Grant Code: AN7055
Title: Development of resistant wheat cultivars for management of Hessian fly in Idaho
Personnel: Steve Odubiyi, Laboratory Coordinator/Manager; Sanford Eigenbrode, Professor of Entomology; Johnny Li, Assistant Professor of Soil and Water Systems
Address: Steven Odubiyi, Dept. of EPPN, University of Idaho, Moscow, ID 83844-2329; 208-301-4956; stevenodubiyi@uidaho.edu

Justification/Rationale: Hessian fly resistance is an important trait in breeding program for the Pacific Northwest's spring and winter wheat varieties. Yield reductions due to Hessian fly infestation of spring wheat was estimated to be up to 24% in the absence of resistance (Smiley et al. 2004). Based on this and current yields, acreage and wheat prices, Hessian fly resistance in Idaho can be valued at up to $4M annually. Widespread economic losses in Idaho and in the PNW have not occurred in recent years primarily due to effective Hessian fly resistance in many of the most widely planted and highest-yielding spring wheat varieties. The UI variety Jefferson, and WSU's Louise, Diva, Whit, Glee, and Kelse are soft white and hard red spring Hessian fly resistant wheat varieties that are widely planted in the PNW. Other important UI varieties with resistance to Hessian fly include Jerome and Cataldo, which are hard red and soft white spring wheat respectively. Since the appearance of Hessian fly in Treasure Valley in 2015 and the alarming increase in their infestation levels in winter wheat (including a November 2021 report in volunteer wheat in the Treasure Valley), there is a need for developing new varieties that have Hessian fly resistance that are suitable for planting under Snake River Plain agroecological conditions. Warmer falls in recent years might have contributed to the higher incidence of Hessian fly in winter wheat. As such, screening for Hessian fly resistance in the PNW winter wheat and barley germplasm is now crucial. Our laboratory assays in 2020 found that the wheat cultivar Milie is resistant to Hessian fly. In 2023 we continued our screening efforts in winter wheat and barley in collaborations with researchers from the WSU breeding program and found the two winter wheat cultivars Canvas and Battle AX, and barley cultivars KWS Fantex, LCS Diablo, and 20WAM-721.1 are resistant to Hessian fly. Due to the existence of virulence against the *H3* resistant gene and other genes in Idaho Hessian fly populations (Ratcliffe et al. 2000), the utilization of multiple genes for resistance is important. Our screening program relies on a Hessian fly colony established from flies collected in Idaho and the PNW some years ago. If new genetic variants of the fly have established in the region, the validity of our screening method could be jeopardized. This project will collect Hessian flies from several sites in the region, establish colonies from these flies and test them against a panel of Hessian fly-resistant and susceptible wheat lines. The result will either verify that our standard colony is representative, or it will indicate a need to develop a new Hessian fly colony for screening. Finally, our 2023 finding that wheat seedlings are susceptible at least to the third node indicates a need to establish whether known Hessian fly resistant lines maintain effective resistance to that growth stage with implications for stable plant protection through host plant resistance. Based on the existing economic damage estimates and continued prevalence of the damaging Hessian fly in Idaho, the return on investment to Idaho grower if the project is funded will be substantial.

Objectives:
1. Screen segregating wheat and barley populations and advanced breeding lines for resistance to Hessian fly in the laboratory (continuous)

2. Assist the breeding program in the development of effective molecular markers for Hessian fly resistant genes (continuous).
3. Quantify severity of Hessian fly infestations on, highly resistant, moderately resistant, and susceptible wheat cultivars at four developmental stages (new, single year)
4. Survey, collect and establish wild Hessian fly populations and test them against known differential wheat panels (new)
4. Develop low-altitude aerial hyperspectral imaging for monitoring/detection purposes (second year).

Methods/Plan of work: Screening will take place at the Manis Entomological Laboratory in Moscow, Idaho. Genotypes to be tested are from various market classes of both winter and spring wheat. Incorporation of Hessian fly resistance into adapted germplasm will be a continuing effort. Focus will be on a diversity of genes. Mapping populations will be screened to assist in the development of molecular markers to expedite breeding efforts. Wheat lines will be seeded in pots and placed in cages at the two-leaf stage and exposed to Hessian fly females to lay eggs for 24 hours, Response of plants to larval infestations will be evaluated 21 days later Plants will be dissected and the number of Hessian fly larvae and puparia per plant determined. Measurements of plant height will be taken twice, one-day and 21-days after infestation. Severe stunting is an indication of fly susceptibility. The number of resistant and susceptible plants per entry will be recorded (Obj., 1 & 2). To address Obj. 3, selected highly resistant, moderately resistant, and susceptible lines will be subjected to the same procedure as in Obj. 1 & 2, but exposed to the flies at one-, two-, three-, and four-leaf stages. Plants will be evaluated for the number of Hessian fly larvae and puparia per plant. The information will help to understand the effect of planting date on Hessian fly infestations in the field. To address Obj. 4, Hessian fly populations will be sampled and collected from commercial fields in Idaho and Washington, mass reared and established into new colonies, which will be tested against known wheat differential panels. Priority will be given to flies from fields where resistance to the fly is suspected to have partially broken down. Objectives 1-4 will be performed by Odubiyi and Eigenbrode. For remote sensing of Hessian fly, in Objective 5 we will build on last year's finding to improve the multispectral imaging quality and the effectiveness of our neural network-based wheat plant leaf pixel segmentation and vegetation indices computing. Variety Alturas will be planted into trays, grown in the greenhouse and exposed to Hessian fly following standard protocols. Imaging will be conducted out of doors to remove the greenhouse indoor lighting effects to assess multispectral imaging under field conditions. For comparison we will impose other stresses: acid soil, drought and heat to develop a robust algorithm to discriminate Hessian fly injury from these other stresses, a necessary step for scaling up to field detection of fly infestations.

Duration: 3 years: 2023-2026; Year 2 of 3

Cooperation/Collaboration/Complementation: UI: J. Chen, K. Schroeder; WSU: M. Pumphrey, C. Neely, A. Carter. This project supports ongoing publicly funded wheat breeding projects at Washington State University and the University of Idaho. The work supports the entire wheat production industry where the Hessian fly poses a threat but does not directly complement other ongoing activities of private industry.

Anticipated Benefits, Expected Outcomes and Impacts, and Transfer of Information: The results of this ongoing work have been crucial in enabling breeders to maintain effective Hessian

fly resistance in new wheat varieties that are agronomically suitable for Idaho as they are released. The project will provide information on the effectiveness of currently deployed fly resistance genes that is needed to enhance sustainable management of Hessian fly. Research results will be made available to growers through presentations at grower meetings and through extension publications. In addition, this year's Hessian fly surveys will ensure the establishment of Hessian fly populations that represent the fly biotypes across Idaho.

Literature Review: The Hessian fly is a severe pest known to be present in all major wheat growing areas of the US, including the PNW (Ratcliffe and Hatchett 1997). Feeding by fly larvae on the wheat plant results in stunting and weak stems/lodging, which reduces yield and is detrimental to grain quality. In northern Idaho, there are at least two generations of Hessian fly per year; one in the spring and one in the early summer (Castle del Conte et al. 2005). Hessian fly population from Idaho and Washington contained one or more of the virulent biotypes D-H, J, and L-O; however, only biotypes E, F, and G occurred at frequencies greater than 12%. The avirulent biotype GP made up 25-57% of Idaho and Washington populations (Ratcliffe et al. 2000). The Hessian fly was found in the Treasure Valley for the first time in 2015. Adult flies emerge from infested cereal stubble or wild hosts in the spring. Insects mate and females lay 200 to 300 eggs on leaves of young cereal plants. Once eggs hatch, larvae migrate to the crown of the young seedlings where they feed on plant sap. In approximately 2 to 3 weeks larvae form puparia (or "flaxseeds"). Larvae survive the summer within puparia or dry stubble. The puparia stage allows survival during adverse weather conditions in both summer and winter (Ratcliffe and Hatchett 1997). Resistant varieties are the most reliable means for Hessian fly control (Ratcliffe et al. 2000, Schotzko and Bosque-Pérez 2002). To date, thirty-seven genes for resistance have been identified (Li et al, 2013; Zhao et al., 2020, Carter et al. 2014). Field survey conducted in Tunisia revealed that Hessian larvae are found on wheat plants at different growth stages (Amira et al.2020). Utilization of multiple genes for resistance coupled with the enhancement of existing natural enemies has the potential to improve durability of resistance. Planting date modifications to escape infestation (e.g., early seeding of spring wheat), destruction of volunteer wheat, and crop rotation are also considered valuable Hessian fly management strategies.

References

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Carter, A.H., S.E. Cambron, H.W. Ohm, N.A. Bosque-Pérez, and K.K. Kidwell. 2014. Hessian fly (*Mayetiola destructor* [Say]) resistance identified on chromosome 1AS in the spring wheat (*Triticum aestivum* L.) cultivar 'Louise'. Crop Science. 54: 1-11.

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Zhao, L., Ragab, N. A., Xu, Y., Chen, M.. S., Feng, Y., Kong, L., et al. (2020). Identification of two novel Hessian fly resistance genes H35 and H36 in a hard winter wheat line SD06165. Theor. Appl. Genet. 133, 2343-2353

FY2025
COMMODITY COMMISSION BUDGET
Principal Investigator: *Steven Odubiyi*

Allocated by Idaho Wheat Commission *(Commission/Organization)*	during FY2023	$	19,998
Allocated by Idaho Wheat Commission *(Commission/Organization)*	during FY2024	$	23,082

REQUESTED SUPPORT: Budget Categories	*Awarded for FY2024*	*Requested for FY2025*
(10) Salary *(staff, post-docs, et NOTE: Faculty salary/fringe NOT allowed*	$ -	$ -
(12) Temporary Help/IH	$ 17,800	$ 18,000
(11) Fringe Benefits	$ 1,497	$ 1,494
(20) Travel	$ 1,720	$ 1,376
(30) Other Expenses	$ 2,065	$ 2,025
(40) Capital Outlay >$5k	$ -	$ -
(45) Capital Outlay <$5k	$ -	$ 6,000
(70) Graduate Student Tuition/Fees	$ -	$ -
TOTALS	$ 23,082	$ 28,895

TOTAL BUDGET REQUESTED FOR FY2025:	$ 28,895

BREAKDOWN FOR MULTIPLE INDEXES:

Budget Categories	*(Insert Co-PI Name)*	*(Insert Co-PI Name)*	*(Insert Co-PI Name)*	*(Insert Co-PI Name)*
(10) Salary *(staff, post-docs, et*	$ -	$ -	$ -	$ -
(12) Temporary Help	$ -	$ -	$ -	$ -
(11) Fringe Benefits	$ -	$ -	$ -	$ -
(20) Travel	$ -	$ -	$ -	$ -
(30) Other Expenses	$ -	$ -	$ -	$ -
(40) Capital Outlay >$5k	$ -	$ -	$ -	$ -
(45) Capital Outlay <$5k	$ -	$ -	$ -	$ -
(70) Graduate Student Tuition/Fees	$ -	$ -	$ -	$ -
TOTALS	$ -	$ -	$ -	$ -
			Total Sub-budgets	$ -

IWC CAPITAL OUTLAY REQUEST
Outline

Request: Microscope and Multispectral Tarp and Controller

Amount (IWC): $6000 Total Amount: $5000

Party(ies) making request: Steven Odubiyi (PI)

Contact information: Steven Odubiyi, Dept. of EPPN, University of Idaho, Moscow, ID 83844-2329; 208-301-4956; stevenodubiyi@uidaho.e

Description, Function, or Purpose:

1. Leica S9E dissecting microscope - $2500
2. Multispectral tarp for calibrating image capture ($2500) and controller ($1000) for imaging
    a. https://www.group8tech.com/multispectral-content

Justification:

1. *The microscope is required for counting Hessian fly eggs as part of routine screening. Currently, an aging scope shared with other programs is used for this purpose. The new microscope will ensure efficient and accurate counts are made. With servicing this instrument should be functional indefinitely.*
2. *The tarp and controller are required to enable accurate, calibrated image capture from infested and control wheat plants in this study. It is essential for the desired level of accuracy. After this year's greenhouse and microplot efforts, the equipment can be used to scale up the system for field level trials for detection.*

Timeline for purchase or implementation:

- As soon as funding is secured, the equipment will be purchase. There should be no delays from suppliers.

Collateral Expenses:

None are anticipated. The microscope will require professional servicing after several years and this will be arranged for and funded through indirect costs accruing to the insect pest management program of the co-PI (Eigenbrode)

Shared Funding:

NA

Ownership:

University of Idaho

Permanent Location of Item or Project:

Microscope – H.C. Manis Insect Host Plant Resistance Laboratory
Calibrating equipment – Laboratory of co-Investigator J. Li. IJ Iddings Building, UI Campus

What projects or researchers will use or benefit from the capital outlay?

Microscope – S. Odubiyi and S. Eigenbrode. With this purchase, the older microscope can be assigned for other, less exacting purposes at the H.C. Manis laboratory
Calibrating equipment – J. Li will oversee the use of this equipment. It can be employed to improve other remote sensing and imaging projects at the University.

ANNUAL REPORT

Grant Code: AN7055

Title: Development of resistant wheat cultivars for management of Hessian fly in northern Idaho

Personnel: Sanford Eigenbrode, Professor of Entomology, EPPN
Steve Odubiyi, Laboratory Coordinator/ Manager
Johnny Li, Assistant Professor, Soil and Water Systems
Patrick Hatzenbuehler, Assistant Professor, Extension Specialist
Jae Ryu, Associate Professor

Address: Sanford Eigenbrode, Dept. of EPPN, University of Idaho, Moscow, ID 83844-2329; 208-885-2972; Sanforde@uidaho.edu

Abstract:

The Hessian fly is one of the most destructive insect pests of wheat worldwide. Host plant resistance is the most effective and reliable control method for this pest. In Idaho and the PNW, Hessian fly-resistant spring wheat cultivars have been developed and are widely grown. Genes *H13, H22, H24*, *H26* and *H32* remain highly effective. This project maintains the only colony of Hessian fly representative of our region and conducts regular screening to ensure Hessian fly resistance is maintained in wheat varieties as they are developed and released. This year, we screened over 340 advanced wheat breeding lines and 13 barley lines for Hessian fly. It also confirmed that Hessian fly can attack and injure susceptible wheat plants past the initial seedling stage. To complement host resistance efforts, the project worked on remote sensing technology for Hessian fly. In greenhouse experiments a multispectral reflectance index was able to detect Hessian fly injury, indicating promise for this approach.

Background/Objectives:

1. Screen segregating populations and advanced breeding lines for resistance to Hessian fly in the laboratory (continuous)
2. Assist the breeding program in the development of effective molecular markers for Hessian fly resistant genes (continuous).
3. Quantify severity of Hessian fly infestations on susceptible wheat cultivars at four developmental stages (new, single year)
4. Develop low-altitude aerial hyperspectral imaging for monitoring/detection purposes (new).
5. Based on satellite imagery and economic analysis, update economic loss estimates for Hessian fly in Idaho (ongoing).

Results/Accomplishments:

Objectives 1 and 2 - Genotype screening

The Hessian fly colony established in our laboratory at UI in 1998 continues to be used regularly to conduct resistance screening tests and other biological studies. In 2023, we optimized our mass-rearing program to accommodate more extensive Hessian fly screening efforts. In this reporting year we screened 341 advanced wheat breeding lines and varieties for fly resistance. Segregating lines originating from crosses with several Hessian fly resistance sources were

tested. Several of the lines evaluated had a high proportion of resistant plants. In addition, 13 barley lines with potential Hessian fly resistance were screened, detecting three with resistance to our laboratory population (Table 1).

Table 1. Percent plants of wheat and barley genotypes infested with Hessian fly after screening in the laboratory and rating score, Moscow, ID, May - June 2023.

Genotype	Class/Crop*	% Resistant	Response**
20WAM-721.1	BLY	100	R
20WAM-783.1	BLY	0	S
Carleton (HO517-245)	BLY	0	S
KWS Fantex	BLY	100	R
KWS Thalis	BLY	0	S
LCS Diablo	BLY	100	R
WA8358 CL+	HRS	0	S
WA8411	HRS	100	R
WA8412	HRS	100	R
WA8413	HRS	100	R
WA8414	HRS	100	R
WB 9636	HRS	0	S
WA8383	SWS	85	R
WA8384	SWS	0	S
Hollis	HRS	100	R
Alturas	SWS	0	S

* BLY = Barley, HRS = Hard red spring wheat, SWS = Soft white spring wheat
** R = Resistant, no larvae or a few larvae (0-15%); S = presence of larvae and/or puparia

Objective 3 – Hessian fly susceptibility at different developmental stages

Response of wheat cultivar Alturas was to Hessian fly attack was measured at different node stages. Plants infested at the 1-leaf to 3-leaf stage were 100% susceptible, while plants at the 4-leaf stage showed some maturity related resistance, with 80% susceptibility to Hessian fly (Figure 1). This information is crucial to the wheat breeding efforts and Hessian fly management in the Pacific Northwest.

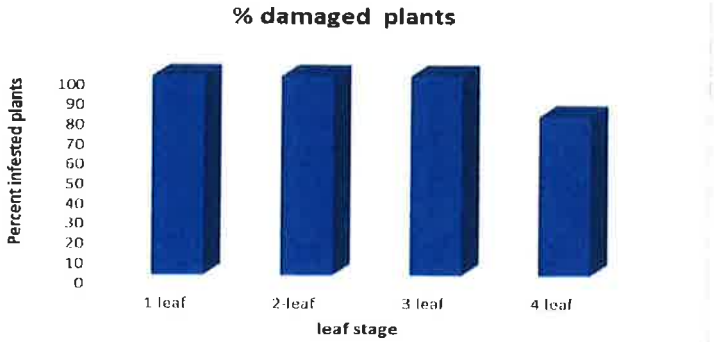


Figure 1. Response of susceptible wheat cultivar Alturas at four different leaf stages to our laboratory reared Hessian fly population, Moscow, ID, September-October 2023

Objective 4 - Spectral reflectance of Hessian fly infested plants:

The susceptible cultivar, Alturas, was planted in the pots and the plants were exposed to Hessian fly at 10 days after planting following our standard laboratory protocols. The first greenhouse experiment was replicated 10 times per treatment, while the second experiment was replicated at 12 times per treatment (each period with 4 replicates). A total of 120 plants per replicate were screened per replicate in the first experiment while a total of 24 plants per replicate were screened in the second experiment. In the first greenhouse experiment, images were captured at two-time periods after infestation (14 and 21 days). In the second greenhouse experiment, image were captured at three time periods after infestation (8, 15 and 21 days). A neural network machine learning model was developed with the Adam optimizer and sparse categorical cross-entropy loss function to segment the vegetation pixels from the soil and background after radiometric calibration (Fig. 2a). Multispectral images were used to compute vegetation indices: Normalized Difference Vegetation Index, NDVI=(NIR - Red) / (NIR + Red), and the Normalized Difference Red-Edge Index, NDRE= (NIR - Red Edge) / (NIR + Red Edge) as potential indicator of plant health vs HF infected (Fig. 2b). NDVI did not detect differences between Hessian fly-infested and non-infested plants (Fig. 3a and b) but NDRE was effective at 14 and 21 days (Fig. 3c and d).

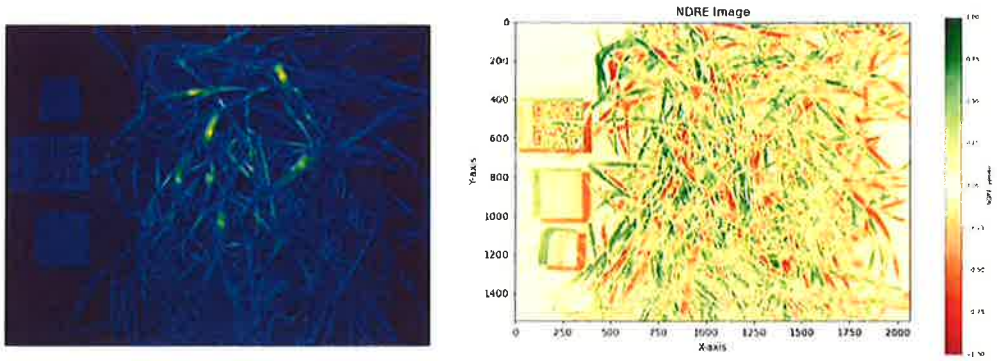
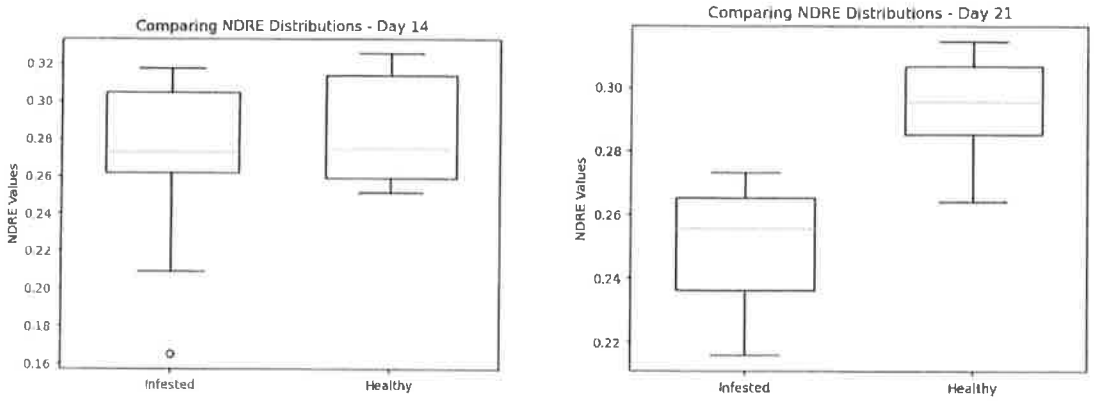


Fig. 2. (a) Multispectral imaging of infected plant (b) vegetation indices computing results

(a) NDVI indicator after 2-week's infection (b) NDVI indicator after 3-week's infection



(c) NDRE indicator after 2-week's infection (d) NDRE indicator after 3-week's infection

Figure 3. Multispectral imaging and vegetation indices analysis using NDVI and NDRE after 2 week and 3 week's HF infection.

Objective 5 - Update economic loss estimates for Hessian fly in Idaho

This work depends on remote sensed Hessian fly attack based on satellite imagery, which has not yet been realized. Work on this will be suspended until remote sensing methods have been perfected.

Outreach/Applications/Adoption:

The project has enabled incorporation of Hessian fly resistance into spring wheat varieties grown in Idaho.

Next Steps/Projections:

The goal of this project is to provide growers with new spring wheat varieties that combine resistance to Hessian fly, disease resistance and improve agronomic characters and quality. The research objectives also include providing updated information on the nature of Hessian fly populations in Idaho. Yield reductions due to Hessian fly infestation of spring wheat without resistance range from 11-24%, or $45 to $104 per acre in the PNW, based on Smiley et al. (2004). Applying these values to Idaho at current yields, prices and acreage of spring wheat, a conservative loss estimate without Hessian fly resistant varieties would be $2M to $4M annually. We will continue to see Hessian fly infestations in northern Idaho every year, and sampling with pheromone traps in 2012 has led to estimates of hundreds to thousands of flies at every location sampled. The Hessian fly has been detected in southern Idaho as well, and it has the possibility to spread via the movement of cereal residue. The main control mechanism for Hessian fly remains crop genetic resistance ensured through continual expert screening to serve breeding programs. Selecting for and maintaining Hessian fly resistance in new varieties requires the reliable resistance screening procedure that we utilize in our laboratory at UI. The return on investment to Idaho growers, if this project is funded, is therefore substantial. Evaluation of breeding materials and mapping populations in the laboratory will continue during 2024-2025.

Information from this research will help growers manage pest populations and optimize productivity of wheat.

Publications/Presentations/Popular Articles/News Releases/Variety Releases:

1. Milton V.O, A. Marzougui, C. Zhang, S. Bali, S. Odubiyi, V. Sathuvalli, N. A. Bosque-Pérez, M. O. Pumphrey, and S. Sankaran.2022. Biogenic VOCs emission profiles associated with plant-pest interaction for phenotyping applications. *Sensors 22 (13), 4870*
2. Garland-Campbell, K. A; Bellinger, B; Carter, A. H.; Chen, X; DeMacon, P. L; Engle, D. A.; Hagerty, C; Kiszonas, A; Klarquist, E. F; Murray, T; Morris, C; Neely, C; Odubiyi, S; Rashed, A; See, D; Steber, C. M.; Wen, N. 2022. Registration of 'Cameo' Soft White Winter Club Wheat. Journal of Plant Registration 16(3).
3. Prather, S., T. Schneider, J. G. Godoy, S. Odubiyi, N. A. Bosque-Perez, A. Rashed, S. Rynearson, M. O. Pumphrey. 2022. Reliable DNA markers for a previously unidentified, yet broadly deployed Hessian fly resistance gene on chromosome 6B in Pacific Northwest spring wheat varieties. Frontier Plant Sci. 13, 77906
4. Bosque-Pérez, N.A., E.A. Alalwan, S.O. Odubiyi, V.A. Oliveras, and M. Pumphrey. 2018. Response of a differential panel of wheat varieties to geographically diverse Hessian fly populations. 23rd Biennial International Plant Resistance to Insects Workshop. Harpenden, England, March 7-9, 2018. (Poster presentation).

Note: Publications 1-3 are for information purposes. No IWC funds were utilized for these research works.