**Project FY22-DU-006:** Recurrent Selection to Improve FHB Resistance in Durum Wheat

Note: Report must cover the *entire* duration of the project period of performance, May 1, 2022-July 30, 2026.

1. **What are the major goals and objectives of the research project?**
   The objectives of this project are to (1) improve FHB resistance through recurrent phenotypic selection in a durum wheat population and (2) develop genomic selection (GS) models and utilize GS to accelerate genetic improvement of FHB resistance in durum wheat.

2. **What was accomplished under these goals or objectives?** *(For each major goal/objective, address these three items below.)*
   **What were the major activities?**

   *Objective 1: improve FHB resistance through recurrent phenotypic selection*

   1. From May 2022 to August 2024, two cycles of phenotypic selection (PS-C3 to PS-C5) were conducted, with one cycle per year (Table 1).

   *Objective 2: develop GS models and utilize GS to accelerate improvement*

   1. **Develop and validate genomic prediction models**: GS models for FHB disease index, plant heigh, and days to flowering were developed and validated using the PS-C3, PS-C4, and PS-C5 populations as training population.
   2. **Conduct two cycles of GS**: Two cycles of GS (GS-24SD and GS-25JA) were conducted from September 2024 to April 2025 (Table 1). Within each GS cycle, 190 plants were genotyped using a 40K SNP array. Based on genomic estimated breeding values (GEBVs), the top 40 plants were selected. The GS-selected plants were intermated and self-pollinated.
   3. **Evaluate GS effectiveness**: The 20 PS-C6 $S_o$:$_1$ lines, 40 GS-24SD $S_1$:$_2$ lines, and 44 GS-25JA $S_o$:$_1$ lines were evaluated in field nurseries at Fargo and Prosper, ND, from May to August 2025 to assess the effectiveness of GS.
   4. **Update genomic prediction models and develop prediction model for DON:** The top 20 lines based on the 2025 field evaluation were selected and intermated in the greenhouse using their remnant seeds from September to December 2025. A total of 200 $S_o$ seeds produced from the intermating were planted and self-pollinated from January to April 2026. A total of 193 $S_o$:$_1$ lines resulting from self-pollination, designated as the PS-C7 population, were evaluated in field nurseries at Fargo and Prosper, ND, from May to August 2026. The 193 $S_o$ parents were genotyped using genotyping-by-sequencing (GBS). GS models for FHB disease index, plant height, and days to flowering will be updated by incorporating data collected from the 193 lines evaluated in 2026. All 193 lines were harvested, and DON content will be tested from September to December 2026. A GS model for DON content will then be developed and validated.

Table 1. Phenotypic selection (PS) and genomic selection (GS) for FHB resistance in the durum wheat population from May 2022 to August 2026.

| Year | Month | PS/GS cycle | # of lines or plants | Activity |
|---|---|---|---|---|
| 2022 | May-Aug | PS-C3 | 132 $S_{0:1}$ lines | Phenotyped the 132 $S_{0:1}$ lines at Fargo and Prosper, ND, and selected the top 20 lines. |

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|---|---|---|---|---|
| 2022 | Sep-Dec | PS-C4 | 180 $S_1$ plants | Planted 180 $S_1$ remnant seeds from the 20 selected $S_{0:1}$ lines and intermated the resulting $S_1$ plants. |
| 2023 | Jan-Apr | PS-C4 | 200 $S_0$ plants | Planted 200 $S_0$ seeds from the intermating and self-pollinated the resulting $S_0$ plants. |
| 2023 | May-Aug | PS-C4 | 196 $S_{0:1}$ lines | Phenotyped the 196 $S_{0:1}$ lines at Fargo and Prosper, ND, and selected the top 20 lines. |
| 2023 | Sep-Dec | PS-C5 | 180 $S_1$ plants | Planted 180 $S_1$ remnant seeds from the 20 selected $S_{0:1}$ lines and intermated the resulting $S_1$ plants. |
| 2024 | Jan-Apr | PS-C5 | 200 $S_0$ plants | Planted 200 $S_0$ seeds from the intermating and self-pollinated the resulting $S_o$ plants. |
| 2024 | May-Aug | PS-C5 | 139 $S_{0:1}$ lines | Phenotyped the 139 $S_{0:1}$ lines at Fargo and Prosper, ND, and selected the top 20 lines. |
| 2024 | Sep-Dec | PS-C6<br>GS-24SD | 190 $S_1$ plants<br>40 $S_{1:2}$ lines | Planted 190 $S_1$ remnant seeds from the 20 selected $S_{0:1}$ lines; genotyped the resulting $S_1$ plants; and selected the top 40 $S_1$ plants. Intermated and self-pollinated the 40 GS-selected $S_1$ plants. |
| 2025 | Jan-Apr | GS-24SD<br>GS-25JA | 190 $S_0$ plants<br>44 $S_{0:1}$ lines | Planted 190 $S_0$ seeds from the intermating; genotyped the resulting $S_0$ plants; and selected the top 44 $S_0$ plants.<br>Self-pollinated the 44 GS-selected $S_0$ plants. |
| 2025 | May-Aug | PS-C6<br>GS-24SD<br>GS-25JA | 20 $S_{0:1}$ lines<br>40 $S_{1:2}$ lines<br>44 $S_{0:1}$ lines | Phenotyped the 20 PS-C6 $S_{0:1}$, 40 GS-24SD $S_{1:2}$, and 44 GS-25JA $S_{0:1}$ lines at Fargo and Prosper, ND, and selected the top 20 lines. |
| 2025 | Sep-Dec | PS-C7 | 180 $S_1$ or $S_2$ plants | Planted 180 $S_1$ or $S_2$ remnant seeds from the 20 selected $S_{0:1}$ or $S_{1:2}$ lines and intermated the resulting $S_1$ or $S_2$ plants. |
| 2026 | Jan-Apr | PS-C7 | 200 $S_0$ plants | Planted 200 $S_0$ seeds from the intermating and self-pollinated the resulting $S_0$ plants. |
| 2026 | May-Aug | PS-C7 | 193 $S_{0:1}$ lines | Phenotyped the 193 $S_{0:1}$ lines at Fargo and Prosper, ND, and selected the top 30 lines. |

**What were the significant results?**

*Objective 1: improve FHB resistance through recurrent phenotypic selection*

1. The durum wheat recurrent selection program for FHB resistance was initiated in 2019. Three cycles of phenotypic selection (PS-C0 to PS-C3) were conducted from May 2019 to April 2022. During the project period, two additional cycles of phenotypic selection were completed (PS-C3 to PS-C5) from May 2022 to August 2024. The FHB disease index decreased from 71.2% in PS-C0 to 59.8% in PS-C1, 56.7% in PS-C2, 52.0% in PS-C3, 48.7% in PS-C4, 52.1% in PS-C5.
2. In the 2024 field evaluation, 11 $S_{0:1}$ lines from the PS-C5 population exhibited significantly lower FHB disease indices than the check cultivar ND Riveland. Five of these 11 lines were sampled and evaluated for deoxynivalenol (DON) concentration, and two lines had significantly lower DON levels than ND Riveland.

*Objective 2: develop GS models and utilize GS to accelerate improvement*

1. GS models were developed and validated with prediction accuracies of 0.53 for the FHB disease index, 0.53 for plant height, and 0.77 for days to flowering.
2. Two cycles of GS were conducted. Based on field evaluations at Fargo and Prosper, ND, in 2025, both GS cycles showed lower FHB disease index than the 20 lines from the PS-C6 population, demonstrating the effectiveness of GS.
3. Further genomic selection and phenotypic selection reduced the FHB disease index from 52.1% in PS-C5 to 42.8% in GS-24SD, 41.8% in GS-25JA, and 35.7% in PS-C7.
4. In the 2025 field evaluation, 38 of the 84 lines from the GS-24SD and GS-25JA populations showed significantly lower FHB disease index than the check cultivar ND Riveland. Among these, 14 lines had lower DON concentrations than ND Riveland.
5. In the 2026 field evaluation, 142 of the 193 lines from the PS-C7 population showed significantly lower FHB disease indices than ND Riveland. Samples from these lines are currently being evaluated for DON concentration.

**List key outcomes or other achievements.**

*Objective 1: improve FHB resistance through recurrent phenotypic selection*

1. Recurrent phenotypic selection progressively improved the FHB resistance.
2. Numerous lines from the advanced populations were identified with significantly lower FHB disease index and DON content than the check cultivar ND Riveland.

*Objective 2: develop GS models and utilize GS to accelerate improvement*

1. Genomic prediction models for FHB disease index, plant height, and days to flowering were developed, and two cycles of GS demonstrated the effectiveness of genomic selection.
2. In the 2025 field nurseries, root diseases may have caused overestimation of FHB disease index and biased selection for FHB resistance.
3. In addition to enhancing selection efficiency by shortening the selection cycle, GS can reduce the effects of environmental variation on selection and improve the accuracy of selection for FHB resistance.

**3. What opportunities for training and professional development has the project provided?**

All graduate and hourly students participated in inoculation and disease scoring activities in both greenhouse and field nurseries, providing valuable hands-on training in phenotypic evaluation of FHB resistance. In addition, graduate students received training in phenotypic selection, marker genotyping, genomic prediction modeling, and genomic selection. Graduate students attend the National FHB forum.

**4. How have the results been disseminated to communities of interest?**

The results were shared with wheat breeders and research scientists through personal communications and presentations/posters at the annual FHB Forum.

**5. What do you plan to do during the next reporting period to accomplish the goals and objectives?**

Not applicable, this is the final report for the agreement.