Project FY22-HW-004: Developing Winter Wheat Varieties with Enhanced Resistance to FHB for South Dakota

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1. **What are the major goals and objectives of the research project?**
   Our primary goal is to develop and release new superior winter wheat varieties with enhanced resistance to FHB and reduce fungal mycotoxins, primarily deoxynivalenol (DON) to limit the loss of grain yield and quality. The specific objectives of this proposal are 1) to develop FHB-resistant and low DON winter wheat varieties for South Dakota and surrounding regions; (2) pyramiding major and minor genes for FHB resistance by developing and implementing phenotypic and genomic selection models for SDSU winter wheat program.

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

   What were the major activities?
   More than 100 crosses were performed to combine FHB resistance including Fhb1, Fhb6, and native sources of resistance to FHB into South Dakota breeding materials. Nearly 80 populations were advanced $F_{2:3}$ using speed breeding of mini bulks and 45 $F_{2:4}$ mini bulk from the last season are being selected in the field.

   Breeding lines and released cultivars from other public and private breeding programs were evaluated in a locally grown mist-irrigated and inoculated FHB field nursery. These nurseries include the South Dakota Crop Performance Testing nursery (CPT), and Hard Winter Wheat FHB nursery (Public and Private). State Variety/Crop Performance trials (with and without fungicides at Brookings) were conducted to determine the impact of FHB on different varieties and elite lines.

   Evaluation of genome-wide selection models was performed along with the development of high throughput phenotyping-based machine learning models for FHB using RGB/NIR/ hyperspectral imaging, for disease incidence, FDK, and DON content.

   What were the significant results?
   Data was collected on 46 Elite, and 126 Advanced Yield Trial entries from the SDSU winter wheat breeding program in mist-irrigated FHB nurseries. Six SDSU advanced breeding lines ranked among the top 10 in Northern Regional Performance Nursery (NRPN) and three advanced breeding lines ranked in the top 10 in the SD State Variety Trials.

   The FHB disease ratings on regional germplasm in the Northern Hard Winter Wheat FHB Public and Private Nurseries and South Dakota CPT are made available to South Dakota producers, and colleagues at other participating institutions and private industries.

   We evaluated 243 advanced breeding lines from the SDSU wheat breeding program for DON content and performed hyperspectral imaging of the meal samples. We evaluated

three conventional machine learning (ML) models and two deep learning (DL) models along with data augmentation. Among the conventional ML models, Partial Least Squares regression (PLSR) (with $R^2P=0.88$ and $R^2P=0.90$ for original and augmented datasets, respectively) demonstrated the highest prediction accuracies for DON content. However, the one-dimensional Convolutional Neural Network (1D-CNN) achieved the highest prediction accuracies ($R^2P=0.90$ and $R^2P=0.96$ for original and augmented datasets, respectively) as compared to all tested models and had the lowest error. In conclusion, the integration of advanced hyperspectral imaging with ML approaches exhibits significant potential for high-throughput and cost-effective estimation of DON content in wheat, thereby accelerating wheat breeding efforts for reduced DON levels.

List key outcomes or other achievements.

Advanced breeding line SD18B025-8 (HRW) ranked overall 1st in eastern and central SD state trials over 3 years and 3rd and 4th in the NRPN trials in 2022 and 2023, respectively. Demonstrating excellent yield potential, protein, and test weight, SD18B025-8 was released as 'SD Pheasant' in Fall 2023. It has a good resistance package for leaf rust and an average tolerance for FHB. 'SD Pheasant' was rated excellent for milling and baking quality and won the miller's choice 'Best of Show' award at the 2023 Wheat Quality Council meetings.

3. **What opportunities for training and professional development has the project provided?**
A graduate student (100%) and postdoc (partially 70%) supported through this grant. The research was presented at the National Association of Plant Breeders Annual Meeting, ASA, CSSA, and SSSA Annual Meeting National American Plant Phenotyping Network, and Plant Science Symposium at UNL.

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

FHB resistance ratings collected on released cultivars are made available to growers as a part of the annual South Dakota Crop Performance Testing Hard Winter Wheat report. Additionally, data collected from Northern Hard Winter Wheat FHB Public and Private Nurseries is shared with colleagues from both public and private breeding programs. The results from this project were shared through field days and articles in appropriate popular press sources, word of mouth, Twitter, brochures, and Extension press releases from the Agricultural Experiment Station.

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

We will continue to 1) develop FHB-resistant and low DON winter wheat varieties for South Dakota and surrounding regions; (2) to pyramid major and minor genes for FHB resistance by developing and implementing phenotypic and genomic selection models for the SDSU winter wheat program.