Grant Code:	AN6310
Title:	Development of resistant wheat cultivars for management of Hessian fly in Idaho
Personnel:	Sanford Eigenbrode, Distinguished Professor of Entomology Steve Odubiyi, Laboratory Coordinator/Manager Johnny Li, Assistant Professor, Soil and Water Systems Patrick Hatzenbuehler, Assist. Professor, Extension Specialist–Crop Economics Jae Ryu, Associate Professor of Precision Agriculture
Address:	Dept. of EPPN, University of Idaho, Moscow, ID 83844-2329

Justification/Rationale: Hessian fly resistance is an important trait 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; resistance in the PNW was valued at up to $104 per acre based on a study by Smiley et al. (2004). Widespread economic losses in the region have not occurred in recent years in large part due to effective resistance in many of the most widely planted and highest-yielding 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. Since the appearance of Hessian fly in Treasure Valley in 2015 and the alarming increase in the Hessian fly infestations 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 and are amenable 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 is now critical. Our laboratory assays in 2020 found the cultivar Milie resistant to Hessian flies. We continued our screening efforts in winter wheat in collaborations from WSU breeding programs and found the two cultivars Canvas and Battle AX also resistant to Hessian flies. 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. This proposal will develop protocols for early detection of Hessian fly damage in the field and update estimates of economic losses in Idaho, based on current market values. The latest available economic estimates by Smiley et al. (2004) are outdated and not representative of statewide assessments specific to Idaho. However, based on the existing economic damage estimates and continued existence of damage causing Hessian flies in Idaho, the return on investment of Idaho grower funding for this project will be substantial. Two additional issues need to be addressed. The Hessian fly colony used for screening was established in 2000? and should be refreshed with field-collected flies to ensure it is relevant to screen for resistance to fly populations in Idaho. Flies can infest wheat plants during seedling growth, but screening has been limited to wheat plants at first node. Known sources should be evaluated to confirm resistance is maintained to second node stage.

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
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).

Procedures/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. Lines will be seeded in pots, placed in cages and infested at the one-leaf stage with Hessian fly females to lay eggs. Response of plants to larval infestations will be evaluated 21 days later (Obj., 1 & 2). To address Obj. 3, susceptible lines will be seeded in pots, placed in cages and infested at the one-, two-, three-, and four-leaf stage with Hessian fly females to lay eggs for 24 hours and evaluated as in Obj. 1 & 2. Plants will be dissected and the number of Hessian fly larvae and puparia per plant determined. The information will help understand the effect of planting date on Hessian fly infestations in the field. Objectives 1-3 to be performed by Odubiyi and Eigenbrode). To address Obj. 4 (co-PI, Li), flats of susceptible wheat (cv. Alturas) will be grown in the greenhouse and infested with Hessian fly or left uninfested as controls. Hyperspectral imaging will be collected weekly to capture spectral signatures infested and uninfested plants. To address Obj. 5 (co-PIs Ryu and Hatzenbeuhler), satellite hyperspectral imagery from southern Idaho will be used to generate yield damage estimates. These will be combined with wheat planted area estimates to obtain statewide aggregate estimates of wheat production reductions due to Hessian fly damage. Multiplication of production reduction estimates with prices will provide total economic loss estimates.

Duration: 3 years: 2023-2026 (this funding request is for one year)

Cooperation/Collaboration/Complementation: UI: J. Chen, K. Schroeder; WSU: M. Pumphrey, 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: Results of this ongoing work has been critical in enabling breeders to maintain effective Hessian fly resistance in new wheat varieties agronomically suitable for Idaho as they are released. The results of surveys and yield and economic loss estimates 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 approach remains effective. A new element is refinement of spectral imaging work that can form the basis of regional surveys and enable farm level surveys for Hessian fly infestations using drones. Dr. Li, a new investigator, brings this expertise to the project.

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). 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 in spring wheat or dry stubble. The puparial 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). Over thirty-two genes for resistance have been identified (Sardesai et al. 2005, Carter et al. 2014). Utilization of multiple genes for resistance coupled with the enhancement of existing natural enemies has the potential to enhance 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

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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Bullock, D.G, N.A. Bosque-Pérez, J.B. Johnson, and F.W. Merickel. 2004. Species composition and distribution of Hessian fly (Diptera: Cecidomyiidae) parasitoids in northern Idaho. Journal of the Kansas Entomological Society. 77: 174-180.

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Smiley, R.W., J.A. Gourlie, R.G. Whittaker, S.A. Easley, and K.K. Kidwell. 2004. Economic impact of Hessian fly (Diptera: Cecidomyiidae) on spring wheat in Oregon and additive yield losses with Fusarium crown rot and lesion nematode. Journal of Economic Entomology 97: 397-408.

FY2024

COMMODITY COMMISSION BUDGET

Principal Investigator: Eigenbrode

Allocated by _____ *(Commission/Organization)*	during FY2022	$	19,997
Allocated by _____ *(Commission/Organization)*	during FY2023	$	19,998

REQUESTED SUPPORT: Budget Categories	*Awarded for FY2023*	*Requested for FY2024*
(10) Salary *(staff, post-docs, e NOTE: Faculty salary/fringe not allowed*	$ 10,024	$ -
(12) Temporary Help/IH	$ 5,000	$ 17,800
(11) Fringe Benefits	$ 675	$ 1,497
(20) Travel	$ 2,379	$ 1,720
(30) Other Expenses	$ 1,920	$ 2,065
(40) Capital Outlay >$5k	$ -	$ -
(45) Capital Outlay <$5k	$ -	$ -
(70) Graduate Student Tuition/Fees	$ -	$ -
TOTALS	$ 19,998	$ 23,082
TOTAL BUDGET REQUESTED FOR FY2024:		$ 23,082

BREAKDOWN FOR MULTIPLE INDEXES:

Budget Categories	*Odubiyi*	*Hatzenbuehler*	*Ryu*	*Li*
(10) Salary *(staff, post-docs, e*	$ -	$ -	$ -	$ -
(12) Temporary Help	$ 9,600	$ -	$ 1,000	$ 7,200
(11) Fringe Benefits	$ 835	$ -	$ 36	$ 626
(20) Travel	$ -	$ 430	$ 1,116	$ 174
(30) Other Expenses	$ 1,465	$ -	$ 600	$ -
(40) Capital Outlay >$5k	$ -	$ -	$ -	$ -
(45) Capital Outlay <$5k	$ -	$ -	$ -	$ -
(70) Graduate Student Tuition/Fees	$ -	$ -	$ -	$ -
TOTALS	$ 11,900	$ 430	$ 2,752	$ 8,000
			Total Sub-budgets	$ 23,082

Budget Justification

$	17,800	(12) IH - Hessian fly colony and sampling, 640 h; spectral imaging, 480 h (both @ $15/h); satellite imaging analysis, 40 h @ $25/h
$	1,497	(11) Odubiyi and Li; IH at 8.7%; Ryu IH for student at 3.6%
$	1,720	(20) Travel for imaging work: One-way field trip is 11.6 mile, $0.625/mile, weekly field data collection over three summer months. 11.6mile*2*4*3*$0.625/mile=$174; Satellite imaging: Round trip from Moscow to/from Boise for data collection for the project; 600 miles RT *$0.625/mile =$375; 3 days per diem = $55/day*3* 2 people = $330; hotel $103/night *2 nights* 2 people =$411; Total =$1116; Economic analysis travel: Round trip from Twin Falls to/from Boise for team meeting with Ryu in project years 1 and 2. 128miles*2*2*$0.625/mile=$320; 2 days per diem = $55/day*2 = $110
$	2,065	(30)-Cage repairs ($200), potting soil ($840), growth light replacement ($425), traps and pheromone lure($400), shipping, molecular kits/testing of H-fly samples ($1044), $2,909; battery and parts=$600

Annual Report

PROJECT NO: AN6310

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

PERSONNEL: Steve Odubiyi, Support Scientist
Patrick Hatzenbuehler, Assistant Professor, Extension Specialist
Jae Ryu, Associate Professor

ADDRESS: Steve Odubiyi, Dept. of EPPN, University of Idaho, Moscow, ID 83844-2329; 208-301-4956; stevenodubiyi@uidaho.edu

ABSTRACT:

Hessian fly is a destructive pest of wheat in most of the wheat growing regions in the world. Host plant resistance is the most effective and reliable control method. Several resistant wheat cultivars have been produced and planted to tame the hessian fly damaging effect. However, occurrence of virulent biotypes that can attack these resistant lines had been reported. Virulent biotypes are now capable of overcoming the H3 resistance gene. Wheat breeders and entomologists continuously search for new sources of resistance to protect both spring and winter wheats from Hessian fly attacks: Incorporation of multiple resistance genes like H5, H13, H15, H22, H25, H26, H31 and H34 into the wheat breeding efforts is paramount in Pacific Northwest.

OBJECTIVE:

Our program objectives include screening of segregating populations and advanced breeding lines for resistance to Hessian fly in the laboratory and assisting the breeding program in the development of effective molecular markers for Hessian fly resistance genes.

ACCOMPLISHMENTS:

Genotype screening: The Hessian fly colony established in our laboratory at UI in 1998 continues to be used regularly to conduct resistance screening tests. The laboratory screening procedure is working very effectively. In 2022, we optimized our mass-rearing program to accommodate our more extensive Hessian fly screening efforts. We have continued our screening efforts with over 300 advanced breeding lines and varieties evaluated for fly resistance in the laboratory during 2022. Lines originating from crosses with several Hessian fly resistant sources were tested. Among them are HWS lines derived from the crosses IDO1203S/SRRN-6028, IDO1203S/SRRN-6032, and IDO1203S/SRRN-6038. In addition, HWS lines derived from the cross IDO1203S/SY10136 were tested. They all exhibited a high proportion of resistant plants (Table1). Some winter wheat and barley lines were also evaluated

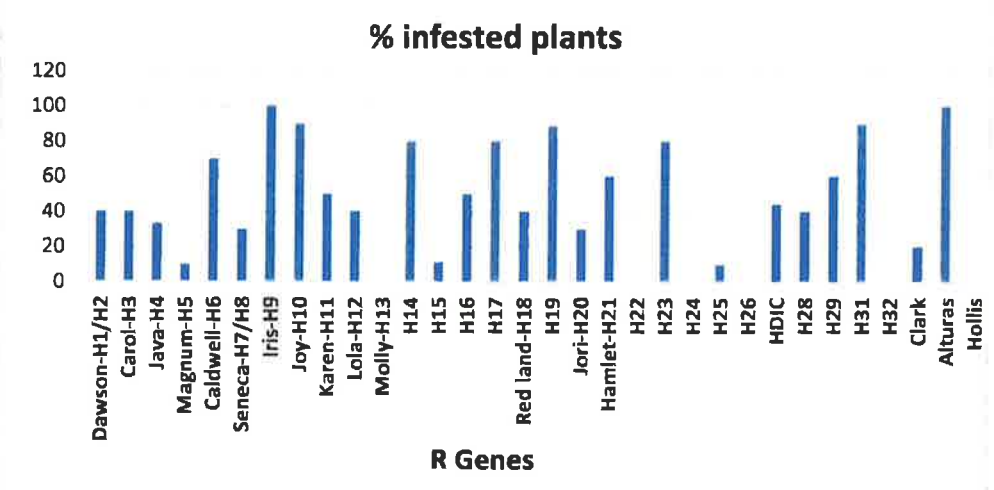
As part of our screening efforts, our laboratory population was evaluated to 33 resistance genes (H1-32 and Clark). Eight out of 33 selected H genes confer resistance to our laboratory population of Hessian fly. Among the resistance panels are H5, H13, H15, H22, H24, H25, H26, H32 and Clark. H3 is 40 percent susceptible to our laboratory population. Percentage of susceptibility of other H genes varying between 30% -100%(Figure1). This information is crucial to the wheat breeding efforts in the Pacific Northwest.

Table 1. Percentage of plants resistant to Hessian fly in the laboratory, Moscow, ID, January-March 2022.

Line no.	ID	Pedigree	Class	% Resistant plants
212001	A14276S-19	IDO1203S/SRRN-6028	HWS	100
212002	A14276S-22	IDO1203S/SRRN-6028	HWS	100
212017	A14279S-7	IDO1203S/SRRN-6032	HWS	100
212021	A14279S-17	IDO1203S/SRRN-6032	HWS	100
212056	A14286S-9	IDO1203S/SRRN-6038	HWS	95
212057	A14286S-11	IDO1203S/SRRN-6038	HWS	100
212091	A14169S+AI4171S-63	IDO1203S/SY10136	HWS	100
212093	A14169S+AI4171S-69	IDO1203S/SY10136	HWS	100
Hollis	Hollis	Resistant check	HRS	100
Alturas	Alturas	Susceptible check	HRS	0

R = absence of larvae and/or puparia (0-15% infested)
MR= Moderately resistant; some larvae and/or puparia present (low susceptibility)
S = presence of larvae and/or puparia
Response= indicates the outcome of the screening

Figure 1. Response of selected differential panels of wheat (R genes) to our laboratory Hessian fly population, Moscow, ID, January 2022



OUTREACH / APPLICATIONS / ADOPTION:

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

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% and fly resistance in the Pacific Northwest is valued from $45 to $104 per acre based on a study by Smiley et al. (2004). Applying these values to Idaho, a very conservative loss estimate without resistant varieties would be over one million dollars per year. We will continue to see Hessian fly infestations in northern Idaho every year, and sampling with pheromone traps has led to estimates of hundreds to thousands of flies at every location sampled. We will also analyze the reflectance spectra of different wheat cultivars (both resistant and susceptible) in both infested and non-infested plants to identify to detect the presence and intensity of damage at the field scale and to quantify economic loss to this pest in the study area. 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 genetic resistance identified by continual expert screening. Selecting for and maintaining Hessian fly resistance in new varieties requires the reliable resistance screening procedure that we utilize in our laboratory at UI as well as the selected study area. The return on investment of Idaho grower funding for this project is substantial. Evaluation of breeding materials and mapping populations in the laboratory will continue during 2023-2024. Information from this research will help growers manage pest populations and optimize productivity of wheat.

PUBLICATIONS AND PRESENTATIONS:

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.