Treating Small Grains as a Cash Crop: stepping up small grain variety selection for Cornbelt farmers

Final report for LNC18-400

Project Type: Research and Education
Funds awarded in 2018: $199,817.00
Projected End Date: 09/30/2021
Grant Recipient: Practical Farmers of Iowa (PFI)
Region: North Central
State: Iowa
Project Coordinator:

Sarah Carlson
Practical Farmers of Iowa

Project Information

Summary:

Extended crop rotations, which kept living roots in the ground year round, were replaced in the 1960s by a short, "warm-season-only" system of corn and soybeans. This has resulted in increased nutrient pollution to surface waters leading to the hypoxic zone in the Gulf of Mexico and increased farmer dependence on purchased inputs like synthetic fertilizers and pest and weed control products. Although cover crops are critical to improving water quality, cover crops alone are not enough to sustain and improve the environmental quality and natural resource base on which agriculture depends because they are limited in their ability to break pest cycles and significantly reduce the need for synthetic fertilizers. Extended crop rotations do provide these additional benefits, making them crucial for soil and ecological health. These crop rotations additionally spread out labor throughout the year, enhancing the quality of life for farmers and repopulating communities due to more consistent labor demand. When small grains left the landscape in the 1960s, robust university breeding programs, extension efforts and farmer decision making tools shifted to focus on corn and soybeans only. Today corn and soybean farmers, along with their agronomists, use voluminous data to select high yielding seeds.

Our project - *Treating Small Grains as a Cash Crop: stepping up small grain variety selection for Cornbelt farmers* acts on the theory that small grains should have the same data-driven support as corn and soybeans and tests a technology platform to amplify the limited university small grains research that exists today. We created and trialed a genotype-by-environment prediction model that powers a public website and generates top performing small grain varieties based on a user's zip code. After this model was created, 10 farmers planted randomized, replicated trials with 2 small grain varieties, one recommended by the tool and one of their choosing. These farmers shared the results with other farmers through presentations and field days, fostering learning and excitement about small grains variety selection. University small grain breeders were convened throughout the project to share their data, increase collaboration, and leverage their work to more

farmers across the Midwest.

Project Objectives:

We propose to build a small grain decision-support tool for corn and soybean farmers, including organic producers, that will use a genetics by environment model calibrated with small grains variety trial data from around the Midwest to improve farmers' confidence in variety selection. The tool will then be validated and further calibrated by randomized, replicated, on-farm research trials evaluating performance of the top two varieties selected by the tool. This publicly available and easy to use tool will result in improved small grain yield performance and profitability of these soil health boosting crops by helping farmers select the right variety for their climate.

Introduction:

Today, farmers primarily plant soybean opposite corn across the Cornbelt (states with >1% of the national corn production are Iowa 18%, Illinois 17%, Minnesota 10%, Wisconsin 4%, South Dakota 4%, North Dakota 2% and others from 2006-2010 USDA NASS data), but this has not always been the case. Previous to the 1960s the common crop rotation in states that drain into the Upper Mississippi River Basin included corn, a warm-season crop, planted opposite cool-season grasses and legumes. But since the 1970s, soybean, a warm-season legume, has replaced cool season crops in the rotation. Previous to the 1970s, small grains like oats in Iowa and northern Illinois; winter wheat in central Illinois, Indiana and Ohio; and barley in Minnesota and Wisconsin dominated the landscape. Small grains were traditionally established as nurse crops for cool-season legumes like red clover and alfalfa. Other times, small grains were sole-seeded and followed by leguminous summer cover crops. Planted acres of red clover in 1969 were 251,512 acres across 12 states in the Cornbelt. Alfalfa was planted on over 13.7 million acres in those same states (USDA NASS 1959-69). Today, nearly 36.3 million acres of soybeans are grown in Illinois, Iowa, Indiana, Minnesota, Ohio, and Wisconsin, occupying much of the acres grown opposite corn (USDA NASS 1982-2012).

The move to corn and soybean rotations has had a negative impact on water quality, soil health, and greenhouse gas production. Because soybeans and corn are both warm season plants, every winter the ground is left bare and vulnerable to soil erosion and nutrient leaching for four or five months, one third to one half of the year. This is resulting in a water quality crisis. Agriculture accounts for over 70% of the nitrogen (N) and phosphorus (P) that enters the Gulf of Mexico via the Mississippi River, nutrients that have already created a nearly 5000-km2 low-oxygen, or "hypoxic," zone that threatens marine life in one of the nation's largest and most productive fisheries (White et al. 2014). Cover crops in corn and soybean rotations have been widely promoted for their critical role in improving water quality, but cover crops alone are not enough to sustain and improve the environmental quality and natural resource base on which agriculture depends because they are limited in their ability to break pest cycles and significantly reduce the need for synthetic fertilizers. Another benefit is that yields of crops grown in extended rotation are typically 10% higher than those of crops grown in simple grain crop monocultures, and as much as 25% higher in drought years (SARE Crop Rotations Web; Bennett et al., 2012). Extended crop rotations provide these additional benefits, presenting a low cost, high impact (multiple co-benefits) practice to adopt relative to other water quality and soil health interventions.

With 2018 predicted to be the fourth year in a solid streak of extremely low corn and soybean prices, there has been a groundswell of interest in revisiting these traditional rotation crops. However, a significant barrier for these farmers to reintroducing small grains into crop rotations in the Cornbelt is a dearth of research into small grains breeding and best practices. Farmers have requested more small grains cost share than PFI can accommodate with our funding for 3,650 acres over Iowa, Minnesota and Wisconsin, demonstrating not only the interest in growing small grains, but the need for additional support to do so profitably. When small grains left the landscape in the 1960s, robust university breeding programs, extension efforts and farmer decision-making tools shifted to focus on corn and soybeans only. Today corn and soybean farmers, along with their agronomists, use voluminous data to select high yielding seeds while small grains farmers do not benefit from such tools and resources they can use to continuously improve small grains production on their farms. Without these tools, small grains yields and quality lag behind market demands and create slim, risky profit margins. Furthermore, 80 farmers and researchers at an August 2018 small grains conference and research meeting PFI hosted in Ames, IA identified that even when information such as variety trial data is available, it is difficult to translate into appropriate decisions for their farm because no decision making tools exist to filter and translate data into a usable form.

Our project will amplify the small grains variety trial data that exists and create the decision tool that is lacking to improve the profitability to farmers and associated agricultural businesses. Lucia Gutierrez Chacon with other researchers tested mixed models as a predictive tool for small grains performance in different sets of mega-environments by relying on data from 35 location-years of wheat variety trials. They found that the models were highly predictive achieving great accuracy compared to collected field data (Lado et al. 2016). We intend to expand this model to other small grain varieties using variety trial data from throughout the Cornbelt. This model will generate best performing varieties for barley, oats, wheat (spring and winter), winter rye, and winter triticale based on the mega-environment, located through a zip code. Our hope is that through this process we can effectively leverage the small amount of breeding work currently funded in the Cornbelt to inform small grains decision making over a wider area and, through this collaboration, small grains researchers from the six states can identify breeding gaps and align research programs with farmer needs for maximum impact. With appropriate research support and decision support tools farmers will be able to grow small grains more profitably, therefore increasingly the viability of returning these crops to the landscape and realizing the many environmental and natural resources benefits they provide.

Previous SARE projects have looked at small grain production, such as “Optimizing yield, milling quality, and disease management in spelt and other heritage grain production in the mid-Atlantic,” and “Developing best management practice for growing grain suitable for malt in the Northeast.” However, no projects provide a variety selection tool for the NCR region as this proposal.

References:

1. Bennett *et al.* (2012) Biological Reviews 87: 52-71
2. Lado et al. 2016. “Modeling Genotype x Environment Interaction for Genomic Selection with Unbalanced Data from a Wheat Breeding Program.” Crop Sci. 56, pp. 2165-2179.
3. n.d. Building Soils for Better Crops 3rd Edition – Crop rotations. Web.

4. USDA NASS. (1959-69). Crops Harvested: 1969, 1964, 1959. Web.
5. USDA NASS. (1982-2012). Historical Highlights: 2012 and Earlier Census Years. Web.
6. White, M.J., Santhi, C., Kannan, N., Arnold, J.G., Harmel, D., Norfleet, L., Allen, P., DiLuzio, M., Wang, X., Atwood, J., Haney, E., and Vaughn Johnson, M. 2014. Nutrient delivery from the Gulf of the Mississippi River to the Gulf of Mexico and effects of cropland conservation. J Soil Water Conserv. 69(1), pp. 26-40.

Cooperators

- Dr. Lucia Gutierrez-Chacon (Researcher)

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  University of Wisconsin - Madison (1862 Land Grant)

Research

Hypothesis:

We will build a variety selector tool for small grains for each geographical region in the Midwest by modeling the genotype by environment interaction to group environments with similar raking of varieties and then predicting the performance of all varieties for a specific geographic region using well established mixed models developed by Dr. Gutierrez's group (Lado et al., 2016). We believe that due to large genotype by environment interaction that do not follow physical distances but is associated to environmental properties, this tool will predict better the performance of a line than using the information from the closest location regardless of the environmental conditions.

Materials and methods:

We coordinated small grain breeders from the North Central region housed at land grant universities to populate a central database with historical and on-going small grain variety trial information. Breeders provided ARS at Cornell variety trial results and added to the historical multi-environment variety testing trials available at the Triticeae Toolbox (T3) data base (https://triticeaetoolbox.org) to evaluate the performance of small grain varieties in the Midwest and to characterize the genotype by environment interaction among varieties.

The oat (Avena sativa L.) data used in this study were retrieved from publicly available T3/Oat database (https://triticeaetoolbox.org/oat/). A total of 3,051 genotypes (i.e. advanced inbred lines and released cultivars) were grown in 69 locations across 10 states (IA, IL, IN, MN, ND, NE, NY, OH, SD, and WI) from 1996 to 2020. These experiments were primarily from oat public breeders' regional evaluations, variety testing trails and regional nursery evaluations by public institutions. Most of the oat genotypes were evaluated for agronomic-, quality-, and disease-related traits. Of the 3,051 genotypes evaluated, nearly 1,152 genotypes were genotyped using different genotyping platforms such as GBS and Infinium chip sequencing. For the remaining genotypes, pedigree information was retrieved from the POOL and T3 database.

Estimating genotype x environment interaction and identifying mega-environments using biplot analysis requires two-way genotype environment tables. In this variety trial dataset, very few sets of similar lines were tested across all locations within a year, leading to highly unbalanced multi-year and multi-location data. Therefore, it is challenging to characterize genotype x environment interaction as well as to delineate mega-environments. To overcome this challenge, we are using GGE biplots (genotype main effect with genotype by environment interaction) to find groups of locations with similar ranking of the genotypes. Mean performance at each location was estimated by a linear mixed model across years for each location before building GGE biplots. Five mega-environments were identified in the Midwest for the oat dataset. At this stage, we are further working on characterizing GxE and identifying stable mega-environments for each state in the Midwest. The mega-environments were re-estimated in 2021 including historical information adding the latest 2019 and 2020 trial information. The historical dataset at T3 has been further curated to disambiguate location and trait information. Due to the loss of disease resistance of varieties that have been grown for a long period of time, grain yield and test weight were predicted with information from the latest five years and only the latest three years were used to predict crown rust diseases severity for all genotypes. This caused some changes in the mega-environmental conformation, but all the changes make agronomic sense. Discrete testing locations were transformed into regional mega-environments by using *ad-hoc* geographical information. Later, zip-codes in ND, SD, MN, IA, WI, and IL were assigned to the regional mega-environments. Finally, grain yield, test weight, and crown rust performance were predicted for a balanced set of genotypes for every mega-environment in the Midwest, and therefore, for every zip-code. These predictions were obtained by fitting a linear mixed model that borrows information from related genotypes using a relationship matrix based on both molecular marker information and pedigree information. This strategy overcomes the unbalanced nature of the dataset.

Bread wheat (Triticum aestivum L.) is basically divided into five different wheat classes such as hard red spring, hard red winter, soft red winter, soft white and soft red wheats. The majority of wheat produced in the midwestern region consists of soft- and hard red winter wheat classes. Therefore, the current project has been mainly focused on soft- and hard-red winter wheat type.

The wheat data used in this study were retrieved from publicly available T3/Wheat database (https://triticeaetoolbox.org/wheat/). For the evaluation of hard red winter wheat in the Midwest, a total of 1,123 lines were grown in 67 locations across six states (IA, KS, MN, ND, NE, and SD) from 2000 to 2018. These experiments were primarily obtained from varietal testing trails and regional nursery evaluations by public institutions. Most of these lines were tested for multiple-traits throughout the growing season such as days to heading, plant height, disease-pest severity scores, test weight, thousand grain weight, grain yield, and some quality traits such as protein content. Of these 1,123 lines evaluated, nearly 286 lines were genotyped using different genotyping platforms, and 3,121 consensus markers were generated from the consensus tool implemented in T3/Wheat.

Similarly, for the evaluation of soft red winter wheat across the Midwest, a total of 2,275 lines were tested in 43 locations across nine states (IL,IN, KS, MI, MO, NE, NY, OH, and WI) from 2000 to 2018. These experiments were also primarily obtained from varietal testing trails and regional nursery evaluations form public institutions. Most of these lines were tested for multiple-traits throughout the growing season such as days to heading, plant height, disease-pest severity scores, test weight, thousand grain weight, grain yield, and some quality traits such as protein content.

Out of 2,275 lines, 110 lines have marker information available. At this stage, we are working on retrieving pedigree information for these lines so that it can be used in the prediction model.

Research results and discussion:

At this phase, we have performed genomic predictions using our models on oats, hard red winter wheat and soft red winter wheat. For the remainder of this project we are going to be focused on refining our process and predictions for oats only. In the summer of 2020 we generated predictions for hard red winter wheat and soft red winter wheat. We originally focused on using the soft red winter wheat for on-farm trials, however, as noted above, we only had limited marker and pedigree information available for lines. Given that most farmers are using private, commercial varieties of soft red winter wheat, our predictions were not useful for their operations. While we anticipated this might be an issue, nonetheless we took the opportunity instead to pivot and focus on updating and refining the process for predicting oat varieties, given that pedigree and marker information for oats is more widely available. Going forward, we will still plan to incorporate predictions for wheat into our models and selector tool, however that will likely happen outside the scope of this grant period.

Lado B, Barrios PG, Quincke M, Silva P, Gutiérrez L. Modeling genotype× environment interaction for genomic selection with unbalanced data from a wheat breeding program. Crop Science. 2016;56(5):2165-79.

Vargas M, Crossa J, van Eeuwijk FA, Ramírez ME, Sayre K. Using partial least squares regression, factorial regression, and AMMI models for interpreting genotype× environment interaction. Crop science. 1999;39(4):955-67.

Yan W. Biplot analysis of incomplete two-way data. Crop Science. 2013 Jan 1;53(1):48-57.

Yan W. LG biplot: a graphical method for mega-environment investigation using existing crop variety trial data. Scientific reports. 2019 May 9;9(1):7130.

Research conclusions:

From this work we can clearly see the potential advantages that a decision tool can provide, however, we can also see that it continues to need to be calibrated. On-farm trials are essentially for ground-truthing our work and the 10 trials we performed indicate that the majority of the time, the farmer does choose a variety well suited to their operation. Cooperation from University breeders to submit data into the public T3 portal is also essential, as it will only serve to improve the performance of the model going forward. These type of open-source projects are only possible with public-facing small grain varieties and show the importance of public investment in improving small grains.

Participation Summary

10 Farmers participating in research

Project Activities

Design genetics by environment model that predicts small grain performance

10 farmer researchers conduct on-farm trials to test the tool varieties and provide data

to strengthen the model

Cooperators (farmer researchers) share project results

University small grains breeders share project results

University small grains breeders are better organized

5 interactions with food and beverage companies demonstrate the power of the tool to increase quantity and quality of small grains grown in the Cornbelt

Collect and enter small grains variety trial data into T3 online database.

Code and install a webpage that returns model results to the user for their location.

Educational & Outreach Activities

3 Curricula, factsheets or educational tools

10 On-farm demonstrations

1 Online trainings

2 Published press articles, newsletters

20 Webinars / talks / presentations

18 Workshop field days

2 Other educational activities: Small grain meet-ups in Iowa and Minnesota.

PARTICIPATION SUMMARY:

900 Farmers

120 Ag professionals participated

Education/outreach description:

Remaining education and outreach, not already reported in Project Activities:

Workshops and Field Days:

- Plagge, L. and A. Plagge. "Cover Crops from Start to Finish." PFI Field Day on August 6. 54 attendees.
- Wilcox, R. 2021. "Live from the Farm: Small-Grain Harvest and Post-Harvest Handling in the Little Sioux Valley." PFI Virtual Field Day on July 27. 18 attendees. 428 archived views on Youtube.
- Wedemeier, S. 2021. "Organic Small Grains and Relay-Cropping Soybeans, Barley and Rye." PFI Field day (limited attendance) on July 15. 14 attendees.
- Amundson, A. "Relay-Cropping Rye and Soybeans." PFI Field Day on July 13. 21 attendees.
- Linker, D. 2021. "Wheat and Oat Production with Clover." PFI Field day (limited attendance) on June 30. 18 attendees.
- Brannaman, N. 2021. "Wheat Production and Cover Crops." PFI Field day

(limited attendance) on June 24. 19 attendees.

- Larsen, M. 2020. "No-Till Oat and Rye Production." PFI Virtual Field Day on June 24. 63 attendees. 478 archived views on YouTube.
- Blair, A. 2020. "Growing High Quality Food-Grade Oats." PFI Virtual Field Day on August 11. 22 attendees. 334 archived views on YouTube.
- Moseley, J. 2020. "Wheat: A Gateway Crop to Soil Health, Resilience and More." PFI Virtual Field Day on August 13. 26 attendees. 468 archived views on YouTube.
- Smith, M. and K. Pecinovsky. 2020. "Oat Variety Trial and Evaluation --- Virtual Field Day." Albert Lea See Virtual Field Day. Jul. 7.
- Wendt, N. and C. Akin. 2020. "Flame Weeding and Crop Rotation for Weed Control" PFI Virtual Field Day. Jun. 30. 33 attendees. 699 archived views on Youtube.
- Brunsman, W. 2019. "Using Small Grains to Protect Your Bottom Line" PFI field day. Jun 18. 47 attendees.
- Cramer, D. 2019. "30 Years of Small Grains and No-Till on an Ohio Farm" PFI field day. Jun. 26. 15 attendees.
- Bhatta M. and L. Gutierrez. 2019. "Variety selector tool for small grains farmers and breeders." Industry Field Day on August 09, Madison WI.
- Bhatta M. and L. Gutierrez. 2019. "Variety selector tool for small grains in the Midwest." Small Grains Field Day on July 15, Arlington WI.

Webinars, Talks and Presentations:

- Becker, J. 2021. "Hybrid rye production and use in swine rations" PFI shared learning call Jul. 2. 7 attendees.
- Wiersma, J. 2021. "Management for Fusarium in Small Grains." PFI shared learning call. Feb. 5. 22 attendees.
- Frederick, B. 2021. "Entrepreneurial Opportunities With Seed Cleaning Small Grains" PFI shared learning call. Jan 8. 43 attendees.
- Schwinke, C. 2020. "Profitably Selling Wheat to Milling Markets." PFI small grains conference. Mar. 5. 14 attendees.
- Gentry, L. 2020. "Minimizing Nutrient Loss by Diversifying Crop Rotation." PFI small grains conference. Mar. 5. 32 attendees.
- Harper, J. 2020. "Illinois Soft Wheat Milling Market: Advantages and New Opportunities." PFI small grains conference. Mar. 4. 18 attendees.
- Bishop, D. 2020. "Increasing Profitability on Small Grain Acres with Cover Crops and Livestock." PFI small grains conference. Mar. 4. 32 attendees.
- Stein, H. and M. McGhee. 2020. "Experience Feeding Barley and Hybrid Rye to Pigs." PFI small grains conference. Mar. 5. 10 attendees.
- Franzen, D. 2020. "Small Grains Fertility." PFI shared learning call. Feb. 7. 26 attendees.
- Madsen, V. and M. Krieger. 2020. "The Role of Small Grains in Organic Transition." PFI shared learning call. Mar. 6. 16 attendees.
- Duley, C. 2019. "Bringing Malting Back to Western Wisconsin." PFI small grains conference. Aug. 15. 13 attendees.
- Wepking, H. and J. Wepking. 2019."Market Development and Grain Handling

for Artisan Grain Products." PFI small grains conference. Aug. 16. 14 attendees.
- Lammers, P. 2019. "Evaluating Oat Varieties for Feed." PFI small grains conference. Aug. 16. 10 attendees.
- Walsh, A. 2019. "Production of Small Grains for Seed Markets." PFI small grains conference. Aug. 16. 22 attendees.
- Graham, A. 2019. "What's winter farming all about? Small Grains Production and Marketing" PFI small grains conference. Aug. 15. 12 attendees.
- Byamukama, E. 2019. "Small Grains Disease Management for Maximum Return." PFI annual conference. Jan. 18. 21 attendees.
- Wiersma, J. 2019. "Growing High-Yielding Hybrid Rye and Other Winter Small Grains." PFI annual conference. Jan. 19. 44 attendees.

Published press articles/newsletters:

- In November of 2021, Practical Farmers of Iow published a blog "Considerations for choosing the right oat variety" featuring the selector tool. The blog includes a video tutorial for using the tool.
- In February 2020, Successful Farming published an article "Oats Find a Fit" featuring information on the tool.
- In December 2019 PFI's small grains newsletter featured a short article on the project.

Meet-ups:

- "Oat Meet-up." North central Iowa. February 2020. 21 attendees.
- "Oat Meet-up." Southern Minnesota. February 2020. 20 attendees.

Learning Outcomes

92 Farmers reported changes in knowledge, attitudes, skills and/or awareness as a result of their participation

Key areas taught:

- Small grain production and variety selection

Project Outcomes

10 Farmers changed or adopted a practice

Key practices changed:

- Tried a new oat variety

- Added oats to their rotation

1 Grant applied for that built upon this project

1 Grant received that built upon this project

2 New working collaborations

Success stories:

A row crop farmer from Central Iowa stated "We are looking to move to a three crop rotation + hay, with oats being a good candidate for the third cash crop. I would like to increase yield while improving quality to sell for milling. This [research trial] will help to determine viability of that plan."

After participating in the on-farm research trial funded by this work, this farmer is looking to continue to do on-farm research with PFI and will continue to fine tune adding oats into their rotation.

Information Products

- Oat Selector Tool Trial 2021 (Article/Newsletter/Blog)
- Oat Selector Tool Trial 2020 (Article/Newsletter/Blog)