	16.3^{a}	36.4^{a}
Untreated	20 DAA	---	0^{a}	---	0^{a}	4.3^{a}	4.6^{a}	17.9^{a}	51.6^{a**}
Treated	20 DAA	---	40^{a}	---	24^{a}	3.5^{a}	4.6^{a}	19.5^{a}	45.0^{a}

Table 3. Sunflower tolerance to dicamba (2123)

		Injury				Density		Height	
Treatment^{ab}	Planting	18-Jun	24-Jun	1-Jul	19-Jul	10-Jun	8-July	8-Jul	28-Jul
		------------------%------------------				plants/m of row		-------cm-------	
Untreated	7 DAA	0^{b}	---	0^{b}	0^{b}	3.3^{a}	3.4^{a}	42.5^{a}	98.0^{a}
Treated	7 DAA	23^{a}	---	19^{a}	13^{a}	3.0^{a}	3.4^{a}	39.9^{a}	96.0^{a}
Untreated	20 DAA	---	0^{a}	---	0^{a}	2.6^{a}	3.2^{a}	28.6^{a}	90.5^{a}
Treated	20 DAA	---	3^{a}	---	4^{a}	2.3^{a}	2.9^{a}	32.1^{a}	95.3^{a}

*Significant at a-0.10 **Significant at a=0.15

[a]Treatments were analyzed by individual planting date. DAA=Days after application

[b]Means followed by the same letter do not significantly differ (a=0.05)

Strategies for Reducing Erosion Through Spring Cover Crops

Principal investigator: Mike Ostlie, David Kramar, and Greg Endres, NDSU Carrington Research Extension Center

Background: Nobody likes wind and water erosion. But for low residue and sometimes high disturbance crops like dry beans, there are often few options to combat soil loss. Reduced tillage practices such as strip till are one of the things that can be used to reduce erosion, but it requires specific equipment and has a large time sink. Fall rye seeded prior to or after a dry bean crop will help with erosion but some years it is difficult to plant due to weather and it requires knowing the next crop in the crop rotation one season ahead. One of the other options to consider is planting a spring cereal cover crop prior to dry bean seeding. This strategy is used by some sugar beet growers to aid in emergence and protect young seedlings from wind damage. In dry bean production, a cereal crop can provide ground cover during the early growing season, help suppress early season weeds, and depending on termination timing it may provide post-harvest benefits to erosion management.

In the following study, we wanted to test different herbicides and cereal species in combination to effectively manage weeds and erosion in our operations. We were also going to test different cover crop termination timings and cereal seeding dates. One benefit of cereals in this system is the ease of termination pre- or post-emergent in dry beans. In-crop, both imazamox (ie Raptor) or grass products like clethodim or quizalofop (ie Select and Assure II) will kill the cereals any time prior to heading.

Objective: Develop dry bean cover crop management recommendations that reduce erosion potential of soils in the spring while not negatively affecting dry bean yields.

Methods: Two trials were conducted at the Carrington Research Extension Center in 2021. The first trial consisted of 21 treatment combinations which included 3 cereals crops planted in the spring (barley, oats, winter rye) and 7 Pre-emerge herbicides (non-treated, Sonalan, Treflan, Spartan Elite, Prowl H2O, Dual II Magnum, and Outlook). The herbicides were applied within 24 hours (before if PPI or after if PRE) of planting both dry beans and cover crops. The cover crop was seeded first, then the dry beans were planted in a second operation. Cover crop establishment was estimated prior to termination at the V2-3 stage.

The second study con-

Table 1. Comparison of cover crop and herbicide combinations for injury potential to dry beans and green foxtail control

Cover Crop	Herbicide	Cereal Stand	Phytotoxicity	Green Foxtail Control
		pl/a	%	%
Oats	Check	809352	0.0	3.8
Oats	Sonalan	671747	26.3	52.5
Oats	Treflan	843690	3.8	20.0
Oats	Dual II	888079	1.3	25.0
Oats	Outlook	798995	5.0	25.0
Oats	Prowl H2O	767923	11.3	55.5
Oats	Spartan Elite	722054	0.0	18.8
Barley	Check	915885	0.0	50.0
Barley	Sonalan	844863	3.8	90.0
Barley	Treflan	852261	0.0	61.3
Barley	Dual II	899609	2.5	63.8
Barley	Outlook	764963	5.0	65.0
Barley	Prowl H2O	775321	0.0	55.0
Barley	Spartan Elite	837465	0.0	53.8
Rye	Check	726493	0.0	3.8
Rye	Sonalan	630318	15.0	75.0
Rye	Treflan	793076	0.0	11.3
Rye	Dual II	847822	10.0	10.0
Rye	Outlook	821189	5.0	18.8
Rye	Prowl H2O	781239	6.3	55.0
Rye	Spartan Elite	856700	8.8	17.5
LSD (0.05)		145990	8.3	14.0

sisted of planting cereals 3 weeks prior to dry bean planting or at dry bean planting. This paired with terminations at planting and V3 for the early seed cover crops and just at V3 for the late planted cover crops. All three of barley, rye, and oats were seeded this year.

The plan was to collect yield data on both trials, but due to the drought there was no dry bean harvest at this site. The plants remained stunted and green until after the first frost, resulting in little/no mature seed produced. UAS data were not collected due to high density of green foxtail remaining after termination treatments, which was also related to drought.

Results: Since no yield was recorded, the primary output for this season is the cover crop and herbicide interaction. There were several notable outcomes from this study. First, most pre-emerge herbicides were safe to use in conjunction with the cereal cover crops (Table 1). However notably, Sonalan caused the highest injury both visually and through stand reduction in rye and oats. There was no treatment that causes significant injury to barley. Even the highest injury resulted in only a 19% stand reduction (26 % visual injury) which is likely palatable to most operations. A 25% injury rating likely still allows one to accomplish the objectives of the cover crop.

Green foxtail was controlled to varying degrees with the treatment combinations. With these treatments, neither rye nor oats provided meaningful levels of suppression. At the time of rating the cereals were at the 2-3 leaf stage, which may be too small for a crop like rye to provide its well-known suppression. Barley, without any other herbicide, provided 50% green foxtail control. When combined with Sonalan, the barley provided 90% green foxtail suppression. Other cereals and herbicide treatments also synergistically acted to reduce weed pressure, but most of the treatments outside of Sonalan and Prowl H2O did not provide adequate control. This year proved to be exceptional in many ways, one of which was highlighting a very resilient green foxtail population in the face of drought. Likely under more normal moisture conditions, more of these products would have performed better. Without yield data, we also cannot say whether barley would pose a risk to dry bean yield compared to the other two crops.

We hope to continue the study in 2022.

Soybean Cyst Nematode Resistance Evaluation in Dry Bean Varieties

Principal Investigators: Dr. Guiping Yan, Plant Nematologist, Dr. Berlin Nelson, Plant Pathologist, Dr. Juan Osorno, Dry Bean Breeder, and Harkamal Kaur, Graduate Student, North Dakota State University

Introduction: Soybean Cyst Nematode (SCN; Heterodera glycines) is the devastating pathogen of soybean in the United States (US) and some other places in the world. It is a tiny, microscopic plant-parasitic nematode, and causes annual yield losses of soybean around $1 billion in the US alone. The above-ground symptoms are usually invisible during early infection which leads to underestimation of its effect on plant growth and yield. By the time symptoms start to be visualized, 30% of the yield losses may have occurred. SCN was first detected in the US in 1954 and quickly spread through major soybean producing areas. It was first detected in North Dakota in Richland County in 2003 and now spread across most of North Dakota soybean growing counties **(Figure 1)**.

SCN attacks the roots of the host plants. Its life stage involves egg, four juvenile stages and an adult stage. The second stage juvenile (J2) infects the host roots and then develops into the adult stage after third and fourth stage juveniles. Adult females are lemon-shaped, which protrude out of the roots and extract water and nutrients from host plants. A single female body can contain up to 500 eggs. The adult females mature and become brown cysts. The cysts can protect eggs inside and last for years, and it is nearly impossible to completely eliminate SCN once it is established in the field. The cysts present in the soil in a field can be spread to other fields through any movement of the soil such as soil attached to equipment, flooding, dust storms, birds, animals, and human.

There has been a lot of research going on about

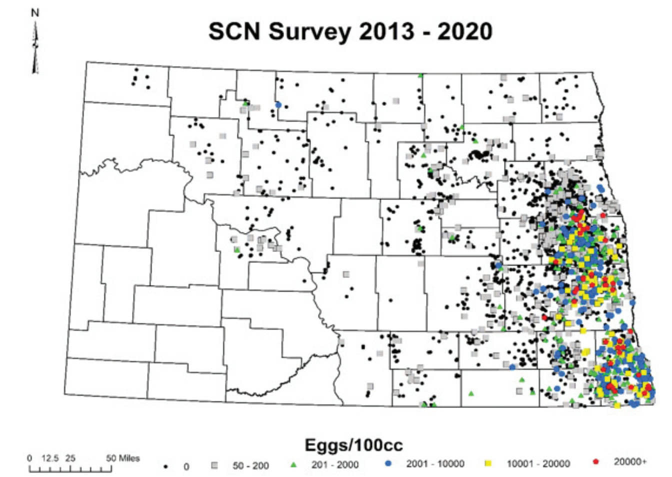

Figure 1. SCN distribution map in North Dakota as determined by grower submitted samples from 2013 to 2020 (Courtesy: Dr. Sam Markell, NDSU).

SCN management in soybean. For dry bean, before 2007, there was little evidence that SCN could infect dry bean growth and yield. The Northarvest Bean Growers' Association funded research at NDSU from 2007 to 2009 which demonstrated that SCN could reduce dry bean yields by up to 60% if a susceptible variety was planted in the soil with a high number of eggs favorable for SCN development and reproduction. In 2019, Dr. Nelson's team collected soil from 116 dry bean fields across 10 counties of North Dakota to check the percentage of bean fields infested with SCN. It was found that 16% of the fields had SCN in low populations with around 50 eggs/100 cc soil. But, nine of the fields had good numbers of eggs between 200 and 3,500/100 cc of soil. SCN cysts can survive in these fields and therefore spread to other fields if caution is not exercised.

Individual SCN nematode populations can be classified into "HG" types, which are similar to "races" or "strains." The HG type indicates which source of resistance that the nematode can reproduce on (thereby rendering the resistance less effective). Before 2015, only HG type 0 population was detected in soybean fields in North Dakota. HG type 0 is the least virulent form and does not attack PI88788, the major resistance source that has been widely used in soybean. In 2015, another SCN population was detected in fields and desig-

Continued on Next Page

nated as HG type 2.5.7 by experiments conducted by Dr. Yan's group at NDSU. HG type 2.5.7 is a more virulent form and reproduces well on PI 88788, the major resistance source in soybean. In this report, we describe an experiment conducted in Dr. Yan's laboratory where 37 commercial cultivars of dry bean were evaluated for resistance reactions to SCN HG type 2.5.7.

Objectives: The Northarvest Bean Growers Association has funded the research on resistance against SCN in dry bean. The main objective of this research is to identify dry bean varieties and breeding lines with resistance against SCN. In this report, 37 commercial varieties of dry bean were tested for reactions to SCN population HG type 2.5.7 to determine their levels of resistance to SCN.

Materials and Methods: In this study, 37 commercial varieties belonging to seven different market classes (Small Red/Pink, Slow dark pinto (SDP), Pinto, Navy, Black, Great Northern and Kidney) of dry bean were obtained from Dr. Osorno at NDSU. For every resistance evaluating experiment, there needs to be a susceptible check to compare the results with. In this experiment, soybean variety Barnes was used as the susceptible check as usual. The seeds of all the varieties were originally treated with different fungicides. To set up the experiment, seeds were first washed properly to remove the fungicides present on the seed surface. Then, the seeds were germinated for 6 days in individual petri dishes. On the 7th day, the seeds were planted in a growth chamber with controlled conditions. Each variety had four replicates and a single seed was planted in each cone-tainer pot containing pasteurized sandy soil. Each pot was inoculated with 2,500 eggs of HG type 2.5.7. The pots with plants were kept in the growth chamber to provide optimum growth condition for the nematodes. During the growing period, the nematode eggs hatched and second-stage juveniles invaded the roots of the growing plants. White female nematodes developed, became swollen and protruded from the roots. The plants were harvested after 40 days of growing period.

The roots were washed and white females were collected from roots and soil and then, observed and counted under a microscope for each replicate of each variety and the susceptible check Barnes. The basic principle for determining resistance is by measuring the rate of reproduction of the nematodes in each variety. For each dry bean variety, female index (FI) was calculated based on the formula, FI = (mean no. of white females produced on a test variety/ mean no. of white females on the susceptible check Barnes) x 100 %. Dry bean entries were then described by the numerical ratings and qualitative classifications; FI < 10%: Resistant (R), FI = 10-30%: Moderately Resistant (MR), 30 < FI ≤ 60%: Moderately Susceptible (MS), and FI > 60%: Susceptible (S).

Results and Discussion: The female index was calculated for each variety using the formula mentioned earlier. Different observations were made using the FI data for each variety. Smaller FI values indicate lower SCN reproduction.

The results showed that the average FI of different market classes ranged from 24.8% to 48.7%. By market class, Kidney had the highest FI of 48.7 while Small Red/Pink had the lowest FI of 24.8 and others ranked in between **(Figure 2)**. The FI of the 37 varieties within all the

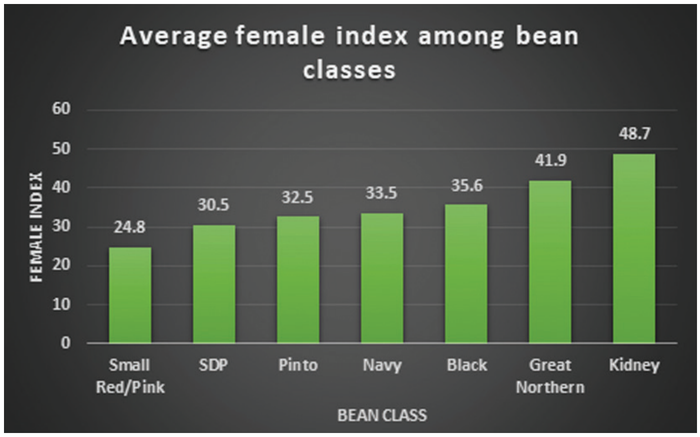

Figure 2. The average female index among different market classes of dry bean, from left to right: Small Red/Pink, Slow Dark Pinto (SDP), Pinto, Navy, Black, Great Northern and Kidney.

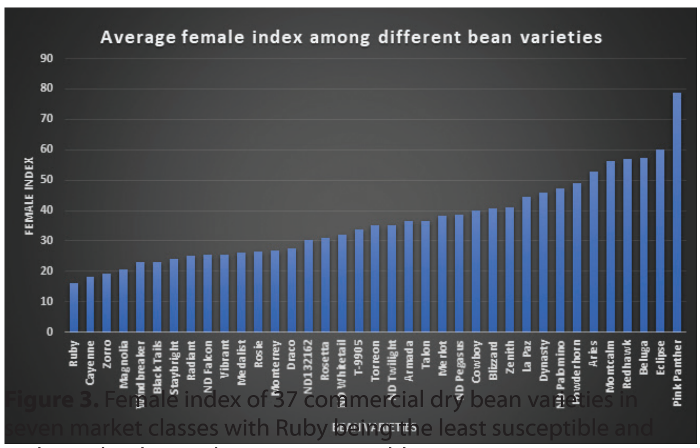

Figure 3. Female index of 37 commercial dry bean varieties in seven market classes with Ruby being the least susceptible and Pink Panther being the most susceptible.

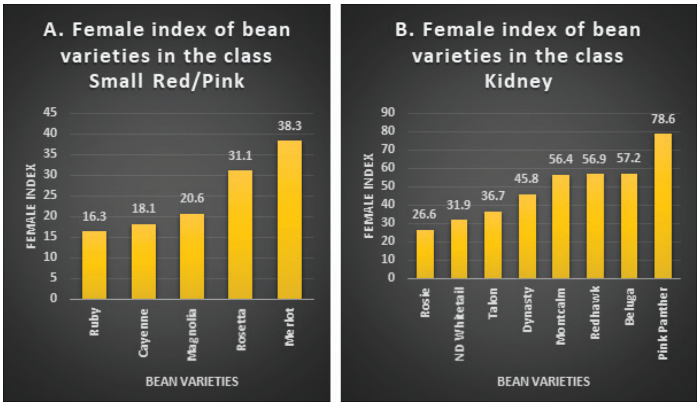

Figure 4. Female index of dry bean varieties in the class Small Red/Pink with the lowest average female index (A) and female index of varieties in the class Kidney with the highest average female index (B).

market classes varied from 16.3 to 78.6 **(Figure 3)**. The variety with highest FI was a kidney bean Pink Panther with FI as high as 78.6, and the variety with lowest FI was a Small Red/Pink bean Ruby with FI of 16.3 **(Figure 4)**. The results of this experiment indicated that none of the total varieties tested was resistant, 38% of the varieties were moderately resistant, 35% were moderately susceptible, and 27% were susceptible to SCN HG type 2.5.7 population based on the resistance rating system described above. There are other reported resistance rating systems in which these varieties may fall into different resistance categories, but the one used here is commonly used in many studies.

Other experiments are also being carried out for testing dry bean resistance levels to SCN population HG type 0. Emphasis is being given to test maximum dry bean germplasm for SCN resistance to develop promising breeding lines and varieties with improved resistance to SCN. The main problem for SCN management is the lack of above-ground symptoms in early growing seasons. Early detection of SCN is very important. Growers should sample the fields and send the soil samples out for SCN testing and scout white females (cysts) on plant roots. If SCN is detected then suitable management practices can be followed to reduce the egg levels in the soil. Growers can follow management practices like crop rotations and planting resistant or least susceptible varieties, and also can follow the NDSU dry bean production guide for more information on how to grow dry bean and deal with the SCN problem.

FROM THE ARCHIVES

1 YEAR AGO

Dry Bean Improvements for the Northern Plains — Each year, the NDSU dry bean breeding program evaluates genetic material from throughout the world. Breeder Juan Osorno conducts research at eight locations across North Dakota. In a recap of the 2019 growing season, Osorno said the beginning of the growing season started with normal conditions during the months of May and June. During flowering and pod filling stages, the most common disease observed common bacterial blight and white mold, while rust was detected at Hatton, ND at the end of the growing season. Heavy rainfall and even snowfall during harvest made difficult to timely collect the seed yield data and seed samples from field trials. Therefore, during the 2019 harvest season, 50 percent of the field trials and nurseries could not be harvested because of weather issues. Except for kidney beans in Minnesota, no selections were made for any of the remaining market classes and therefore, the same breeding material grown in 2019 will be repeated in 2020. Consequently, this will set back the program one-to-two years. On average, it is normal for the breeding program to lose either part or an entire location each year, but this is the biggest loss in the history of the program since its beginning in 1980.

White Mold Research — NDSU Carrington Research Extension Plant Pathologist Michael Wunsch highlighted the use of fungicide applications for the management of white mold in dry beans. The report said applying fungicides with medium droplets (black beans) or medium to coarse droplets (navy and kidney beans) optimized white mold management. Fine droplets, which optimize fungicide performance against foliar diseases that develop in the upper crop canopy, lack the velocity to penetrate dense canopies and conferred sub-optimal control of white mold.

Precision Planting of Dry Edible Beans — In general observations, the precision planter typically produced a more uniform and higher established plant stand but this did not translate into higher yields or better seed quality. Higher seeding rates tended to produce higher plant stands, but these increased stands also did not significantly enhance seed production. A benefit of higher seeding rates and narrow rows is enhanced crop competition with weeds. This is especially important in no-till or reduced tillage systems. Eric Eriksmoen, Research Agronomist, NDSU North Central Research Extension, was the principal researcher.

5 YEARS AGO

NCI to Use Dry Beans in Extruded Food Formulations — The Northern Crops Institute (NCI) would like to thank Northarvest Bean Growers Association for its financial contribution towards the purchase, installation and operation of a new Fluid Bed Dryer. The dryer is a vital component for the NCI's Wenger Twin Screw Extruder. NCI completed installation of its state-of-the-art Buhler OTW-50 Fluid Bed Dryer to complement NCI's Wenger twin screw extruder in November 2015. NCI has successfully produced a variety of quality snack food products through the use of superior food drying technology provided by the Buhler dryer. Dry edible beans are natural, low glycemic, gluten-free and nutrient-dense foods that provide healthy choices for consumers of extruded food products. Once again, NCI is grateful for the financial contribution from Northarvest Bean Growers Association. This contribution has allowed NCI to greatly improve its dry edible bean product development capabilities.

Dry Bean Grower Survey — The 26th annual survey of dry bean growers was sent out in the fall of 2015; however, the results were still being compiled when this Special Edition went to print. Results of the 2014 grower survey are included. A total of 171 growers responded to the survey, representing 13.2 percent of last year's total planted acreage. The two most popular varieties by class were:

- **Black:** 1.Eclipse 2. Zorro
- **Great Northern:** 1. Aries 2. Taurus
- **Kidney:** 1. Montcalm 2. Red Hawk
- **Navy:** 1. HMS Medalist 2. T 9905
- **Pinto:** 1. La Paz 2. Windbreaker

Nearly 74 percent of the growers who responded

Continued on Next Page

ranked excess water as their worst dry bean production problem in 2014. Weeds and diseases ranked as the second and third-worst production problems, respectively. Sixty-four percent of the growers said they direct harvested some of their edible beans last year, including 41 percent who said they direct combined all their dry beans.

Thanks to Growers for Research Plots — The support from the Northarvest Bean Growers Association, NDSU, and the North Dakota Dry Edible Bean Seed Growers Association (NDDEBSGA) has been fundamental for the longterm success of the dry bean breeding program at NDSU and the growers of the Northarvest region. Other funding agencies include USDAARS, USDA-NIFA, National Science Foundation (NSF), ND Department of Agriculture, and the United States Agency for International Development (USAID). Last but not least, we want to thank the following growers for allowing us to do research trials on their farms this year: Paul Johanning (Park Rapids,MN), Mark Dombeck (Perham,MN), Jim Karley (Johnstown,ND), Brian Schanilec (Forest River,ND), Tim Skjoiton (Hatton,ND), and Mark/Jim Sletten (Hatton,ND)

10 YEARS AGO

No Substitute for Quality Research — In the Starting Point column, Northarvest Research Committee Chair Brian Love said there is no substitute for quality research. "U.S. Commerce Secretary John Bryson recently presented a report to Congress on the importance of basic research, saying the competitive position of the United States in the world has eroded because of its failure to invest in research, infrastructure and education. Despite the current budget challenges, Bryson encouraged Congress to make research a higher priority issue. The Northarvest Bean Growers Association supports research. It is a priority for our future success."

Dry Bean Improvements Across the Northern Plains — NDSU Dry Bean Breeder Juan Osorno recapped the 2011 season. Similar as in the previous year, the growing season started with a cool and wet spring. The early rains during May and June flooded several trials. Most of them had a successful recovery with the exception of the trials planted at Prosper, which were lost due to flooding. High moisture also produced high pressure of bacterial diseases, especially bacterial brown spot. Seed corn maggots destroyed several trials at Hatton during emergence and establishment. Trials at Carrington were significantly affected by hail in two instances. Nonetheless, plants survived and seed yields were not affected significantly. Harvest season was very dry which allowed a good steady harvest activity. Seed coat darkening was not as critical as in previous years.

15 YEARS AGO

Dry Bean Breeding Research Report for 2006 — Dr. Kenneth Grafton and Dr. Juan Manuel Osorno cooperated on this report. A total of 1512 test plots of advanced and preliminary yield trials were harvested. In advanced yield trials 48 pinto, 14 navy, 12 black and 20 great northern and red bean lines were tested. After many evaluations in several trials in and out of North Dakota, 2 pinto experimental lines are being considered for prerelease next summer. Further steps: 15 elite pinto lines will be increased and screened for diseases at NDSU greenhouse facilities. Anti aging (seed coat color) pinto material from Idaho will be tested and include as a parent in our crossing block.

Resistance to White Mold in Dry Beans — The objectives of this research are to identify new sources of resistance to white mold and to incorporate that genetic resistance into the breeding program. In previous work, potential new sources of resistance to white mold were identified in dry bean lines from Mexico, Central America, and South America. Those lines were crossed with a susceptible cultivar adapted to this region (Othello) and progeny of these crosses were developed into recombinant inbred (RI) populations that would segregate for reaction to white mold. Those populations were analyzed in the greenhouse and in the field to identify parents for the breeding program. The experiments suggest that genetic resistance to white mold is controlled by multiple genes but is heritable.

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