2021 Research Proposals

and

2020 Research Reports

WRRC Board of Directors - *with term expiration date, December 1, 20__*

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2021 Research Priorities

#1 priorities

- Develop cultivars that are summer bearing, high yielding, winter hardy, machine-harvestable, disease resistant, virus resistant and have superior processed fruit quality
- Fruit rot including pre harvest, post-harvest, and/or shelf life.
- Management options for control of the Spotted Wing Drosophila – including targeting systemic action on larvae
- Mite Management – need new tools and MRLs - Nealta
- Labor saving practices – ex. Pruning efficiency, public/private technology partnerships, harvester automation

#2 priorities

- Understanding soil ecology and soil borne pathogens and their effects on plant health and crop yields.
- Foliar & Cane diseases – i.e. spur blight, yellow rust, cane blight, powdery mildew
- Root weevils
- Cutworm, leafroller management
- Soil fumigation techniques and alternatives to control soil pathogens, nematodes, and weeds

#3 priorities

- Alternative Management Systems – fruit yield per linear foot of bed – planting densities, row spacing, trellising
- Nutrient Management – Revise OSU specs, Consider: timing, varieties, appl. techniques
- Irrigation management – application techniques including pulsing
- Viruses/crumbly fruit, pollination
- Management options for control of the Brown Marmorated Stink Bug (BMSB)
- Cane Management including suppression
- Pest Management as it affects Pollinators
- Effect on BRIX by fungicide and fertility programs
- Season extension: improve viability of fresh marketing
- Maximum Residue Limits (MRL) – residue decline curves, harmonization
- Weed management – horsetail, poison hemlock, wild buckwheat, nightshade

2021 WRRC Research Budget

PAGE	PROJECT TITLE	RESEARCHER (S)	REQUEST	APPROVED	Other $	Source	Approved
PLANT BREEDING			62.71%	0.00%			0.00%
4	Cooperative raspberry cultivar development	Scagel	$15,006				
22	Red Raspberry Breeding, Genetics and Clone Evaluation	Hoashi-Erhardt	$75,758				
34	Advanced Machine Harvest Selection Trials	DeVetter, Hoashi-E	$10,890				
38	Coordinated Regional on-farm Trials	NWBF - Walters	$8,096				
43	Red Raspberry Cultivar Development	Dossett	$10,000				
ENTOMOLOGY			6.28%	0.00%			0.00%
52	Two-Spotted Spider Mites in Red Raspberries	Schreiber	$12,000		$11,500	WSCPR	
55	Improved Management of lepidopteran pests	Gerdeman					
63	Development of Biologically-based RNAi Insecticide	Choi					
WEEDS			5.96%	0.00%			0.00%
67	Preventing Wild Buckwheat Seed Production in Raspberries	Seerfedt	$7,511				
72	Testing Raspberries for Chlorsulfuron Residues	Seerfedt	$3,878				
PHYSIOLOGY			10.78%	0.00%			0.00%
79	Arbuscular Mycorrhizal Fungal Propagules in New Plantings	Bunn/DeVetter	$6,975				
87	Multi-season Plastic Mulches for weed mangement and crop growth	DeVetter	$13,607				
PATHOLOGY/VIROLOGY			14.27%	0.00%			0.00%
94	Management of Fungicide Resistant Botrytis in Raspberries	Schreiber	$15,250		$75,000	SCBG	
99	Control of Cane Blight in Red Raspberries	Schreiber/Jones	$12,000		$15,000	WSCPR	
115	Fungicide Resistance of *Botrytis cinerea* to Kenja and Luna Tranquility	Jones					
128	Refining the microbiome of developing red raspberry fruit tissues	Stockwell					
SOILS			0.00%				0.00%
131	Fumigant Study Group	Walters/Zasada					
134	Measuring and Mitigating Soil Compaction	Griffin/LaHue					
	Total Production Research		**$190,971**		**$101,500**		**$0**
	Research Related	WRRC expenses	$3,500	$3,500			$3,500
	Small Fruit Center fee		$2,500	$2,500			$2,500
	TOTAL		**$196,971**	**$6,000**			**$6,000**
	2021 Research Budget		$180,000	$174,000	report only	applied	

PLANT BREEDING

Project Title: Cooperative raspberry cultivar development program

PI: Carolyn Scagel
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Research Plant Physiologist
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Co-PI: Michael Hardigan, USDA-ARS-HCRL
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Collaborators:
Bernadine Strik, OSU Horticulture
Zachary Wiegand, OSU Food Science

Cooperators:
Mary Peterson, USDA-ARS-HCRL
Amanda Lake, USDA-ARS-HCRL
Wendy Hoashi-Erhardt, WSU
Michael Dossett, Agriculture and Agri-Foods Canada

Year Initiated __2013___ Current Year 2021-2022 Terminating Year _Continuing__

Total Project Request: Ongoing.

Other Funding Sources:
Current pending and support form attached in Appendix I.
The USDA-ARS/OSU cooperative breeding program (Corvallis OR) applies annually for funding from the Oregon Raspberry and Blackberry Commission to support the portion of the cooperative raspberry and blackberry breeding program based at the OSU-NWREC (led by B. Strik). The funding we are requesting here is complementary, not duplicative.

Description of Objectives and Specific Outcomes: (<200 words)

Objectives include continued development of:

- New raspberry cultivars for the PNW in cooperation with Agriculture and Agri-Food Canada and WSU that are floricane-fruiting, high-yielding, winter hardy, machine harvestable, disease and virus resistant and have superior processed fruit quality (#1 WRRC Priority).
- Identify fresh market cultivars that provide "season extension: improve viability of fresh marketing" through floricane or primocane fruiting types (#3 WRRC Priority).

The program focus is currently on cultivars that are able to replace or complement current industry standards, primarily 'Meeker' or 'Wakefield' to help towards the long-term viability of the regional industry.

Justification and Background: (<400 words)

The PNW is one of the most important berry production regions in the world. This success is due to a combination of an outstanding growing environment, top-notch growers, and a strong history of industry support for research and cultivar development. The USDA-ARS caneberry breeding program in Corvallis has a history of developing cultivars that are commercially viable for the PNW region. Cultivars that are able to replace or complement current industry standards, primarily 'Meeker' or 'Wakefield' would help towards that goal. The raspberry breeding programs in the northwest region (Washington, Oregon, and British Columbia) have a history of cooperation that includes the exchange of parents and promising new selections, ideas, and research goals, as well as testing and evaluating each other's germplasm. Genetic resources developed by each of these integrated programs benefit the entire northwest raspberry industry.

The caneberry portion of the USDA-ARS cooperative breeding program (Corvallis, OR), is currently under supervision of Dr. Carolyn Scagel until the position for a caneberry breeder is filled (tentatively spring 2021). The breeding program continues to actively work toward the caneberry breeding goals outlined by Dr. Chad Finn in on-going proposals to WRRC, with the expertise of Dr. Michael Hardigan (Post-doctoral researcher hired June 2020) and Mary Peterson (Technician responsible for caneberry germplasm and breeding lines for over 20 years). Funding is essential for maintaining germplasm located in Corvallis that has taken years to develop, while continuing to move the program forward in support of the Pacific Northwest (PNW) raspberry industry. Maintenance of the current germplasm and continued progress on the breeding strategies will also enable the new caneberry breeder to move toward the goals set forth by Chad Finn that are in alignment with WRRC priorities.

Relationship to WRRC Research Priorities:

The objectives tie directly to the following priorities:

- Develop cultivars that are summer bearing, high yielding, winter hardy, machine-harvestable, disease resistant, virus resistant, and have superior processed fruit quality.
- Season extension: improve viability of fresh marketing. This includes a significant focus on identification of promising early-season selections.

Ideally new cultivars will have improved pest resistance and so this work ties indirectly to the following priorities:

- Fruit rot including pre harvest, postharvest, and/or shelf life (#1 WRRC Priority).
- Foliar & Cane Diseases – i.e. spur blight, yellow rust, cane blight, powdery mildew (#2 WRRC Priority).
- Soil fumigation techniques and alternatives to control soil pathogens, nematodes, and weeds (#2 WRRC Priority).
- Viruses/crumbly fruit, pollination (#3 WRRC Priority).

Objectives:

This is on-going research and all objectives of the following objectives are addressed simulanteously each year:

- Develop cultivars for the Pacific Northwest in cooperation with Agriculture and Agri-Food Canada and Washington State University that are summer bearing high-yielding, winter hardy, machine harvestable, disease and virus resistant and have superior processed fruit quality (#1 Priority).

- Develop new fresh market cultivars that provide season extension: improve viability of fresh marketing through floricane or primocane fruiting types (#3 Priority).
- Develop cultivars using new germplasm that are more vigorous and that may be grown using reduced applications of nutrients and irrigation and that are less reliant on soil fumigation (#3 Priority).

Procedures: (<400 words)

This is an ongoing project in which elite cultivars and selections serve as the basis for generating new populations from which new selections can be made, tested, and either released as a new cultivar or serve as a parent for further generations. Promising selections will be exchanged between cooperating Northwest breeding programs to test performance in a wider range of commercial environments. All of the steps are taking place every year at one or all locations i.e. crossing, growing seedlings, selecting, propagating for field trials, submitting for virus testing and clean-up and evaluating field trials.

Typically, thirty to forty crosses are made each year. No crosses were made in 2020 due to the decision to wait for the new caneberry breeder position to be filled. However, seedling populations from previous crosses will continue to be grown and evaluated in Corvallis, OR (see 2019/2020 progress report). As in previous years, selections are made and propagated for testing at the Oregon State University - North Willamette Research and Extension Center (NWREC; Aurora, OR). Washington State University and Agriculture and Agri-Food Canada selections, in addition to USDA-ARS selections that were outstanding as seedlings or performed well in other trials, are planted in replicated trials (3, 3-plant replications). Other promising selections are planted in smaller observation trials (single, 3 plant plot). Plants in both replicated and observation plots are subjectively evaluated for traits including vigor, disease tolerance, winter hardiness, spininess, and ease of fruit removal. Fruit are machine harvested twice-weekly during the production season and scored objectively for yield, berry size, soluble solids, and acidity, in addition to subjective scoring of color, firmness, flavor. Fruit from the best selections are processed after harvest for evaluation in the off season (OSU Food Science – funded by separate grants).

Selections that look promising are propagated for grower trials, machine harvest trials, and for evaluation at other locations in the Northwest. Selections are included in the formal WRRC machine harvest trials and in separate grower trials in Lynden. This typically involves cleaning up selections in tissue culture and then working with nurseries to generate plants for trials.

Anticipated Benefits and Information Transfer: (<100 words)

This breeding program will develop raspberry cultivars with improved performance over current industry standard varieties, or that will complement current industry standards. In addition, information generated on advanced selections from the WSU and B.C. programs will be summarized and made available to aid in determining their broader commercial viability.

Results of all trials will be made available to the industry to help them make decisions in their operations. Required and invited presentations will be made to the industry.

References

Finn, C.E., Strik, B.C., Yorgey, B.M., and Martin, R.R. (2013). ‘Vintage’ red raspberry. HortScience, 48(9):1181-1183.
Finn, C.E., Lawrence, F.J., Yorgey, B.M., and Strik, B.C. (2004). 'Chinook'red raspberry. HortScience, 39(2):444-445.
Finn, C.E., Lawrence, F.J., Yorgey, B.M., and Strik, B.C. (2001). 'Coho' red raspberry. HortScience, 36(6):1159-1161.

Budget:

Amount allocated by Commission for previous year: $__6,000____

	2021	2022	2023
Salaries[1/]	$9,006	$	$
Time-Slip	$	$	$
Operations (goods & services)	$1,000	$	$
Travel	$	$	$
Meetings	$	$	$
Other[2/]	$5,006	$	$
Equipment	$	$	$
Benefits	$	$	$
Total	**$15,006**	**$**	**$**

Budget Justification

[1/]Student labor (1 student GS-2, 4 months).

[2/]WRRC funds will be used only to support field operations in Corvallis, OR that are essential to the core breeding program. Technician and post-doc salaries, and the bulk of the overall breeding project in Corvallis will be supported by USDA-ARS funds. The requested WRRC funds cover only a portion of OSU-Lewis Brown Farm land costs ($3,500/acre).

Washington Red Raspberry Commission
Progress Report Format for 2020 Projects

Project No: TBD

Title: Cooperative raspberry cultivar development program (Report for proposal submitted by Chad Finn for 2019/2020)

Personnel:

Carolyn Scagel, Research Plant Physiologist (interim Caneberry breeding program supervisor)
Michael Hardigan, Postdoctoral Researcher and Mary Peterson, Biological Sciences Technician
USDA-ARS, HCRL; 3420 NW Orchard Ave. Corvallis, OR 97330

Reporting Period: 2020

Accomplishments:

The USDA-ARS-HCRL breeding program in cooperation with Oregon State University, Washington State University, and the Pacific Northwest industry continues to develop red raspberry cultivars that meet the industry stated objectives. We have continued to test WSU and AgCanada raspberry selections to assess their performance including yield and machine-harvested fruit quality in the northern Oregon trials at OSU-NWREC (Aurora, OR). We have generated results from replicated field trials showing that several recent WSU red raspberry selections that are of interest to growers, including WSU2130, WSU2088, and WSU2188, were among the top performing red raspberry individuals in Oregon. We were also partners in the recent releases of WSU2166 (now named 'Cascade Premier') and 'Cascade Harvest' several years ago. We have several selections in machine harvest trials in northern Washington and a few of these are promising. 'Vintage' and 'Kokanee' have found some small marketing niches. We plan to release the very promising ORUS 4716-1 primocane-fruiting red raspberry in 2021.

Results:

We have continued to move forward on the cultivar development strategy proposed to WRRC prior to 2020. In 2020, we planted ~1,700 new seedlings and we made 53 floricane selections; primocane selection will be completed in 2021, due to inconsistent growth of seelings populations and smoke and ash prohibiting evaluation during bearing period. We did not perform new parental crosses in the caneberry breeding program in 2020, the decisions regarding the generation of new populations will be left to the new USDA breeder starting in 2021. Below is are some highlights from our program for 2020. Appendix II tables contain specific information on selections.

To Be Released:

- **ORUS 4716-1** is a **primocane-fruiting** selection, with yields greater than the cultivar check 'Heritage', and with larger and much higher quality fruit. **The fruit can be picked at a range of colors from light pink to full red and still have sweetness and a good flavor.** The season starts at about the same time as 'Heritage' but it peaks and finishes about 7 d later than 'Heritage'.

Grower Trials
In addition to the above release, the following have been/are going to be propagated for grower trials:

- **ORUS 4371-4.** Floricane, processed. Very good yield machine harvested (MH) fruit at NWREC and Enfield's. Good winter tolerance. High quality fruit. **Best overall yield and 2020 yield for ORUS selections planted in replicated 2017 trials, outperforms 'Meeker'.**
- **ORUS 4373-1.** Floricane, processed. Good yield. Good fruit quality. Excellent root rot resistance at WSU-Puyallup. Fair yield in MH trial in Washington.
- **ORUS 4462-2.** Floricane, processed. Concerned with light color but very productive, winter hardy in Lynden. Machine harvests.
- **ORUS 4600-1.** Floricane, processed. Promising in MH at NWREC. Very high quality. Very good yield.
- **ORUS 4607-2.** Floricane, processed. Promising in MH Trial at NWREC and Enfield's. Excellent quality. Main concern is whether fruit get crumbly too quickly.
- **ORUS 4089-2.** Primocane or floricane fresh. Looked very good in Lynden and at NWREC. Bright firm and attractive as PF
- **ORUS 4487-1.** Primocane, fresh. Very early! 10d < 'Heritage'; Concerned with yield, higher than 'Kokanee' but lower than 'Polka'. May be good enough for an early cultivar but not incredible.

Floricane-fruiting Red Raspberry Trials (Tables RY[1-3]-floricane)

- All machine harvested with Littau harvester.
- **ORUS 4371-4, WSU 2130 and WSU 2088** had excellent machine harvest yields and excellent MH fruit quality, firmness in the 2016 planted trials.
    - **ORUS 4371-4 and WSU 2130** outperformed cultivar standard 'Meeker'.
    - **ORUS 4371-4** may have **improved winter tolerance**, will use as parent.
- **ORUS 4600-1 and WSU 2188** had excellent machine harvest yields and excellent MH fruit quality, firmness in the 2017 planted trials. Both outperformed 'Meeker' with respect to yield and fruit size.
- **ORUS 4961-1 and WSU 2376** had significantly higher yield and size than 'Wakefield' and 'Meeker' in the 2018 planted trial. Some concern with soft fruit in ORUS 4961-1.

Primocane-fruiting Red Raspberry Trials (Tables RY[1-3]-primocane)

- **Yields were down in 2020 due to wildfire smoke interfering with harvest.**
- 2017 planted trials: Only harvested ORUS 5005-1 and ORUS 5005-2, possibly will use for parent material but neither was as productive as existing varieties.
- 2018 planted trials: **ORUS 4487-1** somewhat promising in replicated trials. Very early at 10 d < 'Heritage'. Yield is perhaps acceptable for a cultivar, higher than 'Kokanee' but lower than 'Polka'.
- 2019 planted trials *(early observations)*:
    - **ORUS 5209-1,** BEST replicated selection in 2020. Great flavor. Nice plant with sturdy erect canes and strong laterals. Can be soft when fully ripe, BUT, like ORUS 4716-1 the fruit harvest easily when pink, with excellent flavor and sweetness.
    - **ORUS 5248-3** (unreplicated) was most productive new selection, fruit quality is high but has

“wild” flavor, will likely use as parent.

Evaluation of Root Rot resistance at WSU (2019 report)
Pat Moore at WSU has been screening raspberries in root rot trials. Based on his results he identified a range of responses to root rot. While many would appear to be susceptible, it was exciting to see some at the high end of the graph. The results:

- Probably better than ‘Meeker’: ORUS 4373-1
- Probably comparable to ‘Meeker’: ORUS 4482-3
- Probably comparable to or worse than ‘Meeker': Kokanee, Lewis, Vintage, ORUS 3234-1, ORUS 4090-2, ORUS 4097-1, ORUS 4283-1, ORUS 4289-1, ORUS 4462-2, ORUS 4465-2, and ORUS 4619-1.

Publications:
2020. How new PNW blackberry and raspberry cultivars will bring happiness to your farm! https://www.raspberryblackberry.com/wp-content/uploads/New-PNW-blackberry-and-raspberry-cultivars-Finn-Peterson.pdf

Appendix I: Cutrent and Pending Support Table

Current & Pending Support					
Name (List PI #1 first)	Supporting Agency and Project #	Total $ Amount	Effective and Expiration Dates	% of Time Committed	Title of Project
Current:					
Grunwald, **Scagel**, Weiland	USDA-Floral and Nursery Crop Initiative	$1,350,000	09/2013-09/2023	10%	Improving plant health for nursery production in the Pacific Northwest.
Weiland, **Scagel**	USDA-Northwest Center for Nursery Crop Research	$26,000	09/2020-09/2021	10%	Evaluating the impact of root rot pathogens on nursery crop health.
Scagel, Nackley	USDA-Northwest Center for Nursery Crop Research	$74,622	09/2019-09/2022	10%	Quantifying plant fertilizer use and fertilizer efficiency to decrease nutrient run-off in Oregon nursery production systems.
Nackley, **Scagel**	USDA-Northwest Center for Nursery Crop Research	$24,500	09/2020-09/2022	10%	Evaluating drone use for detection of plant nutrient and water status in Oregon nursery production systems.
Chen et al.	USDA-ARS SCRI	$50,000	09/2020-09/2022	2%	Establishing partnership and building infrastructure for production harvesting, processing, and marketing of US-grown tea.
Pending:					
Scagel and Hardigan	Washington Red Raspberry Commission	$11,006	7/2021-6/2022	10%	Cooperative raspberry cultivar development program.
Hardigan and Bryla	Oregon Blueberry Commission	$9,000	07/2021-06/2022	50%	Evaluating the potential of new genetic markers for predicting blueberry fruit quality and ripening season in a Pacific Northwest breeding population.

Appendix II: 2020 Progress Tables

Table RY1-floricane. Fruit size and yield of floricane-fruiting red raspberry genotypes at OSU-NWREC for trials planted in 2016, harvested from 2019-20. Normally we would include 2nd year (2018) data, but floricanes were cut to the ground prematurely due to rose stem girdler damage in 2017. Plants were mechanically harvested by Littau Harvester.

	Berry Size (g)	Yield (tons·a^{-1})		
Genotype	2019-20	2019	2020	2019-20
Annual Mean				
2019	3.4 a			4.35 a
2020	2.9 b			3.07 b
Replicated Plots				
WSU 2130	3.2 bc	5.28 ab	4.76 a	5.02 a
ORUS 4371-4	4.0 a	5.93 a	3.91 ab	4.92 a
Meeker	**2.6 e**	**4.02 cd**	**3.68 bc**	**3.85 b**
WSU 2088	3.2 bc	4.68 bc	2.87 cd	3.77 b
ORUS 4690-1	3.4 b	4.49 bc	2.03 de	3.26 bc
WSU 2162	3.0 cd	3.04 d	3.06 bc	3.05 c
ORUS 4707-2	2.9 de	3.01 d	1.16 e	2.08 d
Nonreplicated				
ORUS 4692-2	4.6	6.75	3.78	5.27
ORUS 4713-1	3.1	4.44	4.41	4.42
ORUS 4690-3	4.1	4.39	4.18	4.29
WSU 2087	3.6	4.73	3.39	4.06
ORUS 4641-3	2.8	5.00	2.54	3.77
ORUS 4692-4	3.2	4.98	1.49	3.23
ORUS 4707-1	3.0	3.52	2.85	3.19
ORUS 4713-2	3.4	2.63	3.37	3.00

^{z} Groups determined by t-Test (LSD) of replicated plot means, $p \leq 0.05$.

Table RY2-floricane. Fruit size and yield of floricane-fruiting red raspberry genotypes at OSU-NWREC for trials planted in 2017, harvested from 2019-20. Plants were mechanically harvested by Littau Harvester.

	Berry Size (g)	Yield (tons·a^{-1})		
Genotype	2019-20	2019	2020	2019-20
Annual Mean				
2019	3.6 a			4.64 a
2020	3.0 a			3.58 b
Replicated Plots				
ORUS 4600-1	3.3 b	4.76 a	4.65 a	4.70 a
WSU 2188	4.2 a	5.30 a	3.57 a	4.44 a
Meeker	**2.6 c**	**4.35 a**	**3.27 a**	**3.81 a**
WSU 1914	3.1 b	4.13 a	2.82 a	3.47 a
Nonreplicated				
Georgia	**3.4**	**5.47**	**6.10**	**5.78**
WSU 2421	3.5	5.09	4.38	4.74
WSU 2298	2.6	4.70	4.37	4.54
WSU 2088	3.6	5.56	3.23	4.40
ORUS 4837-2	3.7	4.17	4.00	4.09
WSU 2205	3.1	3.94	4.17	4.05
ORUS 4837-1	4.8	3.53	4.33	3.93
ORUS 4851-2	3.1	4.23	3.57	3.90
ORUS 4846-1	5.0	2.73	5.02	3.87
WSU 2366	3.3	4.33	3.02	3.67
WSU 2299	2.5	4.31	2.64	3.47
ORUS 4851-1	3.5	3.47	3.31	3.39
WSU 2123	3.1	4.36	1.88	3.12
WSU 2202	2.8	2.29	3.90	3.10
WSU 2195	3.7	3.58	1.91	2.74
ORUS 3702-3	4.9	3.06	2.19	2.63
ORUS 4373-1	3.9	1.93	2.97	2.45
ORUS 4840-1	2.7	2.85	0.72	1.78

[z] Groups determined by t-Test (LSD) of replicated plot means, $p \leq 0.05$.

Table RY3-floricane. Fruit size and yield of floricane-fruiting red raspberry genotypes at OSU-NWREC for trials planted in 2018, harvested from 2020. Plants were mechanically harvested by Littau Harvester.

	Berry Size (g)	Yield (tons·a^{-1})
Genotype	2020	2020
Annual Mean		
2020	2.9	3.89
Replicated Plots		
ORUS 4961-1	3.7 a	5.60 a
WSU 2376	3.1 ab	5.52 a
Wakefield	**2.7 ab**	**4.90 ab**
WSU 2348	3.1 ab	4.72 ab
ORUS 4640-1	3.1 ab	4.05 bc
Meeker	**2.3 b**	**3.30 cd**
WSU 2385	2.8 ab	2.54 d
ORUS 4463-1	2.8 ab	2.30 d
ORUS 4978-3	2.6 b	2.10 d
Nonreplicated		
Wakehaven	**3.0**	**7.88**
WSU 2372	3.2	6.68
WSU 2377	4.1	6.38
Cascade Harvest	**3.9**	**6.19**
WSU 2510	3.1	6.15
WSU 2234	3.1	6.11
WSU 2278	3.1	5.89
WSU 2268	2.7	5.66
WSU 2505	2.9	5.57
WSU 2506	3.0	5.53
ORUS 4641-3	3.3	5.48
WSU 2511	3.0	5.39
WSU 2298	2.6	5.21
WSU 2357	2.8	4.76
WSU 2432	3.4	4.56
ORUS 4600-3	2.4	4.43
WSU 2437	2.6	4.18
ORUS 4974-1	2.5	3.91
ORUS 4961-3	3.5	3.90
ORUS 4972-1	2.3	3.79
WSU 2442	2.2	3.44
ORUS 4978-2	3.4	3.36
ORUS 4975-1	3.6	2.99
ORUS 4971-2	4.2	2.76
ORUS 4965-1	3.2	2.69
ORUS 4978-1	2.8	2.63
ORUS 4971-3	4.4	2.57
ORUS 4971-1	4.2	2.48
ORUS 4961-5	3.5	2.33

[z] Groups determined by t-Test (LSD) of replicated plot means, $p \leq 0.05$.

Table RY1-primocane. Fruit size and yield of primocane red raspberry genotypes at OSU-NWREC for trials planted in 2017, harvested from 2018-20.

	Berry Size (g)	Yield (tons·a^{-1})		
Genotype	2018-20	2019	2020	2018-20
Annual Mean				
2018	2.7 b			0.92 b
2019	3.4 a			2.08 a
2020	3.5 a			1.84 ab
Replicated Plots				
ORUS 5005-2	3.2	2.08	1.84	1.62
Nonreplicated				
ORUS 5005-1	4.4	4.1	1.49	2.44
Heritage	**2.7**	**-**	**0.69**	**0.69**

[z] Groups determined by t-Test (LSD) of replicated plot means, $p \leq 0.05$.

Table RY2-primocane. Fruit size and yield of primocane red raspberry genotypes at OSU-NWREC for trials planted in 2018, harvested from 2019-20.

	Berry Size (g)	Yield (tons·a^{-1})		
Genotype	2019-20	2019	2020	2019-20
Annual Mean				
2019	3.0 a			3.51 a
2020	3.3 a			2.85 b
Replicated Plots				
Polka	**3.5 a**	**4.68 a**	**4.63 a**	**4.65 a**
ORUS 4487-1	2.8 b	4.44 a	3.01 b	3.72 b
Kokanee	**3.2 a**	**1.42 b**	**0.91 c**	**1.16 c**
Nonreplicated				
ORUS 4858-1	3.1	4.71	2.66	3.68
ORUS 5114-1	4.0	4.13	2.02	3.08
ORUS 5243-3	3.9	3.96	0.72	2.34
ORUS 5118-1	3.0	2.71	1.96	2.34
ORUS 5243-1	4.7	1.79	1.75	1.77
ORUS 5114-2	2.6	2.49	0.86	1.68
ORUS 5109-2	3.8	2.04	0.81	1.43
ORUS 5243-2	3.5	1.78	0.78	1.28
ORUS 4291-1	3.5	1.20	1.33	1.27
ORUS 4985-1	3.5	1.68	0.53	1.11
Vintage	**2.6**	**1.30**	**0.35**	**0.82**
Heritage	**3.0**	**-**	**0.23**	**0.23**

[z] Groups determined by t-Test (LSD) of replicated plot means, $p \leq 0.05$.

Table RY3-primocane. Fruit size and yield of primocane red raspberry genotypes at OSU-NWREC for trials planted in 2019, harvested from 2020.

Genotype	Berry Size (g) 2020	Yield (tons·a^{-1}) 2020
Annual Mean		
2020	3.1	1.59
Replicated Plots		
ORUS 5209-1	3.5 a	2.51 a
ORUS 5250-1	3.8 a	1.91 b
Kokanee	**2.2 b**	**1.38 c**
ORUS 4725-1	2.9 ab	1.17 c
ORUS 5248-1	3.3 a	1.01 c
Nonreplicated		
ORUS 5248-3	4.4	2.54
Polka	**2.7**	**1.97**
ORUS 5211-1	3.4	1.59
ORUS 5209-2	2.5	1.48
ORUS 471-6	2.9	1.19
ORUS 5218-1	3.9	1.12
ORUS 5227-3	3.5	0.97
ORUS 5220-1	1.9	0.79
ORUS 5227-2	4.4	0.58
ORUS 5248-2	3.5	0.53

[z] Group means determined by t-Test (LSD), $p \leq 0.05$.

Table RY-Season. Mean ripening season for all red raspberry genotypes trialed in 2020. Mean is average of 1-4 most recent years harvested at OSU-NWREC.

Genotype	Type[y]	Harvest Season (% Ripe Date)			No. Years in Mean
		5%	50%	95%	
ORUS 4837-2	FL	13-Jun	23-Jun	7-Jul	2
ORUS 4837-1	FL	13-Jun	25-Jun	10-Jul	2
ORUS 4611-1	FL	14-Jun	25-Jun	28-Jun	1
WSU 2511	FL	16-Jun	25-Jun	9-Jul	1
ORUS 4640-1	FL	16-Jun	29-Jun	13-Jul	1
ORUS 4961-1	FL	16-Jun	29-Jun	13-Jul	1
WSU 2377	FL	16-Jun	2-Jul	13-Jul	1
WSU 2505	FL	16-Jun	2-Jul	13-Jul	1
ORUS 4692-1	FL	17-Jun	24-Jun	8-Jul	2
Georgia	**FL**	**18-Jun**	**28-Jun**	**14-Jul**	**2**
WSU 2130	FL	20-Jun	26-Jun	10-Jul	2
ORUS 4846-1	FL	20-Jun	26-Jun	12-Jul	2
ORUS 4692-2	FL	20-Jun	28-Jun	10-Jul	2
WSU 2205	FL	20-Jun	28-Jun	10-Jul	2
WSU 2421	FL	20-Jun	28-Jun	15-Jul	2
WSU 2191	FL	20-Jun	30-Jun	12-Jul	2
ORUS 4603-2	FL	20-Jun	2-Jul	12-Jul	1
ORUS 4607-2	FL	20-Jun	2-Jul	12-Jul	1
ORUS 4641-3	FL	20-Jun	29-Jun	13-Jul	3
WSU 2123	FL	21-Jun	1-Jul	15-Jul	2
ORUS 4600-3	FL	21-Jun	2-Jul	14-Jul	2
WSU 2298	FL	21-Jun	29-Jun	13-Jul	3
ORUS 4965-1	FL	22-Jun	29-Jun	9-Jul	1
Cascade Harvest	**FL**	**22-Jun**	**29-Jun**	**13-Jul**	**1**
ORUS 4465-2	FL	22-Jun	29-Jun	13-Jul	1
Wakehaven	**FL**	**22-Jun**	**29-Jun**	**13-Jul**	**1**
WSU 2268	FL	22-Jun	29-Jun	13-Jul	1
WSU 2506	FL	22-Jun	29-Jun	13-Jul	1
ORUS 4974-1	FL	22-Jun	2-Jul	9-Jul	1
ORUS 4961-3	FL	22-Jun	2-Jul	13-Jul	1
ORUS 4961-5	FL	22-Jun	2-Jul	13-Jul	1
ORUS 4971-1	FL	22-Jun	2-Jul	13-Jul	1
ORUS 4971-2	FL	22-Jun	2-Jul	13-Jul	1
ORUS 4971-3	FL	22-Jun	2-Jul	13-Jul	1
ORUS 4972-1	FL	22-Jun	2-Jul	13-Jul	1
ORUS 4978-1	FL	22-Jun	2-Jul	13-Jul	1

ORUS 4978-2	FL	22-Jun	2-Jul	13-Jul	1
ORUS 4978-3	FL	22-Jun	2-Jul	13-Jul	1
WSU 2278	FL	22-Jun	2-Jul	13-Jul	1
WSU 2348	FL	22-Jun	2-Jul	13-Jul	1
WSU 2357	FL	22-Jun	2-Jul	13-Jul	1
WSU 2372	FL	22-Jun	2-Jul	13-Jul	1
WSU 2376	FL	22-Jun	2-Jul	13-Jul	1
WSU 2432	FL	22-Jun	2-Jul	13-Jul	1
WSU 2437	FL	22-Jun	2-Jul	13-Jul	1
WSU 2442	FL	22-Jun	2-Jul	13-Jul	1
WSU 2510	FL	22-Jun	2-Jul	13-Jul	1
ORUS 4463-1	FL	22-Jun	6-Jul	13-Jul	1
WSU 2385	FL	22-Jun	6-Jul	13-Jul	1
WSU 2299	FL	22-Jun	1-Jul	14-Jul	3
ORUS 4713-1	FL	23-Jun	30-Jun	12-Jul	2
WSU 1914	FL	23-Jun	30-Jun	14-Jul	2
ORUS 3702-3	FL	23-Jun	1-Jul	12-Jul	2
WSU 2087	FL	23-Jun	1-Jul	12-Jul	2
ORUS 4371-4	FL	23-Jun	1-Jul	13-Jul	2
ORUS 4692-4	FL	23-Jun	1-Jul	13-Jul	2
ORUS 4713-2	FL	23-Jun	1-Jul	13-Jul	2
ORUS 4600-1	FL	23-Jun	1-Jul	15-Jul	2
WSU 2202	FL	23-Jun	1-Jul	15-Jul	2
WSU 2366	FL	23-Jun	1-Jul	15-Jul	2
ORUS 4690-1	FL	23-Jun	3-Jul	13-Jul	2
ORUS 4707-1	FL	23-Jun	3-Jul	13-Jul	2
ORUS 4851-2	FL	23-Jun	3-Jul	15-Jul	2
WSU 2188	FL	23-Jun	3-Jul	15-Jul	2
WSU 2234	FL	23-Jun	3-Jul	15-Jul	2
ORUS 4851-1	FL	23-Jun	3-Jul	15-Jul	2
WSU 2195	FL	23-Jun	3-Jul	15-Jul	2
ORUS 4707-2	FL	23-Jun	5-Jul	13-Jul	2
WSU 2162	FL	23-Jun	5-Jul	13-Jul	2
WSU 2088	FL	23-Jun	5-Jul	14-Jul	4
ORUS 4373-1	FL	23-Jun	5-Jul	15-Jul	2
Wakefield	**FL**	**23-Jun**	**5-Jul**	**15-Jul**	**2**
Meeker	**FL**	**23-Jun**	**2-Jul**	**14-Jul**	**6**
ORUS 4715-2	FL	24-Jun	1-Jul	15-Jul	1
ORUS 1154R-3	FL	24-Jun	4-Jul	18-Jul	1
ORUS 3959-1	FL	24-Jun	4-Jul	18-Jul	1

ORUS 4715-1	FL	24-Jun	4-Jul	18-Jul	1
ORUS 4690-3	FL	24-Jun	8-Jul	18-Jul	1
ORUS 4694-1	FL	24-Jun	8-Jul	18-Jul	1
ORUS 4715-3	FL	24-Jun	8-Jul	18-Jul	1
ORUS 4975-1	FL	25-Jun	2-Jul	13-Jul	1
ORUS 4600-2	FL	25-Jun	2-Jul	16-Jul	1
ORUS 4603-1	FL	25-Jun	5-Jul	16-Jul	1
ORUS 4840-1	FL	28-Jun	15-Jul	18-Jul	1
ORUS 4988-2	PF	17-Jul	24-Jul	24-Jul	1
ORUS 4988-1	PF	17-Jul	24-Jul	14-Aug	1
ORUS 4988-3	PF	17-Jul	7-Aug	14-Aug	1
Amaranta	**PF**	**17-Jul**	**7-Aug**	**28-Aug**	**1**
ORUS 4864-1	PF	24-Jul	7-Aug	21-Aug	1
BP-1	**PF**	**24-Jul**	**14-Aug**	**4-Sep**	**1**
ORUS 5005-3	PF	31-Jul	7-Aug	28-Aug	1
ORUS 4981-2	PF	31-Jul	7-Aug	4-Sep	1
ORUS 4858-3	PF	31-Jul	14-Aug	28-Aug	1
ORUS 4873-1	PF	31-Jul	14-Aug	28-Aug	1
ORUS 4872-1	PF	31-Jul	14-Aug	18-Sep	1
ORUS 5005-1	PF	1-Aug	13-Aug	29-Aug	3
ORUS 5005-2	PF	1-Aug	15-Aug	1-Sep	3
ORUS 4291-1	PF	1-Aug	4-Aug	21-Aug	4
ORUS 4988-5	PF	3-Aug	14-Aug	27-Aug	2
ORUS 4858-2	PF	3-Aug	24-Aug	11-Sep	2
ORUS 4289-4	PF	3-Aug	17-Aug	21-Aug	2
ORUS 4725-1	PF	4-Aug	11-Aug	18-Aug	1
ORUS 5209-2	PF	4-Aug	11-Aug	18-Aug	1
ORUS 5211-1	PF	4-Aug	11-Aug	18-Aug	1
ORUS 5218-1	PF	4-Aug	11-Aug	18-Aug	1
ORUS 5250-1	PF	4-Aug	11-Aug	1-Sep	1
ORUS 5209-1	PF	4-Aug	18-Aug	1-Sep	1
Polka	**PF**	**4-Aug**	**14-Aug**	**30-Aug**	**3**
ORUS 4487-1	PF	5-Aug	19-Aug	12-Sep	2
ORUS 4858-1	PF	5-Aug	22-Aug	6-Sep	2
Imara	**PF**	**6-Aug**	**20-Aug**	**11-Sep**	**2**
Kweli	**PF**	**6-Aug**	**24-Aug**	**11-Sep**	**2**
ORUS 4988-4	PF	7-Aug	14-Aug	21-Aug	1
Lagorai Plus	**PF**	**7-Aug**	**14-Aug**	**28-Aug**	**1**
ORUS 4494-3	PF	7-Aug	21-Aug	11-Sep	1
Kokanee	**PF**	**8-Aug**	**26-Aug**	**11-Sep**	**6**

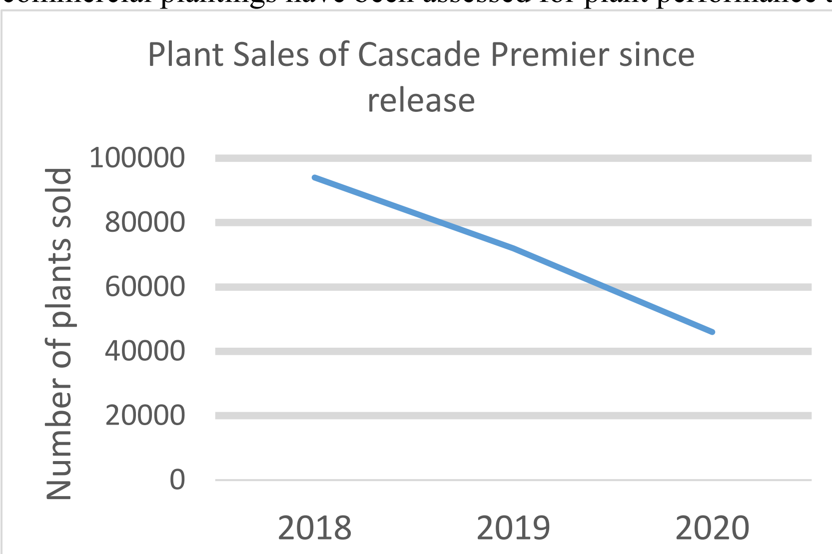
ORUS 4874-1	PF	10-Aug	24-Aug	7-Sep	2
Vintage	**PF**	**10-Aug**	**27-Aug**	**10-Sep**	**5**
ORUS 5248-3	PF	11-Aug	5-Aug	1-Sep	1
ORUS 5248-1	PF	11-Aug	25-Aug	1-Sep	1
ORUS 5118-1	PF	12-Aug	26-Aug	6-Sep	2
Heritage	**PF**	**12-Aug**	**19-Aug**	**2-Sep**	**7**
ORUS 5114-1	PF	12-Aug	26-Aug	6-Sep	2
ORUS 5004-2	PF	14-Aug	21-Aug	21-Aug	1
ORUS 4289-3	PF	14-Aug	21-Aug	4-Sep	1
ORUS 4856-1	PF	14-Aug	21-Aug	11-Sep	1
ORUS 4857-1	PF	14-Aug	28-Aug	4-Sep	1
ORUS 4990-1	PF	14-Aug	31-Aug	22-Sep	2
ORUS 5109-2	PF	16-Aug	29-Aug	2-Sep	2
ORUS 5243-1	PF	16-Aug	29-Aug	10-Sep	2
ORUS 4716-1	PF	17-Aug	26-Aug	10-Sep	3
ORUS 4985-1	PF	19-Aug	26-Aug	6-Sep	2
Kwanza	**PF**	**19-Aug**	**31-Aug**	**15-Sep**	**2**
ORUS 5114-2	PF	23-Aug	2-Sep	10-Sep	2
ORUS 4723-2	PF	24-Aug	4-Sep	18-Sep	2
ORUS 4722-2	PF	24-Aug	10-Sep	22-Sep	2
ORUS 5220-1	PF	25-Aug	25-Aug	1-Sep	1
ORUS 5227-3	PF	25-Aug	25-Aug	1-Sep	1
ORUS 5227-2	PF	25-Aug	1-Sep	1-Sep	1
ORUS 5248-2	PF	25-Aug	1-Sep	1-Sep	1
ORUS 5243-3	PF	26-Aug	6-Sep	12-Sep	2
ORUS 4722-1	PF	28-Aug	18-Sep	26-Sep	1
ORUS 5243-2	PF	29-Aug	6-Sep	12-Sep	2
ORUS 4989-1	PF	3-Sep	14-Sep	22-Sep	2
ORUS 5004-3	PF	3-Sep	14-Sep	22-Sep	2
ORUS 4861-1	PF	18-Sep	18-Sep	26-Sep	1
ORUS 5004-5	PF	18-Sep	26-Sep	26-Sep	1

[y] FL=Floricane fruiting; PF=Primocane fruiting.

Project: 13C-3755-5641
TITLE: Red Raspberry Breeding Genetics and Clone Evaluation
PROJECT LEADER: Wendy Hoashi-Erhardt, Program Lead
WSU Puyallup Research and Extension Center
Reporting Period: 2020

OBJECTIVES:
Develop summer fruiting red raspberry cultivars adapted to machine harvesting with improved yields and fruit quality, and resistance to root rot and raspberry.

Accomplishments:
Released cultivars. 'Cascade Premier' was released in 2017. It is exclusively licensed to Northwest Plant Company and plant sales are outlined in Figure 1. Plant sales may be lower in 2020 for a couple of reasons: 1) the raspberry industry has been contracting over the last few years, with total raspberry plant sales in Washington down by 50% in 2020 compared with 2018, and 2) growers are waiting to devote more ground to Cascade Premier until after the first large commercial plantings have been assessed for plant performance and fruit quality.



Cascade Premier is a cultivar that machine picks well. It has demonstrated good tolerance to root rot, better than Meeker or Cascade Harvest. It is an early season cultivar. In terms of fruit quality, it has large fruit, good firmness, and good flavor. It has similar pH, titratable acidity, and total phenolics content similar to Willamette fruit, and anthocyanins levels similar to Meeker.

Crosses/selections.
New crosses were not performed in 2020. A crossing plan for 2021 was drafted, prioritizing parents with excellent machine-harvested yield, berry firmness, and root rot tolerance. Extra seed of 2019 crosses are being scarified, stratified, and germinated this winter to form the new seedling planting of 2021.
There are 3 seedling fields being maintained for evaluation, indicated in the table below.

Establish-ment year	Number of seedlings	Management achieved in 2020
2018	~5400	Generated from crosses made in 2017. Maintained for two years, selections made in 2020, now slated for removal.
2019	~7700	Generated from crosses made in 2018. Maintain to evaluate for the first time next year and make new selections.
2020	~ 3800	Generated from crosses made in 2019. Established in spring and maintained for first evaluation in 2022.

Crosses made in 2017 were planted at the WSU Goss Farm in 2018 and 56 selections were made in summer 2020. The crosses emphasized parents that are machine harvestable and root rot resistant. Cascade Premier was a parent of 13 of the selections. Selections that were parents of several selections were WSU 1962 (16), WSU 2069 (11), WSU 2068 (10), and WSU 2162 (10). Tips of these selections were collected for establishment in tissue culture and propagation for the next stage of testing in the machine harvesting trial. The new selections were also dug for maintenance as stock plants and virus testing.

Machine Harvesting Trials. A new machine harvesting trial was not planted in 2020. The decision was made between the plant breeder, grower cooperator, and director of the WRRC to postpone planting until 2021. Three machine-harvesting trials were maintained and two were evaluated for yield and fruit quality in 2020 as indicated in the table below.

Establish-ment year	Number of selections	Achievements
2017	54 and 3 cultivars	Maintained; evaluated selections for a second season for fruit quality and yield to drive advancement and discard decisions; planting removed.
2018	47 and 3 cultivars	Maintained; evaluated selections for the first season for fruit quality and yield to drive advancement and discard decisions.
2019	47 and 3 cultivars	Maintained for first evaluation in 2021.
2020	0	Postponed/selections held for a new planting for 2021.

After two years of observational yield and fruit quality evaluation in the 2017 MH trial, the following selections will be advancing for further evaluations for yield and fruit quality:

- WSU 2298. Exceptionally root rot tolerance. Medium size, Meeker-color fruit. Excellent yield similar to Wakefield. Fruit may not be firm enough.
- WSU 2372. Very large size, very high yield, early season. Machines well. Some crumbly fruit seen at Enfields, not known whether this a result of tissue culture.
- WSU 2407. Very large size, high yield, early season. Machines well.
- WSU 2425. Medium size. Very high yield, early-mid season. Machines well.
- WSU 2563. Large size, high yield, early-mid season, machines well, color is lighter than Meeker.
- WSU 2585. Very large size, high yield, early –mid season, machines well. Color is lighter than Meeker.
- WSU 2588. Large size, high yield, early-mid season, machines well; color is lighter than Meeker.
- WSU 2601. Very large size, high yield, early-mid season, machines well.

Grower Trials. WSU 2188 is a very promising advanced selection and is being tested at several regions sites in grower trial. WSU 2188 has similar attributes to Cascade Premier, and hold promise as a new cultivar, pending performance data in grower trial and IQF processing evaluations. Overall, WSU 2188 has large fruit, good firmness, and good flavor. Its season is temporal with Meeker. The WSU plant breeding program successfully leveraged WRRC funding on the development of WSU 2188 and Cascade Premier to procure new funding from the NW Center for Small Fruit Research for a 3-year research project to evaluate Cascade Premier and WSU 2188 in multi-acre plantings to generate large volumes of fruit for extensive evaluations of IQF performance. This project began in October 2020 and is expected to be completed by

September 2023. This IQF project benefits from the strong collaborative relationships within the industry and is a partnership between WSU and Walters Ag Research, the PI on this project. There are 5 other advanced selections that are currently in grower trial on multiple sites in Washington. Each of these selections show a lot of promise from the standpoint of root rot tolerance, machine harvesting, yield, and fruit quality:

Selection	Grower Trial Stage	Description
WSU 2130	364 plants established in 2020 on 4 grower sites	Top or near top yield on multiple yield trials in Puyallup, North Willamette, and Enfields over two harvest seasons. Early ripening season, similar to Willamette. Berries are firm, about similar to Wakefield. The fruit is bigger than Meeker or Wakefield, and smaller than Cascade Harvest.
WSU 2068	50 plants established in 2020 with grower. Also planted at 2 grower sites in 2018.	Early selection, tracking with Willamette season. Higher yield than Meeker over two years of harvest at WSU Puyallup, similar yield to Wakefield in nonreplicated grower trial. Large berries with good firmness. Tolerant to root rot, appears to have better field tolerance than 2069.
WSU 2069	50 plants established 2020 with grower. Also planted at 2 grower sites in 2018.	Early selection, tracking with Willamette season. Higher yield than Meeker over two years of harvest at WSU Puyallup, similar yield to Wakefield in nonreplicated grower trial. Large berries with good firmness. Somewhat tolerant to root rot.
WSU 2088	359 plants established in 2020 on 4 grower sites	High yields in replicated yield trial at WSU Puyallup; high yield and excellent firmness in nonreplicated grower trial compared with Wakefield. Overall dark color berries of medium size. Late season selection, with harvest season about 3 days behind Meeker.
WSU 2087	93 plants established in 2020 with one grower	Two year yields greater than C Harvest and Meeker in a replicated research trial, similar to Wakefield in an unreplicated grower trial. The berries are firm, firmer than Meeker. This is a mid-late season selection, with a midpoint of harvest season 2 days after Meeker. Root rot tolerance.

Yield and Fruit Quality Evaluations (selection trials). We currently have 4 selections trials underway, established in 2017, 2018, 2019, and 2020. The selection trials were not evaluated this year, as there was too much variability within the planting to get high quality data on yield and fruit quality. This decision was not arrived at easily. Various factors, especially irrigation challenges, insect damage (rose stem girdler), and weed pressure impacted the two plantings, and these challenges were exacerbated by the difficulty in hiring and supervising field labor under the restrictions related to COVID-19. This situation led to the decision to focus on the health and quality of these plots instead of spending money on labor to harvest by hand, those are outlined below for the plantings established in 2017 and 2018.

Establishment year	Number of selections	Tasks and plans

2017	8 and 2 cultivars	Maintained; 2nd harvest season yield and fruit quality evaluation postponed for next year because of unacceptable variability in floricane number and health.
2018	11 and 2 cultivars	Maintained; 1st harvest season yield and fruit quality evaluation postponed for next year because of unacceptable variability in floricane number and health.
2019	5 and 3 cultivars	Maintained for first evaluation in 2021.
2020	8 and 2 cultivars	Established in 2020 for first evaluation in 2022.

A new cooperative effort is moving forward with a proposal to move the 2021 selection trial to the NWREC at Mount Vernon under the management of Dr. Lisa DeVetter. This effort holds promise for several reasons: 1) it will be less expensive to use a machine harvester relative to hand harvesting used in Puyallup, 2) it will yield better quality data because the machine harvesting will more closely match commercial practice relative to hand harvesting in Puyallup, and 3) it will establish a valuable "showcase" of advanced WSU germplasm at WSU Mount Vernon to increase visibility to the raspberry industry and for a prospective faculty plant breeder as the hiring process progresses.

Root rot evaluations. The Goss Farm is known for high levels of root rot and is an ideal field to screen selections for their tolerance to *Phytophthora* root rot. 4 plantings are currently being maintained and evaluated at WSU Puyallup as indicated by the table below.

Establish-ment year	Number of selections	Tasks and highlights
2017	29, 8 cvs	Maintained; evaluated selections for root rot tolerance, planting slated for removal in late winter. WSU 2298 and WSU 2069 performed well in this planting.
2018	26, 3 cvs	Maintained; evaluated selections for 2nd time for root rot tolerance. WSU 2442, WSU 2234, and WSU 2376 performed well for root rot tolerance from this planting.
2019	27, 4 cvs	Maintained; evaluated selections for 1st time for establishment. WSU 2516 and WSU 2605 established fairly well in this planting, which is a reflection of plug quality, plant vigor, and root rot tolerance.
2020	20, 4 cvs	Established this root rot planting for first evaluation in 2021.

Each planting contains single-plant plots in four replicates. Results are included in tables 1-3. Of the 7 genotypes highlighted as showing good root rot tolerance above, WSU 1499, a highly root rot tolerant selection was the parent of four of them. Cascade Harvest was the parent of another two selections.

Publications/Presentations

Raspberry and Strawberry Breeding Update, Small Fruit Conference, 1 Dec 2020.

Tables

Table 1. Root rot tolerance of WSU selections and standard cultivars evaluated in the first and third year after establishment in 2017.

Selection	Rating 2020[z]	Rating 2018

WSU 2298	5	a	4.5	abc
Columbia Giant	4.25	ab	3.25	abcde
Hall's Beauty	4.25	ab	4.75	ab
ORUS 4289-4	4.25	ab	5	a
Black Diamond	3.75	abc[y]	3.75	abcd
Columbia Star	3.75	abc	4	abc
ORUS 3219-2	3.75	abc	2	abcde
Columbia Sunrise	3.5	abcd	4	abc
ORUS 4857-1	3.5	abcd	4.5	abc
WSU 2069	3.25	abcde	3	abcde
WSU 2377	3.25	abcde	3.5	abcd
ORUS 3021-1	3	abcde	1.75	abcde
ORUS 3409-1	2.75	abcde	2	abcde
WSU 2363	2.25	abcde	2	abcde
Cascade Harvest	2	abcde	4	abc
ORUS 4465-3	1.75	abcde	3.5	abcd
ORUS 4715-3	1.75	abcde	3.75	abcd
ORUS 4988-1	1.75	abcde	4.25	abc
WSU 2123	1.75	abcde	2.75	abcde
Meeker	1.5	bcde	3.5	abcd
ORUS 5005-2	1.25	bcde	2.25	abcde
WSU 2278	1.25	bcde	1.5	bcde
ORUS 4856-1	1	bcde	3.25	abcde
WSU 1962	1	bcde	3.5	abcd
ORUS 1154R-3	0.75	cde	3.5	abcd
ORUS 4716-2	0.75	cde	2	abcde
ORUS 4988-3	0.75	cde	2.5	abcde
WSU 2190	0.75	cde	2.5	abcde
Kokanee	0.5	cde	2.75	abcde
ORUS 4722-2	0.5	cde	2	abcde
ORUS 5004-4	0.25	de	2	abcde
WSU 2366	0.25	de	2.25	abcde
ORUS 4291-1	0	e	0.5	de
ORUS 4722-1	0	e	0	e
ORUS 4864-1	0	e	1.25	cde
WSU 2068	0	e	2.25	abcde
WSU 2162	0	e	2.5	abcde

[z]Rating was an a scale 0-5, where 0 = dead plant; 5= vigorous, thriving

[y]Ratings within a column followed by the same letter are not significantly different at $P<0.05$.

Table 2. Root rot tolerance of WSU selections and standard cultivars evaluated for two years after the establishment year 2018.

Selection	Rating 2019^z		Rating 2020^y	
WSU 2442	5.0	a^x	3.3	a
WSU 2234	4.3	ab	2.3	abcd
WSU 2376	4.0	abc	2.5	abc
Willamette	4.0	abc	1.0	bcd
WSU 2385	3.8	abc	3.0	ab
WSU 2603	3.8	abc	3.0	ab
WSU 2278	3.8	abc	2.8	abc
WSU 2195	3.8	abc	2.0	abcd
WSU 2407	3.5	abc	2.8	abc
WSU 2298	3.3	abc	2.8	abc
WSU 2372	3.3	abc	2.8	abc
WSU 2162	3.0	abc	1.3	abcd
WSU 2510	3.0	abc	1.3	abcd
Cascade Harvest	3.0	abc	1.0	bcd
WSU 2595	3.0	abc	0.8	cd
WSU 2511	2.8	abc	1.3	abcd
WSU 2348	2.5	abc	3.0	ab
WSU 2377	2.5	abc	3.0	ab
WSU 2506	2.5	abc	1.5	abcd
Meeker	2.5	abc	0.8	cd
WSU 2437	2.5	abc	0.3	d
WSU 2600	2.0	bc	1.0	bcd
WSU 2432	1.8	bc	0.8	cd
WSU 2425	1.5	c	0.3	d
Non-replicated				
WSU 2202	3.3		2.0	
WSU 2357	3.0		2.7	
WSU 2366	1.3		1.3	
WSU 2421	4.0		1.3	
WSU 2505	2.3		1.3	

^{z}Rating was an a scale 0-5, where 0 = dead plant; 5= vigorous, thriving
^{y}Weed pressure due to delayed field activities due to COVID in 2020 caused overall vigor of plants to be lower than expected. Comparative ratings within the column are valuable but not necessarily across years.

^{x}Ratings within a column followed by the same letter are not significantly different at P<0.05.

Table 3. Establishment of WSU selections and standard cultivars planted in 2019 in a root rot infested area at WSU Puyallup.

Selection	Establishment Rating 2020^z

Cascade Harvest	1.5
Meeker	2.3
ORUS 3021-2	3.8
ORUS 4545-2	3.5
Willamette	3.3
ORUS 5094-1	2.8
ORUS 5104-2	2.8
Twilight	2.8
WSU 2162	2.8
ORUS 3381-3	2.5
ORUS 4412-2	2.5
ORUS 4716-1	2.3
ORUS 4959-1	2.3
WSU 2516	2.3
WSU 2605	2.3
ORUS 4487-1	2.0
ORUS 4222-1	1.8
ORUS 4858-2	1.8
ORUS 4870-2	1.8
ORUS 4974-1	1.8
ORUS 4985-1	1.5
ORUS 5106-1	1.5
WSU 2363	1.5
ORUS 5094-2	1.3
WSU 2277	1.3
ORUS 3032-3	1.0
ORUS 4535-1	1.0
ORUS 4965-3	1.0
WSU 2481	1.0
ORUS 4693-2	0.8
ORUS 5106-3	0.8

[z]Rating was an a scale 0-5, where 0 = non established dead plant; 5= vigorous, thriving
[y]Weed pressure due to delayed field activities due to COVID in 2020 caused overall vigor of plants to be lower than expected. Comparative ratings within the column are valuable but not necessarily across years.

2021 WASHINGTON RED RASPBERRY COMMISSION
RESEARCH PROPOSAL

Continuing Project Proposal **Proposed Duration: 1 year**
PROJECT: 13C-3755-5641
TITLE: Red Raspberry Breeding, Genetics and Clone Evaluation
CURRENT YEAR: 2020

PI:	Wendy Hoashi-Erhardt
Organization:	WSU Puyallup Research and Extension Center (WSU-PREC)
Title:	Senior Scientific Assistant
Phone:	253-445-4641
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Address:	2606 W Pioneer Ave., Puyallup, WA 98371

Cooperators: Northwest Berry Foundation, Mary Peterson and Michael Hardigan, USDA-ARS, Bernadine Strik and Pat Jones, OSU; Michael Dossett, BC Berry Council; Tom Walters, Walters Ag Research; Julie Enfield and Lisa Jones, Northwest Plant; Randy Honcoop, other regional growers

Year initiated: 1987 **Current year:** 2020 **Terminating Year:** continuing

Project Request: **$ 75,758**

Other funding sources:
Agency Name: Northwest Center for Small Fruits Research
Amt. Awarded: $32,299
Notes: Funds will be used to provide partial technical support for the program.

Agency Name: Northwest Center for Small Fruits Research
Amt. Awarded: $86,432
Notes: Funds are to evaluate two new red raspberry cultivars , 'Cascade Premier' and WSU 2188, for Individually Quick Frozen (IQF) processing quality, yield, pest tolerance, and winter hardiness. This project aims to fully evaluate the commercial performance of two newly available raspberry cultivars that have the potential to greatly benefit the PNW red raspberry industry.

Description: The program will develop new red raspberry cultivars for use by commercial growers in the Pacific Northwest, with emphasis on new cultivars with high yield, machine harvestability, root rot tolerance and raspberry bushy dwarf virus (RBDV) resistance with superior processed fruit quality. Using traditional breeding methods, the program will produce seedling populations, make selections from the populations and evaluate the selections through multiple stages of performance assessments for yield, plant horticultural characteristics, disease tolerance, and fruit quality, including firmness, color, flavor, and size. Selections will be evaluated for adaptation to machine harvestability by planting selections with cooperating growers. Promising selections will be propagated for grower trials, leveraging grower trial data toward cultivar release decisions. Wendy Hoashi-Erhardt is acting as program lead for the program. In addition to the essential annual activities of this breeding program, a special focus will be directed at preserving germplasm, pivoting the parts of the breeding program toward WSU Mount Vernon, and IQF processing evaluation of advanced clones. Additionally, it is a priority of the current breeder to strengthen the collaborative relationships and active projects between regional breeders, horticultural researchers, extension specialists, and nursery and grower cooperators.

Justification and Background: Washington's growers are leaders in the production of the processed red raspberry in the U.S., and they compete closely with California's industry as well as with international players. To maintain and enhance their competitiveness in this valuable specialty market, Washington's growers need new cultivars emerging from the WSU breeding program. The timeliness of this project lies in three main factors: 1) WSU is one of 3 US public programs breeding floricane-fruiting red raspberry; 2) the cooperation between growers, processors, and researchers is strong; and 3) Washington growers critically need a competitive edge.

New cultivars emerge through an annual cycle of germplasm collection and maintenance, new crosses, new selections from previously planted seedlings, successful propagation, and extensive selection evaluations for machine harvestability, yield, harvest season, fruit quality, and response to disease and abiotic factors. These evaluations occur in research-scale plots at WSU-PREC and other research facilities and commercial-scale plantings across the region. The program proposes to continue the annual plant breeding activities that form the basis of successful plant breeding, as well as intensive evaluations of elite red raspberry selections to accelerate their release as cultivars for Washington's red raspberry industry.

WSU's small fruit breeding program has made significant gains incorporating machine harvestability, excellent fruit quality, and root rot tolerance into its elite germplasm in the last 15 years. This is despite the lack of a machine harvester at the Puyallup REC and a distance of 120 miles between WSU Puyallup and Whatcom County. It represents the high efficiency and value of plant breeding decisions conducted under Pat Moore's and now Wendy Hoashi-Erhardt's direction. This program recently leveraged WRRC funding to secure new funding in evaluating two new WSU genotypes for IQF quality and performance.

WSU's plant breeding program is at a critical period in its tenure. Outside of Oregon, New York, and British Columbia, there is no other floricane-fruiting red raspberry breeding program in the continental United States. Oregon's program is very small, with fewer than 800 floricane-fruiting seedlings planted in 2020 and unlikely to grow in the next year with a vacant USDA breeder position. New York germplasm is unlikely to produce cultivars for Washington's specialty processed market. The BC and WSU breeders work cooperatively to test each other's germplasm and coordinate evaluations. To attract an excellent new faculty breeder to this program, the core germplasm collections need to be preserved, and the active annual processes of traditional breeding strengthened.

Relationship to WRRC Research Priorities: This project addresses a first-tier priority of the WRRC: Develop cultivars that are summer bearing, high yielding, winter hardy, machine-harvestable, disease resistant, virus resistant and have superior processed fruit quality.

Objective: Achieve the next stage of development of new summer-fruiting red raspberry cultivars with improved yields and fruit quality, and resistance to root rot and raspberry bushy dwarf virus; conduct on-farm and disease evaluations to accelerate the release of advanced selections adapted to machine harvesting.

Procedures:

1. Elite advanced selections identified with excellent fruit quality, machine harvestability and high potential yield will be assessed for virus status, then propagated and evaluated at regional grower trials, cooperatively with NBF, Walters Ag Research, and growers.
2. Advanced selections from partnering breeding programs and WSU will be evaluated in replicated plots planted in 2018, 2019, and 2020 for Phytophthora root rot resistance. A new planting of new selections and regional cultivars will be planted in 2021.
3. Crosses will be made for summer fruiting cultivar development, with parents identified as having machine harvestability, root rot tolerance, RBDV resistance, yield and flavor.
4. Seed from crosses made in 2019 will be sown and seedlings grown in a long term pot nursery in spring 2021.
5. Selections will be made among the seedlings planted in 2019. Seedlings will be subjectively evaluated for yield, flavor, color, ease of harvest, freedom from pests, appearance, harvest season and growth form. Based on these observations, the best 1% of seedlings will be selected for propagation and further evaluation. The selected seedlings will be propagated through tissue culture for further testing. Selections that are not successfully established in tissue culture will be propagated by root cuttings, grown in the greenhouse and then propagated by tissue culture.
6. Eight-plant plots of each selection will be planted with a grower for machine harvesting trial. Three plants of each selection will be planted at WSU Puyallup in observation plots.
7. The machine harvesting trials that were established in 2018 and 2019 will be harvested in 2020. Evaluations will be made multiple times through the harvest season.
8. Samples of fruit from promising selections will be collected and analyzed for soluble sugars, pH, titratable acidity and anthocyanin content.
9. Selections that appeared to machine harvest well in recent plantings will be planted in a second machine harvesting trial, in replicated yield and fruit quality plantings at WSU Mount Vernon (separately funded), and screened for root rot tolerance and RBDV resistance.

Anticipated Benefits and Information Transfer:

Because of the project, selections will advance toward release as a new cultivar. Information on root rot response, machine harvestability, and other traits of interest will be available to develop new breeding populations to further the industry's breeding goals. Through these outcomes, the competitiveness of Washington's red raspberry growers in the processed market will be enhanced.

Promising selections and cultivars will be displayed at field days. Presentations and reports will be made on breeding program activities at grower meetings, in refereed journals, and through the program's strong partnership with the Northwest Berry Foundation and their regional newsletter.

References:

Moore, P.P., Hoashi-Erhardt, W., Finn, C.E., Martin, R.R., and Dossett, M. (2019). 'WSU 2166' Red Raspberry. HortScience *54*, 564–567.

Moore, P.P. and Hoashi-Erhardt, W.K. 2019. Comparison of Selection for Root Rot Tolerance and Machine Harvestability. Acta Hort. accepted.

Budget:

Budget		2021-2022
Salaries - 00		$ 21,696
Plant Technician (0.50 FTE)	$ 21,696	
Time-slip Wages - 01		$ 29,400
Goods/Services - 03		$ 8,000
Machine harvest trials	$ 1,000	
Land use fees	$ 2,000	
Supplies	$ 5,000	
Travel - 04		$ 1,239
Benefits - 07		$ 15,423
Total Direct Costs		**$ 75,758**

Budget Justification

Salaries and Wages:
Plant Technician. Plant Tech 3 Pugh will prepare and till fields, maintain equipment, design and plant plots, scout and treat pest problems, prune, trellis, do other plot maintenance, and supervise temporary employees. This equates to 0.5 FTE ($21,696).
Non-student temporary worker. A temporary worker will conduct tissue culture and greenhouse propagation, at a wage of $20/hr for 15 hrs/week for 50 weeks ($15,000)
Student and temporary worker. Seasonal workers will harvest fruit, collect data under supervision of PI, maintain plots, and do field work. This equates to 960 hours at $15/hr ($14,400).

Benefits. Plant Technician benefits are $12,613 for 0.5 FTE. Temporary employee benefits amount to $2,810.

Goods and Services.
Machine harvesting (MH) trials**.** Cooperating grower is paid as a service contractor to maintain MH trial, harvest plots, and communicate with researcher. Total is $1,000.
Land use fees. WSU farm services fees for seedling, selection, and germplasm plantings amount to 20 acres at $100/acre ($2,000).
Supplies. Crop protection products, fertilizers, potting media and containers, irrigation equipment, greenhouse electricity, harvest equipment and consumables, and laboratory reagents and consumables will be needed to conduct this work ($5,000).

Travel. Travel for the project, including to visit trial plots, meet with collaborators, and present results are estimated to be 9 trips between Puyallup and Lynden (round trip and local = 308 miles) in one year. (7 trips x $0.575/mile x 308 miles = ~$1,239).

Current Support for Wendy Hoashi-Erhardt

Name (List PI #1 first)	Supporting Agency and Project #	Total $ Amount	Effective and Expiration Dates	% of time committed	Title of Project
Hoashi-Erhardt	Northwest Center for Small Fruit Research	$33,000	2020-2021	10%	Small Fruit Breeding in the Pacific NW
Walters, TW and Hoashi-Erhardt	Northwest Center for Small Fruit Research	$21,000	2020-2023	3%	Trials of Advanced Raspberry selections to evaluate suitability for IQF processing and to promote adoption
Hoashi-Erhardt	Washington Red Raspberry Commission	$70,000	2020-2021	20%	Red Raspberry Breeding, Genetics and Clone Evaluation
Hoashi-Erhardt	Oregon Strawberry Commission	$6,000	2020-2021	2%	Genetic Improvement of Strawberry
Amonette, J.E., Chen, S., Collins, D. P., Gang, D. R., Garcia-Perez, M., Jobson, B. T., Xiong, X., Yorgey, G. G. Seefeldt, S. S., Hoashi-Erhardt	Washington Dept of Ecology	$450,000	10/19 – 6/21	2%	Waste to Fuels Technology Partnership

Pending Support

Name (List PI #1 first)	Supporting Agency and Project #	Total $ Amount	Effective and Expiration Dates	% of time committe d	Title of Project
DeVetter, L.W. and W. Hoashi-Erhardt	WRRC	$54,086	1/2021-12/2024	3%	Advanced machine harvest selection trials for raspberry grown in northwest Washington

2021 WASHINGTON RED RASPBERRY COMMISSION RESEARCH PROPOSAL

New Project Proposal **Proposed Duration:** 4 years

Project Title: Advanced machine harvest selection trials for raspberry grown in northwest Washington

PI: Lisa Wasko DeVetter
Organization: Washington State University (WSU)
Title: Associate Professor
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Address: 16650 State Route 536
City/State/Zip: Mount Vernon, WA, 98221

Co-PI: Wendy Hoashi-Erhardt
Organization: WSU
Title: Senior Sci Asst/Plant Breeder
Phone: 253.445.4641
Email: wkhe@wsu.edu
Address: 2606 W Pioneer Ave.
City/State/Zip: Puyallup, WA 98371

Cooperators: None

Year Initiated 2021 **Current Year** 2020 **Terminating Year** 2024

Total Project Request: Year 1: $11,888; Year 2: $13,818; Year 3: $14,048; Year 4: $14,332

Other funding sources: None

Description:
For years, the Washington State University (WSU) raspberry breeding program was based in Puyallup. Thanks to an injection of critical funding provided by the Washington Red Raspberry Commission, the new raspberry breeding position will likely move to the WSU Northwestern Washington Research and Extension and Center (WSU NWREC) in Mount Vernon, Washington. This move allows the position to be closer to the raspberry industry concentrated in Whatcom County. However, the new faculty lead for the breeding program has not been identified and the position search is pending. To maintain progress of the former program led by the recently retired Dr. Moore, Ms. Wendy Hoashi-Erhardt and DeVetter are proposing to establish a new advanced selection trial at WSU NWREC. Such a trial will allow promising selections to be systematically evaluated for machine harvestability, yield, fruit quality, and overall performance, thereby allowing the breeding pipeline to continue to progress even though a faculty lead in raspberry breeding is absent. In addition, establishing this trial and transferring some of the plant material from Puyallup to WSU NWREC will facilitate the transition and success of the new raspberry breeder and a collaborative partnership with the Small Fruit Horticulture program led by DeVetter.

Justification and Background:
The success of any agricultural product relies largely on good genetics. For the northwestern Washington raspberry industry, genetics has been instrumental in providing cultivars that are machine harvestable with high fruit quality and some levels of disease tolerance or resistance. However, breeding is not static and new cultivars are needed to help growers meet the evolving

challenges they face that threatens profitability. Essential traits growers need in their summer-bearing raspberry cultivars include high yield potential, machine harvestable, superior fruit quality for the processed market [including individually quick frozen fruit (IQF)], and tolerance or resistance to cold, diseases, and/or viruses.

Raspberry breeders in the Pacific Northwest (PNW) have historically enjoyed a successful and collaborative partnership, whose activities have led to the release or co-release of several cultivars. Yet the raspberry breeding landscape is changing with the recent retirement of Dr. Moore and unfortunate loss of Dr. Finn. The hiring of a new raspberry breeder based at WSU NWREC in Mount Vernon is on WSU's hiring agenda, but the timing of that hire is uncertain (particularly in light of the pandemic). In order to keep the pipeline of breeding and advancing promising selections going in Washington State, we propose to establish an advanced selection yield and fruit quality trial at WSU NWREC that will be overseen and managed by DeVetter and Hoashi-Erhardt. This trial will also help initiate the transfer of raspberry material from Puyallup to Mount Vernon, where the new breeder's lab and program will be based. Furthermore, a selection trial will establish a foundation for more collaborations between DeVetter's horticulture program (also based in Mount Vernon) and the breeding program, which has previously been challenged due to geographical location.

Relationship to WRRC Research Priority(s): This project addresses the top-tier priority: *Develop cultivars that are summer bearing, high yielding, winter hardy, machine-harvestable, disease resistant, virus resistant and have superior processed fruit quality*.

Objectives:

1. Establish a raspberry advanced selection trial at the WSU NWREC, which is closer to the raspberry industry and where the new plant breeding position will be based – *to complete in 2021*
2. Evaluate plant performance in terms of machine harvestability, yield, and fruit quality – *to complete in 2022-2024*
3. Utilize project data to advance promising selections to larger trials with grower cooperators – *to complete 2022 and after the project*

Procedures:
Evaluation plots will be established at the WSU NWREC in Mount Vernon, WA. The field will be established as a randomized complete block with 6-plants/plot for each cultivar/selection randomized three times across the field (6 plants/plot x 3 blocks=18 plants per cultivar/selection). Up to 10 promising selections from the Washington State University Raspberry Breeding program will be planted and evaluated alongside industry standards, 'Meeker', 'WakeField' (and/or 'WakeHaven'), and 'Willamette'. WSU 2188 will also be included, which is nearing release. The planting will be established in spring 2021 on raised beds using black polyethylene mulch for weed management and promotion of crop growth. Mulch will be removed winter 2021 to permit application of dry and liquid fertilizers through the drip system. Plants will be conventionally managed following commercial grower practices as much as possible, although pest and disease management will be less intensive to qualitatively assess how the genotypes respond to these biotic pressures. Machine harvestable yield and fruit quality

data will be collected during the fruiting years, 2022 to 2024. In the event a selection performs poorly and is removed from the trial due to poor machine harvestability, low yields, and/or lack of desirable fruit quality characteristics, a new candidate will be added to replace it. In addition, advanced selections from the USDA-Corvallis and BC breeding programs will be evaluated as available.

The following data will be collected in the trial, with timing of data collection indicated after each variable:

- Vegetative growth (primocane number and height) – each year starting Sept. 2021-2024
- Machine harvestability and yield – each year starting July 2022-2024
- Fruit quality (i.e., firmness, average berry size, total soluble solids/°Brix, pH, and total titratable acidity) – determined weekly from a 100-berry sample/plot during harvest starting July 2022-2024

In addition, we will hold annual field days for growers to evaluate the plants and resultant fruit, as well as to solicit their feedback on commercial acceptability of the evaluated selections. Our first field day would be in 2022, when the planting produces its first crop. If large gatherings are not allowed due to the pandemic, we will digitize our field day in the form of a short video.

Anticipated Benefits and Information Transfer:
Having productive and adapted cultivars that meet growers' needs is essential for ensuring the long-term success of the raspberry industry. Success in cultivar development requires a mechanism to systematically evaluate advanced selections in a field setting in order to maintain a pipeline of evaluation and further advancement of promising material. This proposal provides that mechanism while also establishing plots at WSU NWREC, which will help accelerate the new WSU Small Fruit Breeding Material position by having plant material at the location. Results will be shared during annual field days, conferences, and through reports made in the WSU *Whatcom Ag Monthly*.

Budget: *Indirect or overhead costs are not allowed* unless specifically authorized by the Board

	2021	**2022**	**2023**	**2024**
Salaries[1/]	$4,235	$4,404	$4,580	$4,763
Time-Slip[2/]	$3,140	$5,864	$5,919	$5,977
Operations (goods & services)[3/]	$1,585	$1,935	$1,935	$1,935
Travel[4/]	$348	$232	$232	$232
Meetings	$	$	$	$
Other	$	$	$	$
Equipment	$	$	$	$
Benefits[5/]	$1,582	$1,894	$1,953	$2,013
Total	**$10,890**	**$14,329**	**$14,619**	**$14,920**

Budget Justification
[1/]Salary for Watkinson (technician in DeVetter's program) at $4,235/month and 100%FTE; rates

adjusted for annual inflation.
[2/]Timeslip for DeVetter's program to assist with planting, maintenance, and data collection in field and lab (Year 1: 160 hrs x $14/hr; Years 2-4: 320 hrs x $14/hr); timeslip for Hoashi-Erhardt's program for plant propagation (Year 1: 60 hrs x $15/hr) and fruit firmness evaluation (Years 2-4: 8 hrs x $14/hr)
[3/]Laboratory/greenhouse supplies and rental ($300/year for Hoashi-Erhardt); annual land rental cost for 1 acre minimum at WSU NWREC ($585/year); fertilizer, irrigation, equipment rental, and pesticides at $700 in year 1, $550/year in years 2-4; $500/year in years 2-4 for machine harvester maintenance and repair.
[4/]Travel for Hoashi-Erhardt for planting and transport of selections (one trip in year 1 at $348) and 2 trips/year for years 2-4 to evaluate selections ($232).
[5/]Benefits for Watkinson at 30.3%; benefits for timeslip at 9.6%.

*Budget approved by Jean Canonica on Dec. 10, 2020

Project No: (Tom P, do you have this?)

Title: Coordinated Regional on-farm Trials of Advanced Raspberry Selections and Newly Released Cultivars

Personnel: Tom Peerbolt, Peerbolt Crop Management; Wendy Hoashi-Erhardt, Washington State University; Julie Enfield, Northwest Plants, Eric Gerbrant, Blue Sky Horticulture; Tom Walters, Walters Ag Research.

Reporting Period: 2020

Accomplishments:

- Collected data on plant vigor, fruit quality, machine harvest quality, disease response and grower impressions from three trials of WSU raspberry selections planted in 2017 and 2018

- With grower-cooperators, established three new trials of WSU and OSU selections Spring 2020, and one additional new trial Fall 2020.

- Shared results with breeders and the grower community

Summary of results:
Cascade Premier (WSU 2166): beautiful early fruit, excellent flavor, very good root rot resistance. However, not nearly as much fruit as Wakehaven, and not as firm as Wakehaven Some lateral damage by mid-season. Also noted a disturbing disease on green fruit, which might be Botrytis, but no firm diagnosis from Pathologists yet.

WSU 2188: Good fruit appearance and flavor, large fruit. Droopy habit, long laterals. Also shares the green fruit disease problem of Cascade Premier, but not as bad.

WSU 2010 later-blooming, very uniform, cohesive. Plants smaller statured.

WSU 2162 late fruiting, lots cane Botrytis, but fruit disease not bad. Flavor a bit bland, may be susceptible to root rot.

WSU 2068 Good bud break, dark fruit, good flavor. Held up to root rot. firmness questionable.

WSU 2069 more susceptible root rot than 2068. Flavor just OK, not great.

WSU 1914. Root rot problems, flavor tart.

WSU 1962 Long season, fruit well exposed. potential for fresh? Looks OK in the flat.

Selections planted in 2020 include WSU 2068, WSU 2069, WSU 2088, WSU 2130, WSU 2087, WSU 2188, ORUS 1607-2. These were planted in soils ranging from heavy silt loam (root rot pressure) to well-drained sandy loam.

Publications:

- Information included in Hoashi-Erhardt's presentation at the Small Fruit Conference, Lynden WA
- Information to be included in the Small Fruit Update winter 2020-2021

2020 WASHINGTON RED RASPBERRY COMMISSION
RESEARCH PROPOSAL

Project Proposal **Proposed Duration:** 2 years

Project Title: Coordinated Regional on-farm Trials of Advanced Raspberry Selections and Newly Released Cultivars

PI:
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Co PIs
Tom Peerbolt, Northwest Berry Foundation, Portland OR
Mary Peterson – USDA-ARS-HCRU, Corvallis, OR
Wendy Hoashi-Erhardt – Washington State University, Puyallup, WA
Julie Enfield – Northwest Plant/Enfield Farms, Lynden, WA

Cooperators
Eric Gerbrandt, Sky Blue Horticulture, Ltd., Chilliwack, B.C.

Year Initiated_2020__Current Year_2021 Terminating Year_2021__

Total Project Request: 2020 $9,572 **2021: $8,096**

Other funding sources:

In-kind contributions: $450 (estimated 300 plants for trials in 2021. Plant value is $2.50/plant, less $1/plant paid by this grant)

Description

Maintain an ongoing network of regional on-farm grower trials for evaluating red raspberry advanced selections and newly released cultivars from the WSU breeding program, the USDA-ARS/OSU breeding program, and the British Columbia raspberry breeding program combining public and private resources to accelerate the commercialization of our genetic resources. Over the first years of this project the grower/cooperator network has been developed; trials have been established; the infrastructure has been created and implemented for collecting, recording, and disseminating trial information.

This year's proposed work will continue evaluation of elite selections from the WSU and USDA raspberry breeding programs in Whatcom county growers' fields. The program will evaluate trials established 2017-2020, and will coordinate and establish new trials. These will include 1-2 trials with 50-150 plants each of 3-6 selections in each trial. A 2-4A trial of WSU 2188 for IQF will also be established. We will coordinate trial establishment with growers and the nursery, collect trial data directly and through the grower-cooperators, and disseminate trial findings to the industry at meetings, through the Small Fruit Newsletter and elsewhere.

Justification and Background

We are blessed to have three publicly funded raspberry breeding programs in our region, with one of them based in Washington State. All of these programs develop and trial advanced selections, and growers can see these at field days. However, growers need to know more than what they can learn from small-plot trials before committing to a variety, so adoption of new varieties is usually slow. On-farm trials of advanced selections are needed to see plant and fruit performance firsthand in growers' fields, and to increase awareness of the best selections among growers.

The WSU Breeding program is in transition with the retirement of Dr. Pat Moore. There are advanced selections from this program to be evaluated, and Dr. Moore's successor will be able to get off to a faster start if these evaluations are already underway. Along with Wendy Hoashi-Erhandt's management of the breeding program transition, these trials help prepare the new WSU plant breeder for success.

We plan to address this issue because price pressures on raspberry growers are severe, and there is more need than ever for varieties that yield well and consistently produce high-grade fruit. We believe we are well-positioned to do this work, because we have broad experience in canebery production and pest management, along with local expertise in Whatcom county and BC, and a well-developed, well-read vehicle for information dissemination (the Small Fruit Newsletter). We will coordinate the Washington Trials with trials in Oregon and with Eric Gerbrandt's trials with the BC Berry Council.

For the last eight years the Northwest Berry Foundation has been organizing a commodity commission funded pilot program for on-farm evaluations of caneberry selections and cultivars. In the past year, the Foundation improved regional coordination in NW Washington and reduced travel costs by adding Tom Walters as supervisor for these trials. NBF did not add any new caneberry cultivar trials in 2019, using the year to evaluate existing trials and to improve coordination and procedures.

This project is directly related to and in communication with Dr. Eric Gerbrant's cultivar evaluation projects in British Columbia, and to NBF's ongoing caneberry and strawberry evaluations in Oregon. Together, these projects provide a cohesive system for evaluating advanced selections, compiling data on a common system and disseminating the information to the grower community.

Relationship to WRRC Research Priority(s): Priority 1 Develop cultivars that are summer bearing, high yielding, winter hardy, machine-harvestable, disease resistant, virus resistant and have superior processed fruit quality

Objectives:

In 2021, we will:

- Make final evaluations on 2017 and 2018 on-farm trials.
- Make second year (baby crop) evaluations on the three spring-planted 2020 trials.
- Make first year (establishment year) evaluations on the fall-planted 2020 trial
- Establish 1-3 additional trials of the new selection WSU 2087

- Develop list of selections to be included in onfarm trials in future years and coordinate with Northwest Plant Co for their propagation.
- Disseminate coordinated information from BC, WA and OR trials to growers

Procedures:
We will make final evaluations of plants and fruit in the 2017 and 2018 (Minaker and Dhaliwal) trials. Some of the selections in these trials have been discarded, but we will continue to evaluate Selections including: Cascade Premier, WSU 2188, WSU 2068 and WSU 2069. There will be an emphasis on repeated evaluations of fruit quality; we plan to evaluate fruit a minimum of five times on the plant and three times on the harvester. We will look particularly closely at WSU 2188 to evaluate its potential for IQF processing throughout the season. A selection needs to maintain good quality throughout the season to be suitable for IQF.

We will make overwintering and first harvest evaluations of the three spring-planted 2020 trials, including WSU selections 2068, 2069, 2088, 2130 and USDA selection ORUS 4607-2. These will focus on overwintering, fruit quality and relative growth.

Selection WSU 2087 is in one of the 2020 smaller-scale row trials. We will work with growers to establish 1-3 additional row trials of this selection. We will attempt to locate one of these in a field with root rot pressure.

One grower has prepared for field-scale (4A) evaluation of WSU 2188, which will be planted Spring 2021. This planting is large enough to evaluate fruit in an IQF tunnel in 2022 and 2023. These evaluations will be critical to the decision whether to release this selection. Northwest Plant Company indicates that adequate plant numbers should be available for this trial by Spring 2021. Fruit quality in this trial will be evaluated in 2022 and 2023.

Project guidelines
- Tissue culture plants.
- Maximum of 5 red raspberry selections each year.
- Minimum of 3 grower sites each year.
- 50-150 plants/selection/site.
- Sites will include both well-drained soils and sites with root rot.
- Evaluations will be made of previous year plantings concentrating on fruit quality and yields.
- Plantings over four years old will have reached the end of their evaluation period within this program and may be removed. However, some may be left in for longer term observations.
- Advisory group will be communicating as needed to coordinate activities.
- Administrator will be giving periodic updates to participants and will disseminate and archivie information as needed.

Grower/cooperator arrangements
- Testing agreements will be created and approved by WSU and by USDA.
- Agreements will include: on-site visits by other growers and researchers (arranged and agreed to in advance); participation in the evaluation process; and a prohibition of any on-farm propagation of advanced selections.

Anticipated Benefits and Information Transfer:

- The anticipated benefit to the breeding program, growers, propagators, and wholesale nurseries include the system-wide efficiencies achieved by replacing the ad hoc grower trial system by one that is coordinated and supervised.
- The results will be transferred to users by the Northwest Berry Foundation which will be giving periodic updates to Washington red raspberry growers and the industry. Disseminating and archiving information as needed through meeting presentations, newsletters, and production of summary fact sheets.

Budget

	2020	2021
Salaries[1/]	$4,224	**$3,600**
Travel[2/]	648	**$696**
Outreach[3/] `	1,500	**$1,500**
Other (Propagator payments)[4/]	1,200	**$300**
Offices costs (including AgReports)	2,000	**$2,000**
Total	$9,572	**$8,096**

Budget Justification

[1/] **Salaries**

Tom Walters—7 days a year at 8 hours per day at $50/hour including benefits = $2,800
Tom Peerbolt---2 days a year at 8 hours per day at $50/hour including benefits = $800

[2/] **Travel & related expenses**

Tom Walters—5 trips a year at 120 miles per day at $ .58 per mile = $348
Tom Peerbolt---1 round trips per year between Portland and Lynden 600 at $ .58 per mile = $348

[3/]**Outreach**

Outreach will be accomplished by Northwest Berry Foundation giving periodic updates to Washington red raspberry growers and the industry. Disseminating and archiving information as needed through meeting presentations, newsletters, and production of summary 'fact sheets'

[4/] **Plant costs** ($1 per plant) $300

Covers partial cost of plant fee: $1 per plant paid by this grant, remaining $1.50 fee per plant to be paid by grower-cooperator.

Office costs (including use of AgReports system) $2,000

2021 WASHINGTON RED RASPBERRY COMMISSION RESEARCH PROPOSAL

New Project Proposal **Proposed Duration:** 3 years

Project Title: Red Raspberry Cultivar Development

PI: Michael Dossett
Organization: RIDC/BC Berries
Title: Geneticist/Breeder
Phone: 604-309-0048
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Address: C/O Agassiz Research Centre
Address 2: 6947 Lougheed Hwy
City/State/Zip: Agassiz, BC V0M 1A0

Co-PI:
Organization:
Title:
Phone:
Email:
Address:
Address 2:
City/State/Zip:

Cooperators:
Wendy Hoashi-Erhardt, Michael Hardigan

Year Initiated_____ **Current Year** **2021** **Terminating Year** **2021**

Total Project Request: **Year 1 $10,000** **Year 2 $10,000** **Year 3 $10,000**

Other funding sources: *(If no other funding sources are anticipated, type in "None" and delete agency name, amt. request and notes)*
Agency Name: Province of BC, Raspberry Industry Development Council, Lower Mainland Horticultural Improvement Association, Agriculture and Agri-Food Canada for funding raspberry work (also pursuing funding from BC Blueberry Council, BC Strawberry Growers' Association, to support the blueberry and strawberry portions of our work).

Amt. Requested/Awarded: *(retain either requested or awarded and delete the other)*
Notes: We have received approval of our 5-year proposal from the federal government (April 2018- March 2023). We have also received a commitment from the Province of BC to help support our efforts. Our overall funding for the program was approved at a 60:40 federal:industry matching ratio with the raspberry portion valued at ~$236k annually. Our overall costs have gone up because of a lower matching ratio from past years (previously was 75:25), the need to replace technical support that was provided by Agriculture Canada in the previous policy framework and which is no longer being provided to the program, and the implementation of rental fees for our access to AAFC facilities and land. We have sought in-kind support from some of our growers, Littau harvester, and other sources, which we have been able to leverage towards the receipt of federal funds. After all sources except for the RIDC are accounted for, the outstanding cash portion of the raspberry breeding effort is valued at $59,376, the bulk of which will be covered by the RIDC, the funding we are asking for from the Washington Red Raspberry Commission will be used to help offset this amount, specifically to help hire summer labor for planting, harvest, and field care.

Description: Description: This project is to support the continued effort to breed raspberry cultivars adapted to the PNW. Breeding for disease and insect resistance, yield, and fruit quality is the most sustainable way to address industry needs and ensure long-term competitiveness. We will continue to cross and select from a diverse gene pool and evaluate previous selections with the following specific objectives:

- Develop red raspberry cultivars and elite germplasm, stressing suitability for machine harvest, fruit quality, as well as resistance to root rot, RBDV and other diseases
- Develop red raspberry cultivars and elite germplasm that is suitable for machine harvesting and produces high yields of superior fruit quality and fruit rot resistance.
- Identify and select raspberries with dark red fruit for processing that also exhibit characteristics that are suited for IQF processing
- Identify and incorporate new sources of resistance to aphids, spider mites, and other insect pests.
- Continue development and testing of molecular tools to speed up the process of selecting and identifying parents and seedlings in the program with durable disease resistance and outstanding quality traits.

Justification and Background:
The red raspberry industry is facing challenges with diseases, increased production costs and competition from the global marketplace. Genetic improvement is one of the most sustainable ways for the raspberry industry to maintain its competitive edge in the long-term. Improved quality, yield, and resistance to pests and diseases to help alleviate these problems are realistic and achievable goals that will benefit raspberry producers in Washington State.

The BC breeding program has a long history of producing cultivars with excellent fruit quality characteristics and has been making steady progress in recent years to combine this with improved resistance to *Phytophthora* root rot and RBDV. In 2012, we expanded our efforts to identify machine-harvestability in our selections by contracting with a local grower to machine harvest our replicated plots. This effort was so successful we expanded it to additional plots and evaluation of seedlings in 2013. We plan to continue this, because we believe this is the fastest way to identify selections with merit and weed out selections that lack potential for the majority of PNW growers. Historically, one of the difficulties we have encountered is that our material with a high degree of root rot tolerance has not been machine-harvestable and has been a bit soft. The 2016 and 2017 seasons were our first years of evaluating yield and multi-plant plots of selections that were made from running the machine harvester over seedling plots and crosses that were made using information obtained from machine-harvesting the Clearbrook plots. Through this, we have identified a number of selections with good machine-harvest characteristics and that are expected to have a moderate or high degree of root rot tolerance and have good firmness. Unfortunately, many in this first round have had disappointing yield, however selections in the next round have had better yield and we are adjusting our selection techniques to more readily identify seedling selections with higher yield potential.

While there are currently other raspberry breeding efforts in Washington and Oregon, each program has its strengths and weaknesses inherent in the germplasm base and breeding lines they have established through their history. We will continue to collaborate and exchange information and selections with the programs in Washington and Oregon so that promising material gets evaluated in as many test locations as possible and so that we can continue to combine efforts to complement the strengths of each program. Over the next few years, AAFC has committed to providing limited greenhouse and field space and staff support. While this means that the cost of continuing to staff and run the program has risen dramatically, this project will ensure that the investments of time and money already made towards the program will not be lost and that efforts can continue.

Relationship to WRRC Research Priority(s):
This project directly addresses the WRRC #1 priority to develop cultivars that are summer bearing, high yielding, winter hardy, machine-harvestable, disease resistant, virus resistant and have superior processed fruit quality

Objectives:
Each of the specific objectives listed above will be attempted during the project period and each is an ongoing process that will be addressed in this funding year and in future funding years. While many inferior plants can be identified and eliminated in the early stages of the process, selections must be tested rigorously over a period of several years by the project staff and producers before they can be recommended for release and commercialization. As a result, we work in a rotating system where each year we are making new crosses, selecting from previous selections and discarding selections which don't make the grade during testing.

Procedures:
The breeding program is an ongoing project that continually makes new crosses and selections each year with the objective of developing new cultivars to support the raspberry industry. We are in the first year of a 5-year funding program called Canadian Agriculture Partnership. The program operates on a cycle such that all activities in this project occur at some point in the season of every year. This includes:

- Making new crosses - emphasizing combining the highest yielding parents with machine harvestability and resistance to RBDV and root rot
- Planting new seedling fields from previous year's crosses for future evaluation
- Selection of mature seedling plantings with an emphasis on family yield, fruit quality and machine-harvestability
- Establish replicated trials of selections to assess machine-harvestability, quality, and yield
- Test field plantings for RBDV to establish which selections are susceptible and which may be resistant
- Screen selections in replicated trials for root rot resistance in the greenhouse to establish potential for resistance
- Propagate promising selections for further trial at our substation and on producers' fields.
- Conduct collaborative research and testing with USDA-ARS in Corvallis, WSU, AAFC, and elsewhere.

A specific part of this project with more definite timelines is the development and evaluation of molecular genetics tools to identify markers for insect and disease resistance as well as other traits. The first stage of this work (marker identification) has begun. We are currently in the process of screening markers in two populations that segregate for different sources of root rot resistance, a newly identified source of RBDV resistance, and three sources of aphid resistance (one broken, two unbroken). Basic linkage maps are essentially complete, but we are actively adding markers to these maps to increase their resolution and the ability to identify markers tightly linked to traits of interest. Testing for RBDV infection will be an ongoing process, and we are currently in the process of validating two potential markers for RBDV resistance in this population as well as their transferability to our overall germplasm.

Anticipated Benefits and Information Transfer: (100 words maximum)
Specific benefits that will result from this project include:

- Continued development of new cultivars and selections that will provide alternatives for producers with high fruit quality and improved yield and resistance to pests and diseases.
- Continued development of technologies that will assist this and other breeding programs to more efficiently select promising genotypes in the future.

Results will be transferred to users through regular presentations at field days, and local meetings such as the LMHIA Short Course and the Washington Small Fruit Conference with information on new releases and selections available for testing.

Budget: *Indirect or overhead costs are not allowed* unless specifically authorized by the Board

	2019	2020	2021
Salaries[1/]	$	$	$
Time-Slip	$10,000	$10,000	$10,000
Operations (goods & services)	$	$	$
Travel[2/]	$	$	$
Meetings	$	$	$
Other	$	$	$
Equipment[3/]	$	$	$
Benefits[4/]	$	$	$
Total	**$**	**$**	**$**

Budget Justification

The funding we are asking for will be used to hire summer labor to help with planting and care of breeding plots as well as for harvest of fruit from seedlings and yield trials. See note above regarding matching ratios and how this fits into the overall picture.

Washington Red Raspberry Commission
Progress Report Format for 2020 Projects

Project No:

Title: Red raspberry cultivar development

Personnel:
Michael Dossett
Agassiz Research and Development Centre,
PO Box 1000, 6947 #7 Hwy.
Agassiz, BC, Canada, V0M 1A0
Michael.Dossett@agr.gc.ca Tel: 604-309-0048

Reporting Period: 2020

Accomplishments:

- In 2020, we established ~5200 new seedlings in the field from 2019 crosses, and established a new yield trial with 183 plots of BC and WSU selections. We also evaluated ~10,500 seedlings for the first time and made 26 new selections from these. Many additional seedlings were marked for further evaluation and are expected to be selected next year.
- In 2020, we machine harvested yield trials from 2017 and 2018 plantings, as well as over 5 acres of seedling trial plots planted as replicated families to study heritability of yield components and phenology as well as their genetic correlations to develop a more robust strategy for simultaneously selecting for earliness and high yield. Seedling trial data is still being analyzed but interested parties can contact me for more information.

Results:

- In 2020, yields overall were down slightly from 2019 except in the case of a few genotypes which suffered significant winter injury in 2019.
- In the 2017 yield trial (Fig. 1), BC 10-71-27 stood out as the top performer for the second year in a row. This selection also performed strongly from 2017 - 2019 in the 2015 planting which was removed last winter. It is early (A few days later than Squamish), firm, and machine harvests beautifully, but I am concerned that it may be too light for most processed applications. It will be evaluated for its fresh market potential and is being used in crosses with darker germplasm for its yield potential in the early season and machine-harvest quality.
- WSU 2188 also was impressive in the 2017 yield trial for both its yield and its excellent fruit quality. It has yielded better for us than Cascade Premier in every trial where we have had both planted together, and 2020 was no exception (Fig 1).
- In the first year of harvest from the 2018 Yield Trial, WSU 2069 was the standout performer, with excellent fruit quality and higher yields than WSU 2068, though WSU 2068 may have had slightly better fruit quality. BC 13-31-9 also looked excellent with good quality machine harvest fruit and strong yields. This is our first evaluation of it in a multi-plant trial and we will continue to watch it closely.

Fig. 1. Summary of top performers from the 2017 Yield Trial at the Clearbrook station

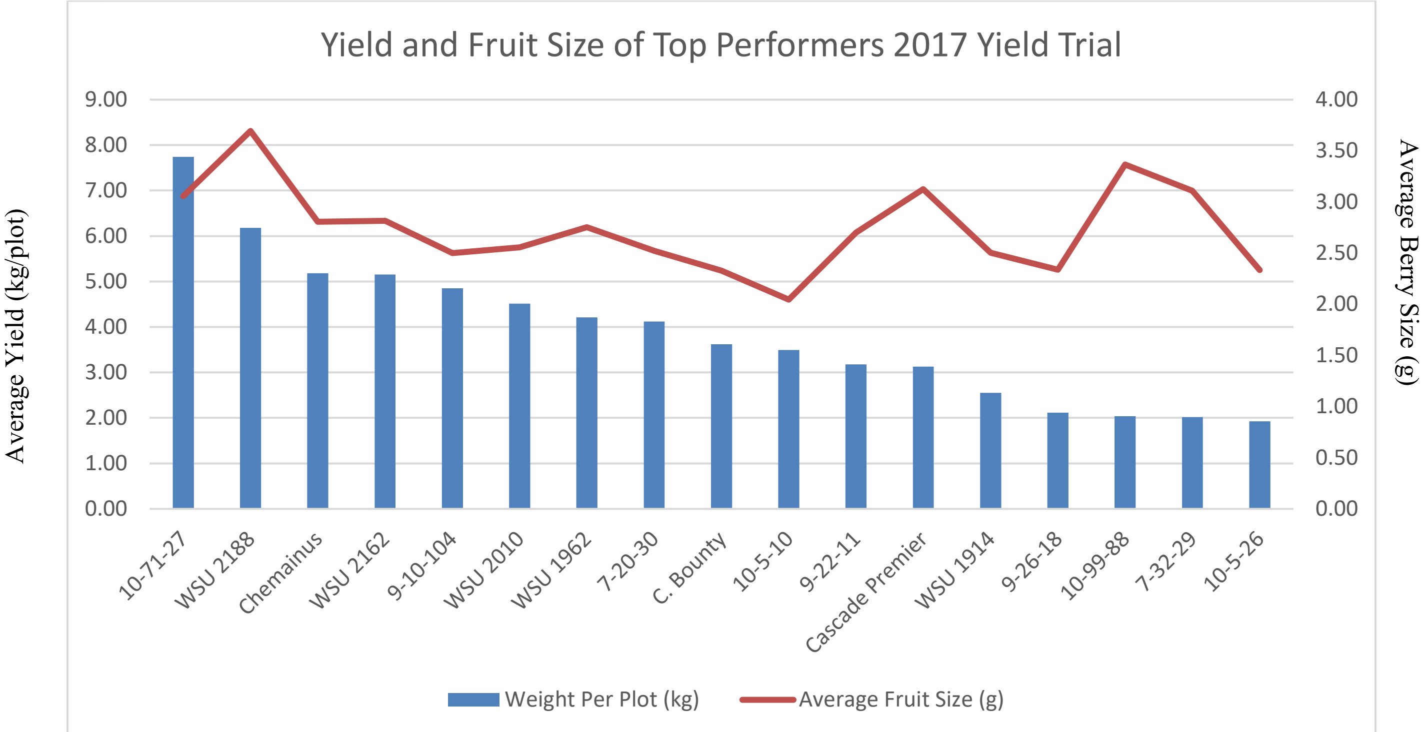
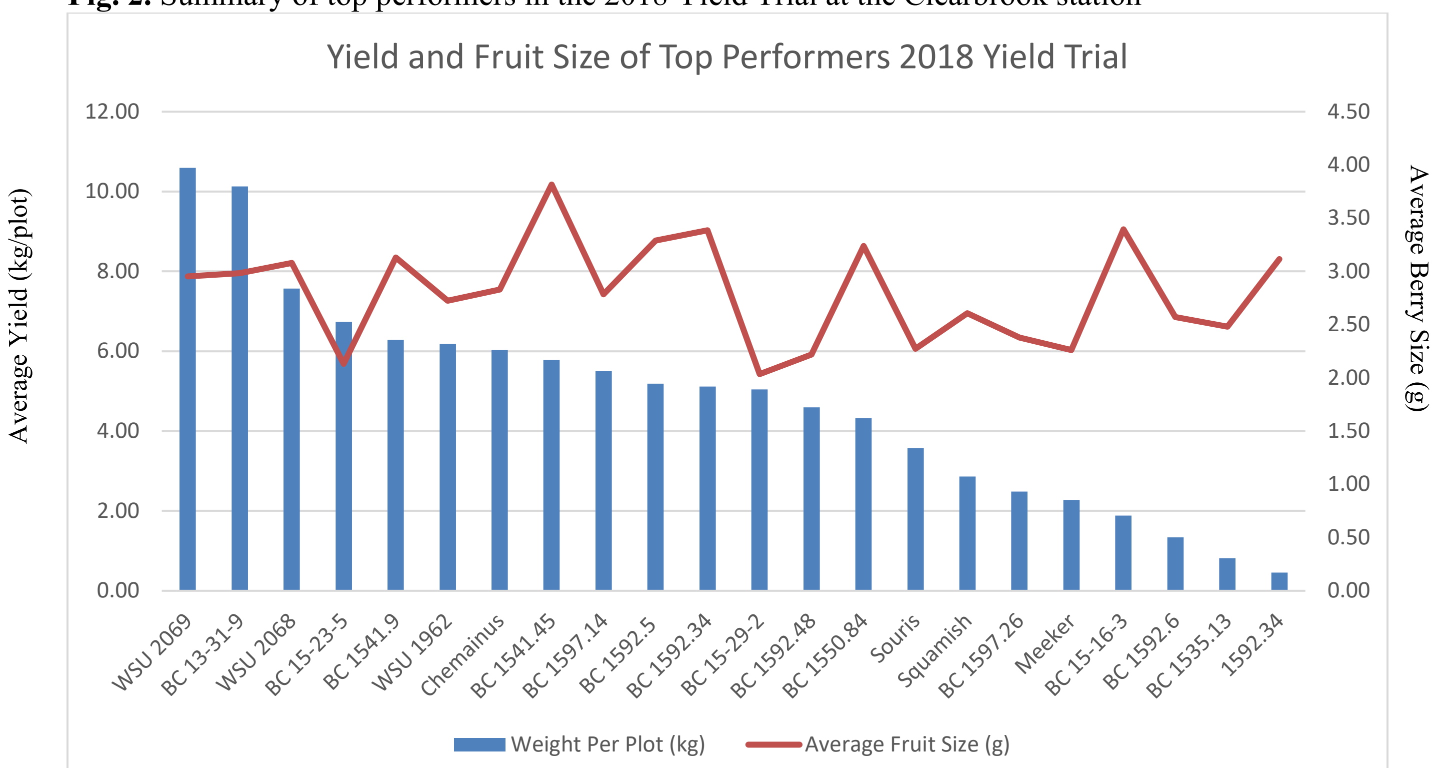


Fig. 2. Summary of top performers in the 2018 Yield Trial at the Clearbrook station



Publications: We had no new publications in 2020 from these trials, but have some in preparation for next year.

Current & Pending Support

Instructions: 1. Record information for active and pending projects. 2. All current research to which principal investigator(s) and other senior personnel have committed a portion of their time must be listed whether or not salary for the person(s) involved is included in the budgets of the various projects. 3. Provide analogous information for all proposed research which is being considered by, or which will be submitted in the near future to, other possible sponsors.					
Name (List PI #1 first)	Supporting Agency and Project #	Total $ Amount	Effective and Expiration Dates	% of Time Committed	Title of Project
Michael Dossett	**Current:** AAFC, BCBC, WBC, LMHIA	$1,694,948	April 1, 2018 – March 31, 2023	55%	Blueberry Germplasm and Cultivar Development for the Pacific Northwest
	AAFC, WRRC, RIDC, LMHIA	$1,232,690	April 1, 2018 – March 31, 2023	40%	Red Raspberry Germplasm and Cultivar Development for the Pacific Northwest
	AAFC, WSC, BCSGA, LMHIA	$154,086	April 1, 2018 – March 31, 2023	5%	Strawberry Germplasm and Cultivar Development for the Pacific Northwest
	Pending:				

ENTOMOLOGY

Project Proposal to WRRC **Proposed Duration:** 3 Years

Project Title: Developing New Miticides on Raspberry

PI: Alan Schreiber
Organization: Agriculture Development Group, Inc.
Title: Researcher
Phone: 509 266 4348 (office), 509 539 4537 (cell)
Email: aschreib@centurytel.net
Address: 2621 Ringold Road, Eltopia, WA 99330

Cooperators: Tom Walters, Walters Ag Research

Year Initiated: 2021 **Current Year:** 2021 **Terminating Year:** 2024

Total Project Request: Year 1 - 12,000 Year 2 - 12,000 Year 3 - 13,000

Other Funding Sources: We have obtained a grant to the Washington State Commission on Pesticide Registration to support the WRRC effort.

Justification and Background:

Historically, two-spotted spider mites have been a moderately important but manageable pest of raspberries. Red raspberries are naturally susceptible to mites. During harvest, picking machines travel through fields every 24 to 36 hours. Tractors applying pesticides twice a week and other field activities create a great deal of dust that exacerbates mite outbreaks. Growers spray for primocane suppression two to three times per season which forces mites living on weeds to move up into the canopy.

Recently Washington red raspberry growers have had increased difficulty controlling two-spotted spider mites in commercial fields. The increased difficulty in controlling mites is thought to be due to one or two reasons. First, the "recent" movement of spotted wing drosophila (SWD) into raspberry fields has resulted in an increased number of insecticides applied during the 40 or so days of harvest. This pest is particularly challenging for growers of IQF fruit which has zero tolerance for SWD. This problem is even more acute for growers exporting fruit as maximum residue limits (MRLs) limit products they can use. Some of the products that are considered essential to SWD control include pyrethroid insecticides which likely are fomenting mite outbreaks by disrupting natural controls of mites. The standard miticide available for use during harvest is Acramite (bifenazate). Growers and crop advisor believe that due to heavy reliance on this product mites have developed resistance and control is failing.

There are several miticides registered for use on raspberries but they have use limitations that limit or prevent their use. Abamectin cannot be used near or during harvest due to the 7 day preharvest interval. Vendex and Savey have MRL restrictions that limit their use to early season. Zeal can be used, but only once and it targets eggs only, so it is used in early season when mite nymph and adult numbers are low. Kanemite is considered ineffective. Current mite programs will use Vendex or Savey early in the season followed by two applications of Acramite and one application of Zeal in mid-season and abamectin postharvest. However, growers feel that Acramite has become ineffective. Some growers insist that two spotted spider mites have developed resistance to Acramite (bifenazate). A molecular marker for bifenazate resistance in mites has been identified making detection of resistance straightforward.

Challenges associated with mites have increased so much that the WRRC has made this one of their top research priorities. The industry is interested in finding miticides that have new modes of action with 1 day preharvest intervals and a high level of efficacy. Ideally, with longer periods of residual control and is translaminar. And more ideally, the products can obtain MRLs in key export markets.

Relationship to WRRC Research Priority: This project directly addresses the WRRC RFP Category "Mite Management" a number one priority.

Objective 1. Collect information on two spotted spider mite biology – including a seasonal phenology on when mites first appear on raspberry to determine when first applications should begin.

Objective 2. Generate data on fungicide efficacy against cane blight.

Objective 3. Determine if Acramite resistance is present in two-spotted spider mite in Washington red raspberry.

Procedures:

Biology Data. We propose to collect data on mites from six fields with applications starting at the first detection of mites until one month after harvest. Raspberry leaves and weed leaves from the base of the plant will be collected from fields, packaged and shipped to ADG where they will be put through a mite brush and counted for each life stage by species of mite. A seasonal phenology for mites on raspberries will be constructed. Since yellow spider mite, McDaniels spider mite and European red mite have also been known as the pests of raspberries, mites will be counted by species as well as life stages (eggs, larvae, nymphs and adults). Predatory mites such as Neoseilulus fallacis will be noted.

Efficacy Data. We proposed to conduct a raspberry efficacy trial against TSSM. The trial would be placed in a field with detectable levels of mites with applications beginning just as mites are first detected on the leaves. Application would be by an over the row sprayer. The trial would be a randomized complete block design with four replications. The location would likely be in an area northeast of Lynden, WA where the PI successfully conducted a spider mite trial on raspberry in 2020. Products that are likely to be included are abamectin (Reaper), fenpyroximate (Fujimite), acequinocyl (Kanemite), azadiractin (Aza-Direct), bifenthrin (Brigade), fenpropathrin (Danitol), hexythiazox (Savey), bifenazate (Acramite) cyflumetofen (Nealta), etoxazole (Zeal), and spiromesifen (Oberon). The pyrethroids are being included to determine if their use flares mites as was demonstrated in WSCPR funded research on blueberries in 2020. Growers are interested in obtaining information about Nealta, a BASF product. BASF has expressed interest in allowing Nealta to be registered on raspberry via the IR-4 Project if sufficient positive efficacy data and lack of phytotoxicity data can be demonstrated. The efficacy portion of this project is expected to be a companion project with Dr. Dani Leightle, at Oregon State University. It is our hope that based on one to two years of efficacy data that BASF will allow this product to enter the IR-4 registration process. Applications would follow labeled use patterns or proposed use patterns.

Resistance Data. We plan to collect mites after applications of Acramite during the 2021 growing seasons from multiple fields. These mites will be assayed for the genes associated with Acramite resistance.

Anticipated Benefits and Information Transfer:

Our goal is to develop biological information that will allow improved control of mites, identification of miticides appropriate for registration, submit miticides for registrations via the IR-4 Project and determine whether resistance to Acramite is present in mites in raspberry fields. This information will be communicated to growers by providing written reports for distribution by the Washington Red Raspberry Commission and in growers meetings such as the CHS grower meeting and the Washington Small Fruit Conference.

Budget:	**2021**	**2020**	**2021**
Salaries	5,000	5,000	5,750
Operations	1,000	1,000	1,000
Travel	500	500	500
Contract Research	4,000	4,000	4,000
Benefits	1,500	1,500	1,750

Total	**$12,000**	**$12,000**	**$13,000**

The funds for Contract Research are for chemical applications by Tom Walters.

The Washington State Commission on Pesticide Registration has agreed to contribute $11,500 to this effort contingent on the WRRC supporting the project at $12,000.

Washington Red Raspberry Commission
2020 Final Project Report

Project No: WRRC 13C-3443-33286

Project Title: Improved Management of Lepidopteran Pests in Washington State Red Raspberry

Personnel: Beverly Gerdeman, Hollis Spitler, Ben Diehl and Jordan Johnson

Reporting Period: January – December 2020

Many lepidopteran pests infest both blueberry and red raspberry and freely move between the berry crops. Therefore, in order to provide a more accurate assessment of risk, moth data from both crops have been combined unless otherwise stated, to provide seasonality and risk for Whatcom County red raspberry.

Accomplishments:

- Eight solar-powered light traps were used for lepidoptera collections in both counties.
- Active light trapping was performed with an LED battery-powered blacklight/pop-up tent Skagit – June 18 and May 28, Whatcom - June 25 and July 27.
- Four pheromone traps for Obliquebanded leafroller (OBLR) were monitored at 3 sites in Whatcom and 1 site in Skagit County, beginning mid-April through September 25.
- Eight Orange Tortrix (OT) pheromone traps were monitored from April 1 – June 3.
- Developed OBLR colony from Whatcom County for resistance bioassays.
- Performed resistance bioassays with Diazinon, Imidan (phosmet) and Danitol (fenpropathrin).

Results and Discussion:

Solar Pheromone Traps - Seasonal moth flight activity was low for 2020 compared with 2019 (Fig. 1). Growing degree-days were 3-5 days behind 2019 (L. Coop, OSU). Light traps were monitored weekly but sample quality in the light traps was poor. Samples collected were dry and few suitable for pinning. In addition, growers adopted aggressive spray schedules for control of OBLR.

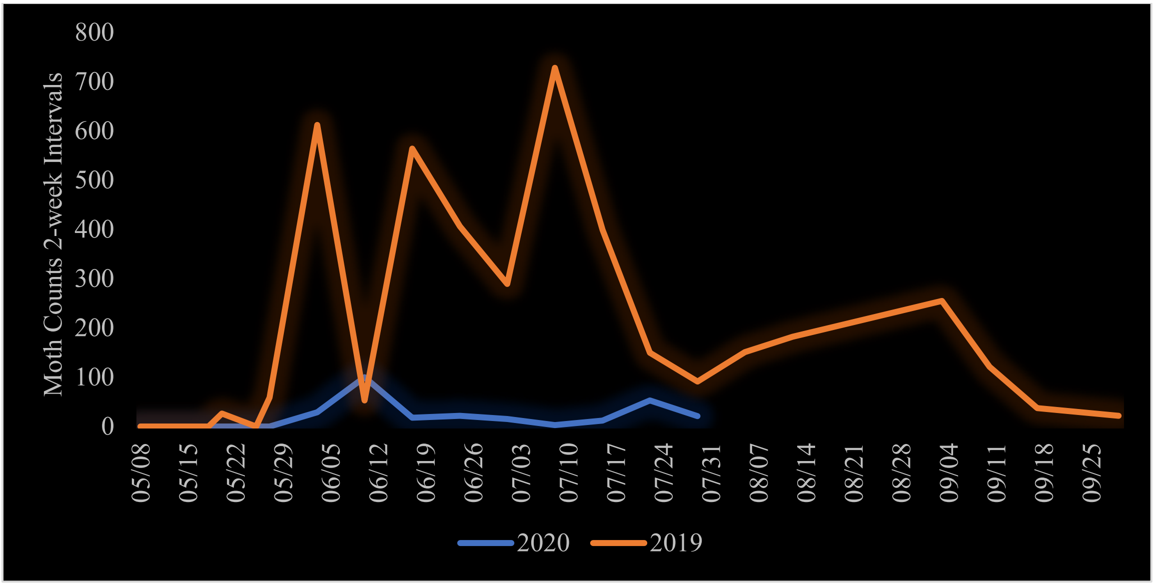


Fig. 1. OBLR Seasonal flight 2019-2020 Whatcom Counties. 2019 anonymous source, 2020 NWREC. Despite the two different sources, our 2020 trapping catches are extremely low compared to any trapping in years past.

Solar-powered light traps are non-selective passive traps. Collections combined from all localities detected 8 identifiable berry pest moths while damaged specimens were reported as unidentified (Table 1).

Table 1. Solar Trap Samples 2020

Location	**Date**	**Taxa**	#
Skagit	6-May	Unidentified Noctuidae	1
Skagit	8-May	Unidentified Noctuidae	1
		Unidentified Tortricidae	1
Skagit	11-May	Unidentified Noctuidae	1
		Hyles lineata	1
		Tyria jacobaeae	1
Skagit	28-May	Unidentified Noctuidae	4
		Unidentified Geometridae	1
Skagit	9-Jun	*Xestia c-nigrum*	2
		Noctua pronuba	1
		Mythimna oxygala	7
		Unidentified Arctiini	1
Whatcom	12-May	Unidentified Tortricidae	1
		Unidentified Geometridae	1
Whatcom	22-May	*Xestia c-nigrum*	1
		Unidentified Pyralidae	2
		Unidentified Noctuidae	3

		Unidentified Geometridae	1
Whatcom	3-Jun	*Deilephila elpenor*	1
		Xestia c-nigrum	1
		Spilosoma virginica	1
Whatcom	11-Jun	*Noctua pronuba*	5
		Unidentified Tortricidae	4
		Unidentified Geometridae	2
		Unidentified Arctiini	2

Unidentified specimens damaged

Active light trapping was performed with an LED battery-powered blacklight/pop-up tent between 7pm and midnight. The light trap was set up close to fields and catches were excellent quality. Nevertheless, catch was low. Trapping in Skagit County occurred – June 18 and May 28. Due to low numbers, Whatcom County trapping events were delayed until night temperatures were warmer with expected increase in moth activity - June 25 and July 27. Light traps are non-selective and trap nontarget moths. Results of the 4 events detected < 10 pest moths. Pests collected = cherry fruitworm (not a pest of red raspberry) and OBLR.

Pheromone traps Obliquebanded leafroller (OBLR) *Choristoneura rosaceana*, were monitored mid-April through September 25. Overall moths averaged 2.6/trap with a single significant peak occurring around 15 April (50). Numbers then dropped, never recovering. Normally there are at least 2 generations in the PNW. These results were low, compared with previous trapping years (Fig. 1).

Orange Tortrix (OT) Argyrotaenia citrana, was monitored from April 1 – June 3. Across 8 weeks with two traps in Whatcom and 6 traps in Skagit. Average moths/trap ranged between 1 and 6 with an overall average of 3 moths/trap. Peaks in flight occurred April 15 (total = 37 for 8 traps) then a slight drop before rising again 3 weeks later May 6 (totals = 42). Numbers dropped after 13 May never rising again. It is unclear if the erratic numbers were influenced by spray events, weather or issues with trapping.

Cutworms Xestia-C-Nigrum (spotted cutworm) pheromones were not available and Bertha armyworm not deployed due to miscommunication with trapper exacerbated by COVID restrictions.

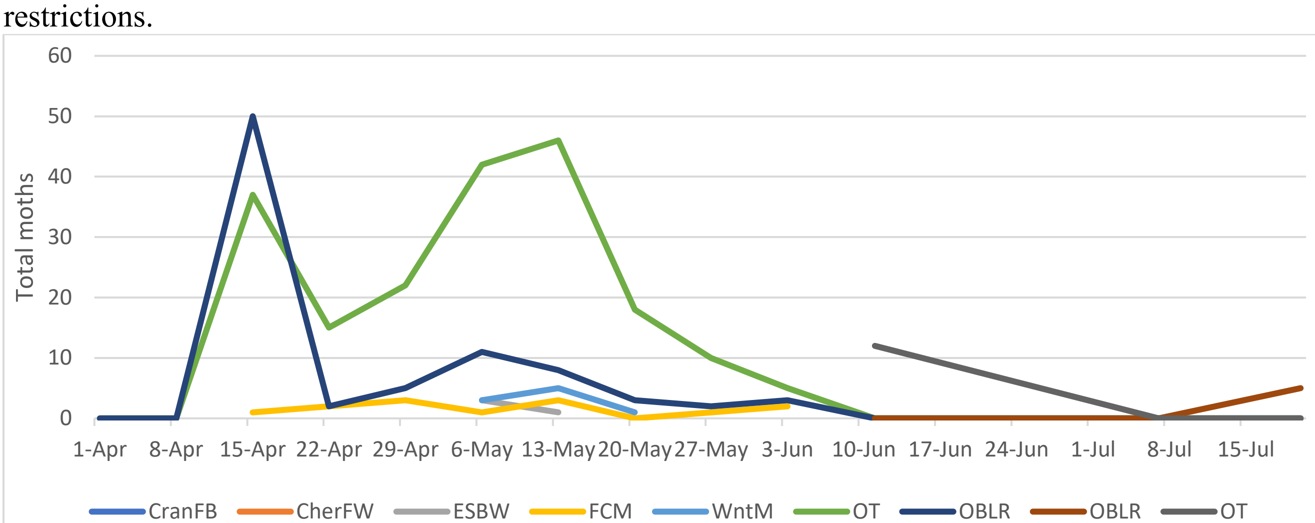


Fig. 2. A total of nine lepidopteran pests were monitored using pheromone traps but of these only OT and OBLR are pests of red raspberry: Cranberry fruitworm (CranFB), Cherry fruitworm (CherFW), Eyespotted bud moth (ESBW), False codling moth (FCM), Winter moth (WntM), Orange tortrix (OT), Obliquebanded leafroller (OBLR). Leafroller traps were pulled at harvest to prevent damage from the harvesters which resulted in 2 lines for both OT and OBLR.

Resistance Bioassays
The OBLR colony intended for the resistance bioassay was to be developed from a Whatcom red raspberry site but despite searching, no caterpillars were found until late July from an abandoned blueberry field source. Because these moths migrate between fields, the population is considered representative of both berry crops for the region. The NWREC OBLR colony was maintained following protocols from Larry Gut, MSU and those developed by J. Brunner, WSU, including use of the modified stonefly diet. By mid-October, the colony was large enough to provide ample 1 to 2-day old larvae, for the resistance bioassays. Although an arrangement had been made to receive a start of the MSU susceptible OBLR colony, no additional response followed the onset of the COVID pandemic however comparison with a UTC provided a reference to identify larval handling effects.

Following a meeting with members of the WRRC /WBC research committee soon after announcement of funding, they provided a list of insecticides they wished to test: Diazinon Ag500 at 1pt/A (Adama), Imidan (registered for blueberry only) 70-W at 1/3 lb/A (Gowan) and *either* Danitol 2.4EC at 16 fl oz/A (Valent) or Mustang Maxx (not selected for this resistance trial). Diet-incorporated resistance bioassays were performed in October using: 2x rate; full field rate; ½ field rate and ¼ field-rate for each active ingredient, along with a UTC. Each dilution was replicated 5 times (125 caterpillars/insecticide).

Results:
All rates of diazinon resulted in 100% mortality. The ¼ rate of Imidan had live caterpillars (Fig. 3) and a % of caterpillars survived in all treatment rates of Danitol (Fig. 4).

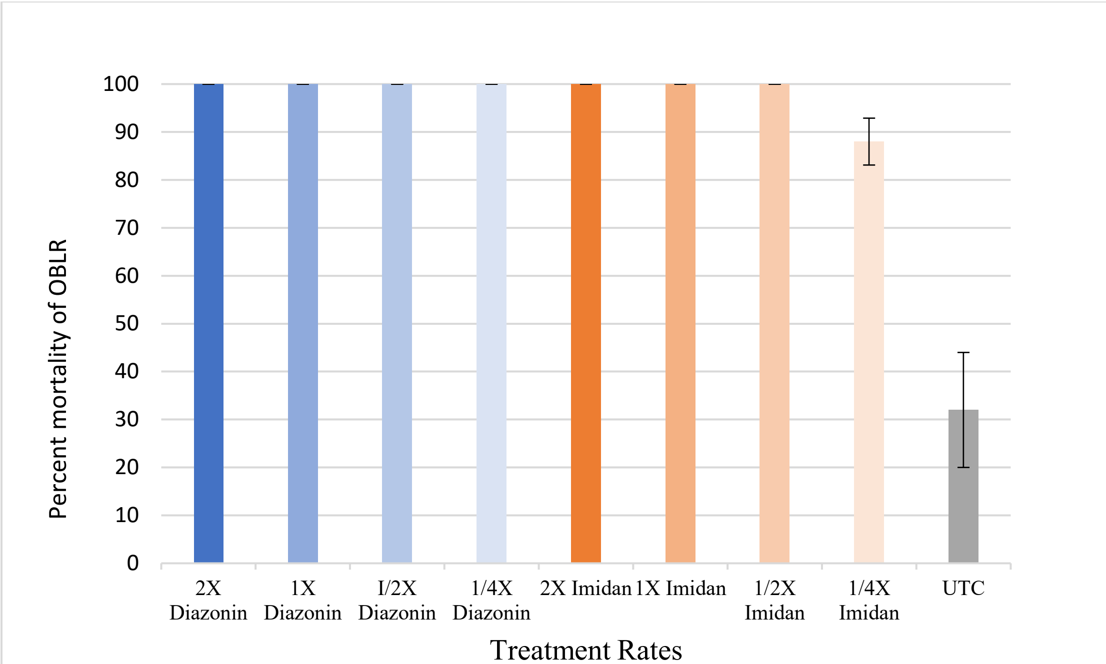


Fig. 3. OBLR % Mortality at 7 DAT for three treatments: Diazinon, Imidan and UTC following resistance bioassays.

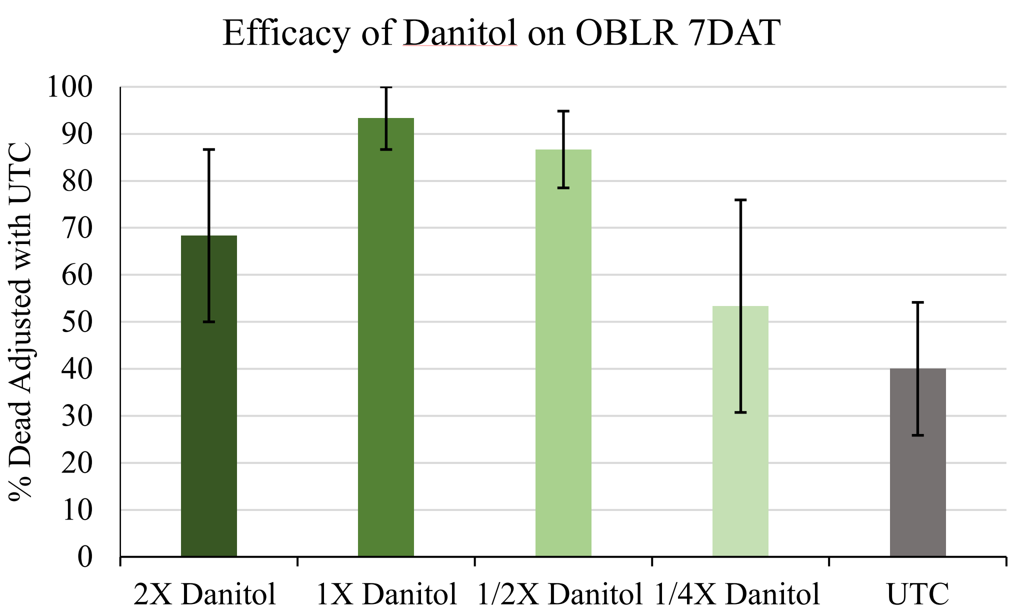


Fig. 4. Efficacy of Danitol for control of OBLR in small fruit at 7DAT.

Probit Analyses:
A probit analysis was performed for the three insecticides. All rates resulted in 100% mortality at 7DAT for Diazinon. (The line, difficult to see, runs along the top of the graph) (Fig. 5).

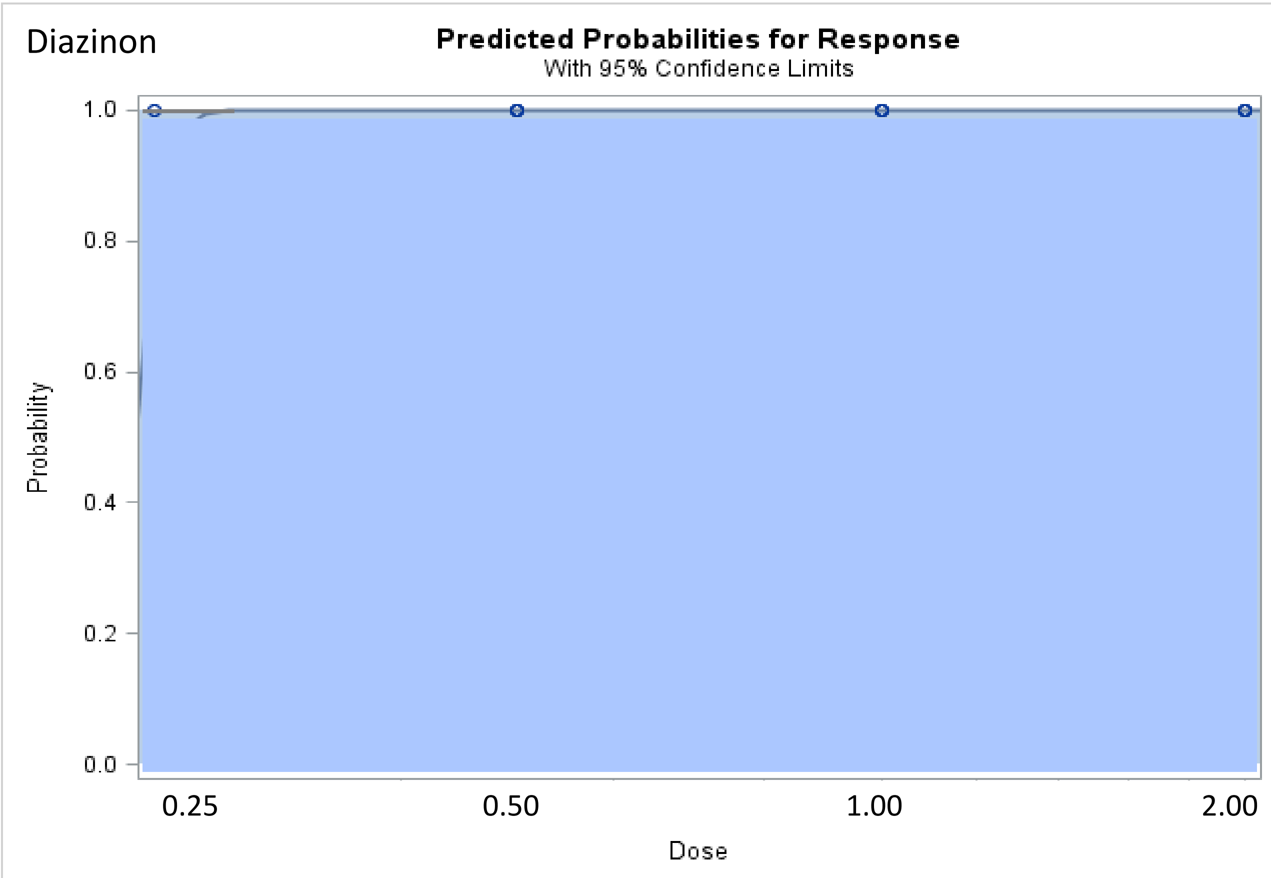


Fig. 5. Diazinon probit analysis.

Imidan was effective at the recommended full rate and ½ field rates. Some larvae did survive at the ¼ rate (Fig. 6).

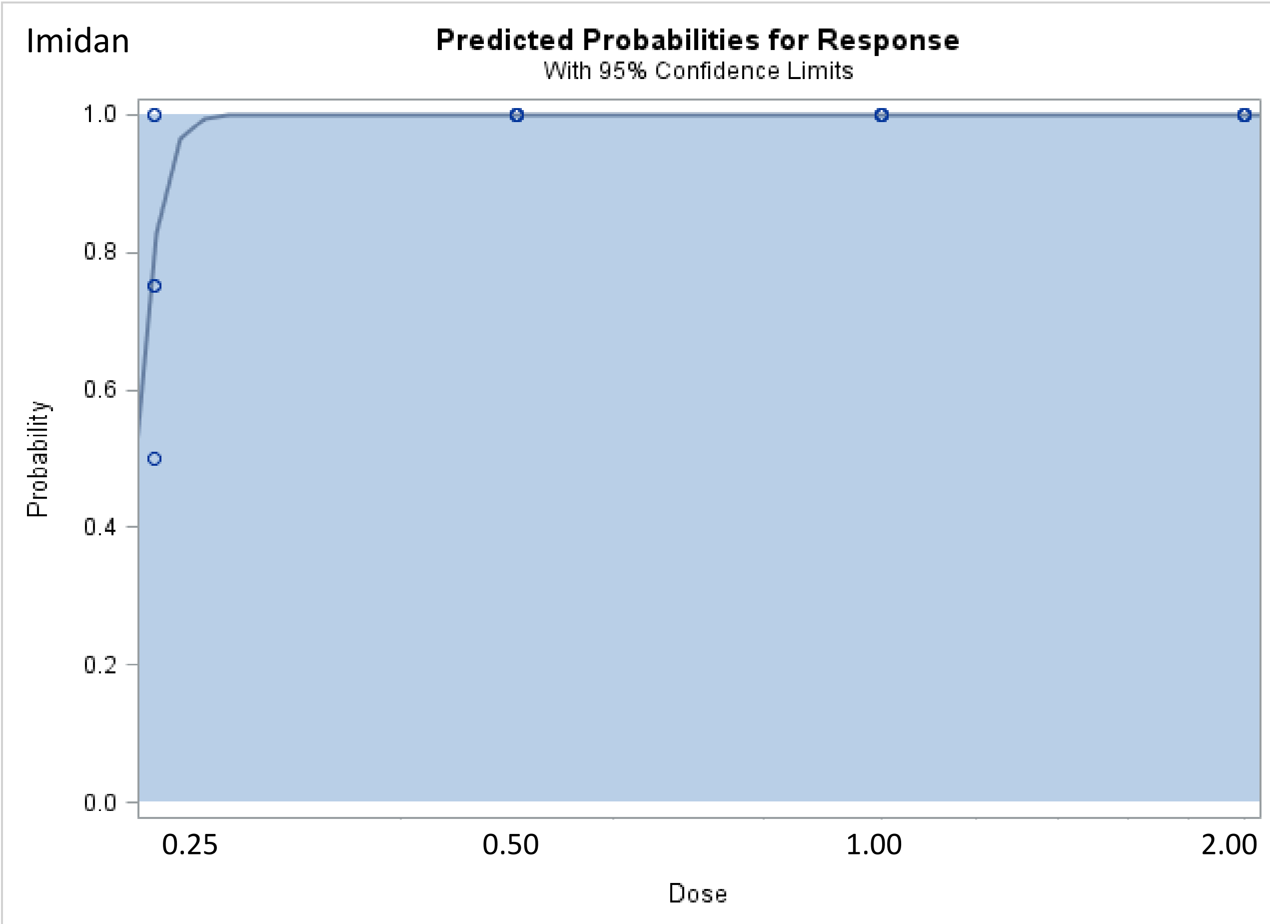


Fig. 6. Imidan probit analysis.

The probit analysis for Danitol, fenpropathrin, a pyrethroid insecticide, indicates approximately 80% mortality occurs through the 2x rate (Fig. 7). 100% mortality extended beyond the chart limits.

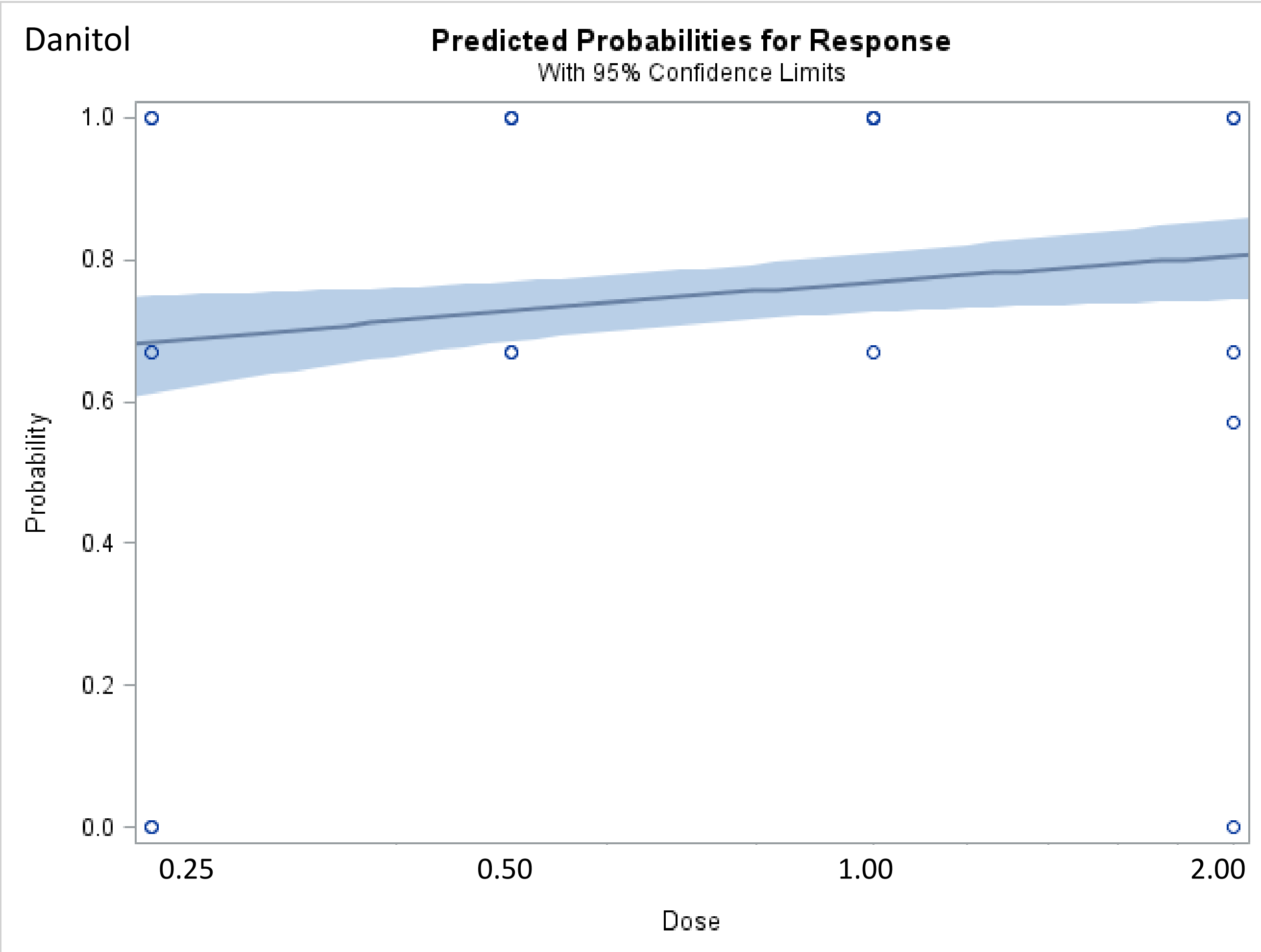


Fig. 7. Danitol probit analysis.

Conclusion

Results of the resistance bioassay indicate diazinon and Imidan are effective for this population but that OBLR is showing signs of tolerance developing toward Danitol. This suggests growers may experience some reduced field efficacy for Danitol. While this represents a single population from an abandoned blueberry field, it underscores the potential for resistance development in OBLR in western Washington. OBLR are strong fliers and can migrate between fields moving among small berry fields of either red raspberry or blueberry and red raspberry growers should heed recommendations for resistance management and be vigilant if products seem to perform less efficiently.

Washington Red Raspberry Commission
Report for 2020 Project

TITLE: Development of biologically-based RNAi insecticide: Delivery of dsRNA with nanoparticles to enhance RNAi effect on SWD

Personnel: Man-Yeon Choi (Research Entomologist), USDA-ARS Horticultural Crops Research Laboratory, and June-Sun Yoon (Postdoctoral associate), Corvallis, OR, Phone office 541-738-4026, e-mail man-yeon.choi@usda.gov

Accomplishment and Significant Findings (2020)

- We found the RNAi impact on the SWD was limited due to the degradation of the dsRNA by RNase enzymes in SWD.
- Identified two dsRNA degradation enzymes from the SWD midgut, and confirmed the genes.
- Evaluated their degradation activities of two dsRNases *in vivo* and *in vitro* assays.
- Investigated gene expressions of two genes for SWD life stages.
- Evaluated RNAi impact on flies fed dsRNA encapsulated with various nanoparticles.

Results & Discussion

1. **Identification of two dsRNA degradation enzymes from SWD:** In the previous project, we confirmed the dsRNA had been gradually disappeared when equivalents of SWD midgut homogenate were increased and incubated with dsRNA. The result suggested dsRNA degradation mainly occurs in the SWD midgut. The result also indicates the dsRNA degradation enzyme would be a type III RNase (=RNase III), which is to degrade dsRNAs, but not single-stranded RNA like mRNA. Under the current project, we successfully identified full sequences of two variants of SWD RNases that are active to degrade dsRNA in the midgut when the fly fed (Fig. 1).

Figure 1. Multiple sequence alignment of dsRNases from *Drosophila suzukii*, *Drosophila melanogaster*, and *Schistocerca gregaria* (desert locust). Signal peptide indicated in yellow was predicted by SignalP 4.1 (http://www.cbs.dtu.dk/services/SignalP/). Threshold for shading was 70% in black with identical, gray with similar and white background with normal.

2. Degradation activity of SWD RNases:

We characterized two enzymes, and evaluated their activities for how fast degrade dsRNA using *in vitro* test. Both enzyme genes were cloned and finically expressed in the insect Sf9 cell lines, producing each enzyme protein. The cell homogenate containing each RNase protein was mixed with a 200ng dsRNA (GFP dsRNA), and evaluated the degradation ability during various incubation periods (Fig. 2).

The degradation of dsRNA was starting from 10 min incubation with the SWD RNase1 (R1), and it was completed by 30 min. When compared degradation activity between RNase1 and 2, R1 is more active than R2. The relative expression levels between the two genes showed R1 was slightly more abundant than R2, although they were not significantly different (data from the previous report).

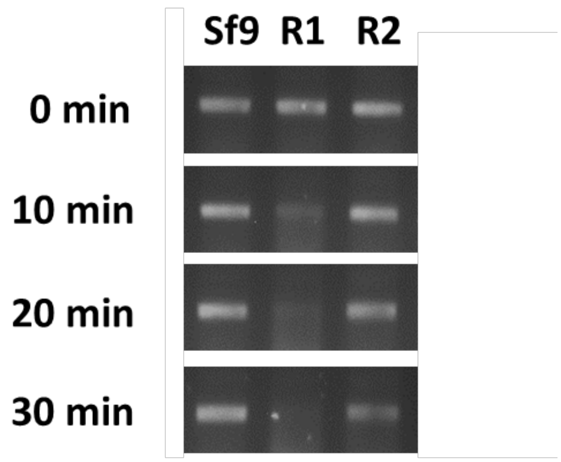


Figure 2. Time-dependent dsRNA degradation assay. Same amount of each samples and dsGFP (200ng) were incubated at different time points.

3. Gene expressions for SWD life stages:

Both RNase genes were expressed during the larval and adult stages, but not found in the embryo (=egg) (Fig. 3). Interestingly, DsRNase1 (R1) is dominantly expressed in the adult, while DsRNase2 (R2) is more abundant in the larval periods. The result corresponds to the two enzyme activities, which indicates R1 is more active in the fly adult (Fig. 3).

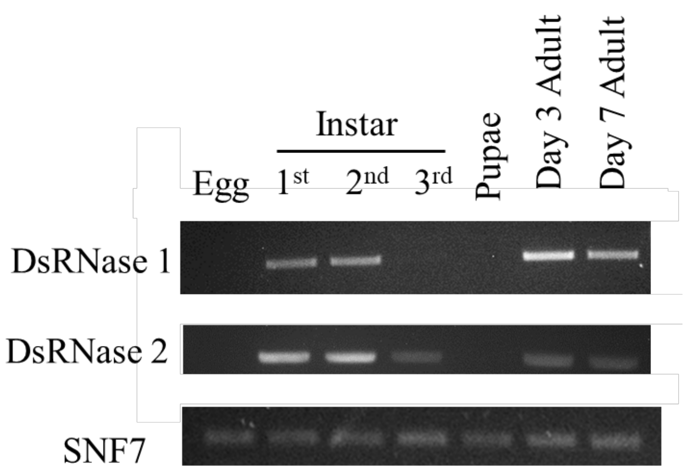


Figure 3. Expressions of SWD RNase genes during SWD developmental stages. SNF7 as a control housekeeping gene was used.

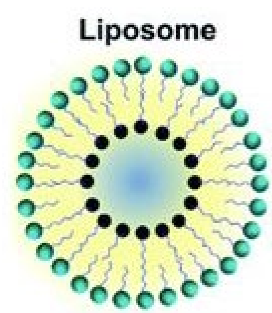


Figure 4. Model of lipid layer nanoparticles encapsulating dsRNA.

4. Evaluate RNAi impact on SWD:

For adult feeding assays, SWD1 dsRNA was mixed in a 20% sucrose solution, or different nanoparticles, cellfectin, lipofectamine, and BAPC, in a mixture of a 20% sucrose solution (Fig. 4). Flies were allowed to feed the dsRNA mixtures and monitored for 4 days.

After feeding dsRNA, flies were monitored for phenotypic changes and possible mortality for 4 days. Survival rates of the fly were reduced from all treatments for 4 days, but were not significantly different compared to the feeding sucrose or nanoparticles only provided (Fig. 5). The mixed results with the high mortality of flies from the sucrose control might have resulted in an insufficient diet for 4 days, or a negative effect of the nanoparticles. To clarify these effects, we need to have more feeding tests with a better experimental design. In addition, individual injection into the fly would be required to evaluate dsRNA delivery with the nanoparticles.

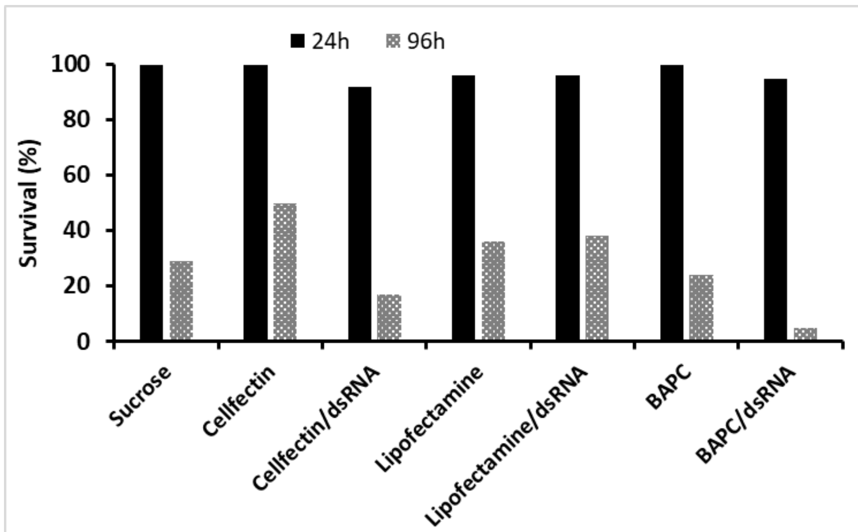


Figure 5. Survival rates for 24h and 96h after fly fed dsRNA encapsulated with nanoparticles.

Conclusion and Future study: From the previous and current studies, we screened potential RNAi targets from various SWD genes using nanoinjection tools and confirmed the RNAi effect to inhibit cell growth of *Drosophila* cells. We have established a bacterial-based system that produces a large quantity of dsRNA for cost-effective dsRNA production (Ahn et al., 2019). For practical RNAi application, however, oral administration of the SWD dsRNA was still challenging due to degradation of the dsRNA in the fly midgut. Therefore, future studies should be focused on more dsRNA pass through the midgut membrane to increase the delivery efficacy in the field. To overcome the huddle, we suggest possible options, protecting dsRNA from the enzyme attacking until delivery into the target cells and/or inhibiting the RNase activity in the midgut.

Publications related in this project:

1. Ahn, S.J. H.W. Oh, J. Corcoran, J.A. Kim, K. C. Park, C. G. Park, M.-Y. Choi. 2020. Sex-biased gene expression in antennae of *Drosophila suzukii*. Arch. Insect Biochem. Physiol. (DOI: 10.1002/arch.21660).
2. Ahn, S. J., K. Donahue, Y. H. Koh, R. Martin, M.-Y. Choi. 2019. Microbial-based double-stranded RNA production to develop cost-effective RNA interference application for insect pest management. Int J Insect Sci. 11:1-8. 2019
3. Choi, M.-Y., J. Lee. 2019. Insecticidal compositions and methods to kill insects. Application No. 62/863,302 (pending).

WEEDS

Washington Red Raspberry Commission
Progress Report Format for 2020 Projects

Project No:13C-3419-3154

Title: Will Chlorsulfuron Safely Manage Horsetail in Raspberries

Personnel: Steven Seefeldt and Chris Benedict

Reporting Period:

- Report for 2020

Accomplishments:

- Chlorsulfuron applications were made to the ground beside raspberry plants (Oct. 15) at 0, 0.08 and 0.16 oz/A. Chlorsulfuron was also applied to horsetail plants as 0, 0.01, 0.02, 0.04, 0.08, and 0.16 oz/A on the same day. Both applications were done at the WSU Mount Vernon NWREC. Plants were rated for injury symptoms 2 weeks after treatment. The treatments were replicated three times and the plot size was 16 ft by 4 ft. At this time there are no data for determining significance of the study in terms of the problem solved or enhancements to the industry.

- Early indications would suggest no injury to raspberry plants.

Results:

- Based on evaluations of herbicide efficacy two weeks after application, no injury to the raspberry plants was measured or observed. There also did not appear to be any injury to the horsetail, however Broadleaf plantain, dandelion, leontodon, and Canada thistle all had injury symptoms (yellowing at the growing point and some leaf curl) at the higher rates. It is expected that horsetail injury will be evident in the spring when it starts to grow. Injury symptoms will be measured this spring and summer and results reported back to the commission. The experiment was to be applied to 3 grower fields, but restrictions on an Experiment Use Permit, may have resulted in growers having to dig up treated plants at the end of the study, so a decision was made to do the treatments at NWREC.

Publications:

- None

NOTE: Limit annual Progress Report to one page and Termination Report to two pages, except for publications.

2021 WASHINGTON RED RASPBERRY COMMISSION
RESEARCH PROPOSAL

New Project Proposal **Proposed Duration:** (1 year)

Project Title: Control Timing to Keep Wild Buckwheat from Producing Seed

PI: Steven Seefeldt
Organization: Washington State Univ
Title: Associate in Research
Phone: 360-848-6157
Email: seefeldt@wsu.edu
Address: WSU - NWREC
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City/State/Zip: Mount Vernon, WA 98273

Co-PI: David Brown
Organization: Washington State University
Title: Director AgWeatherNet
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Email: dave.brown@wsu.edu
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Address 2: P.O. Box 646420
City/State/Zip: Pullman, WA 99164

Cooperators:

Year Initiated 2021 Current Year 2021 Terminating Year 2021

Total Project Request: Year 1 $7,511 Year 2 $ Year 3 $

Other funding sources: *None*

Description: The objective of this project is to develop a module on the WSU AgWeatherNet ***AWNfarm*** web- and mobile app that will estimate dates of wild buckwheat viable seed production. Using grower-provided information on buckwheat main stem leaf numbers, a Growing Degree Day buckwheat phenology model will be applied to local measured and forecasted air temperature to provide up to a 7-day forecast of viable seed production.
The outcome of the study is a tool that growers can use to begin to reduce their wild buckwheat seed bank and potentially eradicate this plant from their fields. As a side benefit, the AWNfarm app will also collect regional data on the presence of buckwheat that could be used to geographically target eradication efforts.

Justification and Background: (400 words maximum)

- We plan to implement a wild buckwheat growing degree day-based model in the AWNfarm app to provide growers with an online tool to control wild buckwheat in raspberries.
- This program would assist driving this plant species to local extinction.
- This project does not relate to any other projects in British Columbia, Idaho and Oregon

Wild buckwheat (*Polygonum convolvulus*) is a climbing plant that will grow through and over the top of raspberry plants. This plant, because of its growth habit, will then interfere with mechanical harvesters in raspberry fields resulting in reduced yields. Wild buckwheat seed survives less than five years (Forsberg and Best 1964) which means a 6-year management program that prevents seed production should result in an elimination of wild buckwheat seeds in the soil. Because seed germination is not light dependent (Hsiao, 1979), soil compaction does not inhibit seed germination (Fisyunov 1975), and seed buried up to 7.5 inches can germinate and produce seedlings (Forsberg and Best 1964), there are continued flushes of this plant throughout the growing season. In addition, high soil fertility levels increase the competitiveness of wild buckwheat (Gruenhagen and Nalewaja 1964) and it can grow in drier soils (Dosland and Arnold 1966).

In 2018 research was funded by the WSDA Specialty Crop Block Grant to fund the development of growing degree day models for 4 annual polygonum studies. In 2019 research results from studies in the greenhouse and field have given a baseline indication of growing degree days needed for wild buckwheat to start producing seeds based on the number of leaves on the main stem (unpublished data). This research was replicated in 2020 and a tentative model of number of growing degree days left before viable seed production begins based on then number of mainstem leaves. In 2021, with assistance from the proposed app, this model will be validated in the field.

The WSU AgWeatherNet has implemented a number of weather-related decision support tools currently available on the AgWeatherNet (weather.wsu.edu) addressing cold hardiness, chemical thinning, GDD- and other temperature-based models, irrigation scheduling and pest management. The new, free AgWeatherNet ***AWNfarm*** platform (awnfarm.org) will eventually host all of these tools and more, with grower-configuration for site- and crop-specific tool delivery.

Relationship to WRRC Research Priority(s): This study is a #3 priority

Objectives:

- Objective 1: We will develop a user-friendly module on AgWeatherNet ***AWNfarm*** platform that will alert growers as to when wild buckwheat will start producing viable seeds given a grower-provided count of mainstem leaves.
- The objective will be addressed <u>this</u> funding year.

Procedures: (400 words maximum)

- Anticipated length of project is 1 year
- Model information will be sent to AgWeatherNet March 2021 to incorporate into their system.
- AWN programming staff will code the GDD model into the AgWeatherNet tool module. The output of the model will then be fed via an application programming interface into the ***AWNfarm*** platform, currently maintained by a private firm. Working with this firm, AWN staff will design a user interface similar to the current design for the apple pollen tube model.
- The model will be beta tested for the 2021 season and evaluated at the end of the season.
- Dr. Steven Seefeldt will facilitate formation of a beta testing grower group for the 2021. This group will review and provide input on design choices, utilize the module during the 2021 growing season, and provide feedback at the end of the season.
- Final project-supported model revisions, based upon both user-feedback and additional field data, will be implemented at the completion of the 2021 season.

Anticipated Benefits and Information Transfer: (100 words maximum)

- Results be transferred to users at the 2021 small fruit meeting held in Whatcom county.
- AWN staff and Dr. Steven Seefeldt will deliver at least one webinar providing training on the use of the buckwheat module. (In addition to regular webinars showing growers how to use the AWNfarm platform.)

References:

Forsberg, VA and KF Best. 1964. The emergence and plant development of wild buckwheat (Polygonum convolvulus L.). Canadian Journal of Plant Science 44:100-103.

Hsiao, AI. 1979. The effect of sodium hypochlorite, gibberellic acid, and light on seed dormancy and germination of wild buckwheat (Polygonum convolvulus) and cow cockle (Saponaria vaccaria). Canadian Journal of Botany 57:1735-1739.

Fisyunov, AV. 1975. The germination of weed seeds in relation to soil moisture content and density. Weed Abstract 1975:24:2114.

Gruenhagen, RD and JD Nalewaja. 1964. Competition between flax and wild buckwheat. Weed Science 17:380-384.

Dosland, JG and JD Arnold. 1966. Leaf area development and dry matter production of wheat and wild buckwheat growing in competition. Abstract Meeting of Weed Science Society of America p. 56.

Budget: <u>*Indirect or overhead costs are not allowed*</u> unless specifically authorized by the Board (***David you need to fill out this bit, I'll be giving myself 40 hours of pay***)

	2021	**2022**	**2023**
Salaries[1/]	$4,019	$	$
Time-Slip	$	$	$
Operations (goods & services)	$	$	$
Travel[2/]	$	$	$
Meetings	$	$	$
Other	$2,000	$	$
Equipment[3/]	$	$	$
Benefits[4/]	$1,492	$	$
Total	**$7,511**	**$**	**$**

Budget Justification

[1/]Specify type of position and FTE.

	2021
Faculty	40 hours $1,380 salary + $570 benefits
Programmer	16 hours AgWeatherNet programmer $2639 salary + $922 benefits

Other Contract $2000 for app development personal services contract extension. AgWeatherNet has contracted with a private firm for front-end app development.

[2/]Provide brief justification for travel requested. All travel must <u>directly</u> benefit project. Travel for professional development should come from other sources. If you request travel to meetings, state how it benefits project.

[3/]Justify equipment funding requests. Indicate what you plan to buy, how the equipment will be used, and how the purchase will benefit the growers. Include attempt to work cooperatively with others on equipment use and purchase.

[4/]Included here are tuition, medical aid, and health insurance for Graduate Research Assistants, as well as regular benefits for salaries and time-slip employees.

Current & Pending Support

Instructions:
1. Record information for active and pending projects.
2. All current research to which principal investigator(s) and other senior personnel have committed a portion of their time must be listed whether or not salary for the person(s) involved is included in the budgets of the various projects.
3. Provide analogous information for all proposed research which is being considered by, or which will be submitted in the near future to, other possible sponsors.

Name (List PI #1 first)	Supporting Agency and Project #	Total $ Amount	Effective and Expiration Dates	% of Time Committed	Title of Project
	Current				
Steven Seefeldt Carol Brown	Pacific Northwest Cooperative Ecosystem Studies Unit	$60,000	7/1/2018 – 6/30/2020	6	Vulnerability Assessment of Wetland Habitats to Reed Canarygrass (*Phalaris arundinacea*) along Ross Lake, North Cascades National Park Service Complex
Steven Seefeldt Chris Benedict	WSDA Specialty Crop Block Grant	$137,128	9/16/2018 – 9/29/2021	20	Integrated pest management of annual polygonum species in northwest Washington specialty crops: Working with plant biology
David Gang Doug Collins Wendy Hoashi-Erhardt Manuel Garcia-Perez B. Thomas Jobson Steven Seefeldt	Washington State Department of Ecology	$450,000	1/1/2018-12/31/2020	2	Integrating compost and biochar for improved soil health, crop yield, and air quality
Steven Seefeldt Carol Brown	Western Region IR-4	$38,500	9/1/2020-8/31/2021	6	Environmental Horticulture
	Pending				
Steven Seefeldt Chris Benedict	WA Blueberry Commission	$3,878	1/1/2021-12/31/2021	2	Will Chlorsulfuron Safely Manage Horsetail in Blueberries
Steven Seefeldt Chris Benedict	WA Raspberry Commission	$3,878	1/1/2021-12/31/2021	2	Will Chlorsulfuron Safely Manage Horsetail in Raspberries
Steven Seefeldt Chris Benedict	WA Blueberry Commission	$7,511	1/1/2021-12/31/2021	2	Preventing Wild Buckwheat Seed Production in Blueberries
Steven Seefeldt Chris Benedict	WA Raspberry Commission	$7,511	1/1/2021-12/31/2021	2	Preventing Wild Buckwheat Seed Production in Raspberries

2021 WASHINGTON RED RASPBERRY COMMISSION RESEARCH PROPOSAL

New Project Proposal **Proposed Duration:** (1 year)

Project Title: Testing Red Raspberries for Chlorsulfuron Residues

PI: Steven Seefeldt
Organization: Washington State Univ
Title: Associate in Research
Phone: 360-848-6157
Email: seefeldt@wsu.edu
Address: WSU - NWREC
Address 2: 16650 SR 536
City/State/Zip: Mount Vernon, WA 98273

Co-PI: Chris Benedict
Organization: Washington State University
Title: Regional Extension Specialist
Phone: 360-778-5809
Email: chrisbenedict@wsu.edu
Address: 1000 North Forest Street
Address 2: Suite 201
City/State/Zip: Bellingham, WA 98225

Cooperators:

Year Initiated 2021 Current Year 2021 Terminating Year 2021

Total Project Request: **Year 1 $3,878** **Year 2 $** **Year 3 $**

Other funding sources: *None*

Description: The objective of this study is to determine if chlorsulfuron applied near the base of red raspberry plants will be taken up by the raspberry roots and become detectible residues in the leaves and fruit. If there are detectable residues, then chlorsulfuron cannot be used to control horsetail in raspberry crops. The outcome of the study is whether this herbicide can be used in raspberry crops.

Justification and Background: (400 words maximum)

- We plan to determine if chlorsulfuron can be taken up by raspberry roots and become residues in leaves and fruit
- Chlorsulfuron has potential use to control horsetail in raspberries
- This project does not relate to any other projects in British Columbia, Idaho and Oregon

Horsetails (*Equisetum* spp.) are an ancient group of plants that flourished over 350 million years ago. These plants do not have flowers and reproduce by spores or vegetatively through their roots. All species of Equisetum are perennial and have an extensive, tuber-bearing rootstock. In the early spring these plants will grow cone-bearing stems where spores are produced. Later in the spring these plants will produce vegetative stems (Cloutier and Watson 1985). In western Washington these plants are native and in raspberries their populations can become dense enough to not only reduce raspberry growth but also to negatively impact harvest by physically keeping the harvester catch plates open resulting in fruit drop.

Horsetails, like many primitive plants, do not have a well-developed vascular system which limits translocation of herbicides. In addition, the small jointed stems do not provide a large surface area for interception and absorption of herbicide applications. Currently growers will use glyphosate-based products to reduce above ground growth (this herbicide does not move into the roots) or multiple applications of dichlobenil (Casaron) (Tim Miller, personal communication). Dichlobenil will decrease horsetail populations, but it has been observed to cause reduced yield and growth in raspberries.

Previous research has determined chlorsulfuron (both Glean and Telar) has excellent efficacy on horsetail (Seefeldt, unpublished data). In these studies, horsetail was not the weed species of interest, but the control of this species was noted. Chlorsulfuron is not registered for use in raspberries as it has activity on broadleaved plants. It is a group 2 herbicide and degradation of the herbicide is slow with an average half-life of 40 days.

Relationship to WRRC Research Priority(s): This study is a #3 priority

Objectives:

- Objective 1: We will determine if autumn soil applied chlorsulfuron can become a residue in red raspberry plants
- The objective will be addressed <u>this</u> funding year

Procedures: (400 words maximum)

- Anticipated length of project is 1 year
- Leaf material will be collected in the spring and fruit will be collected in the autumn and then both will be sent for extraction and analyses in the autumn

On October 15, 2020, the ground beside red raspberry plants at the WSU Mount Vernon Research and Extension Center was treated with 0.16 and 0.08 oz/A chlorsulfuron as part of a study to determine if chlorsulfuron could control horsetail without injuring red raspberries. There were 3 replications of each treatment and there were 3 controls for a total of 9 plots. Two weeks after treatment there were no injury symptoms on the red raspberries, however there was injury to weeds such as dandelions, broadleaf plantain, leontidon, and Canada thistle.

In late spring when plants are fully leafed out, one 1-pint zip lock bag will be filled with raspberry leaves in each plot (9 bags) and put immediately into a chilled cooler. These leaf samples will be frozen at -20 C. In the Autumn when the fruit is ripe, one 1-pint zip lock bag will be filled with raspberry leaves in each plot (9 bags) and put in a chilled cooler. These fruit samples will then be frozen at -20 C. Once all 18 sample bags are frozen, they will be sent to Synergistic Pesticide Lab where they will do the extraction and analyses at $100/sample. They will then send the data to us.

Anticipated Benefits and Information Transfer: (100 words maximum)

- If there are no chlorsulfuron residues in the leaf and fruit samples, then a case be made to work towards getting a label for chlorsulfuron to control horsetail in raspberries.
- Results be transferred to users at the small fruit meeting held in Whatcom county in 2021.

References: Cloutier, D. and A.K. Watson. 1985. Growth and regeneration of field horsetail (*Equisetum arvense*). Weed Science 33:358-365

Budget: *Indirect or overhead costs are not allowed* unless specifically authorized by the Board

	2021	2022	2023
Salaries[1/]	$1,297	$	$
Time-Slip	$	$	$
Operations (goods & services)	$2,000	$	$
Travel[2/]	$	$	$
Meetings	$	$	$
Other	$	$	$
Equipment[3/]	$	$	$
Benefits[4/]	$581	$	$
Total	**$3,878**	**$**	**$**

Budget Justification

[1/]Specify type of position and FTE.

	2021
Faculty	8 hours
Technician	40 hours

Operations (goods and services) - $1,800 will pay for the residue analyses conducted by Synergistic Pesticide Lab and $200 will cover purchase of materials, dry ice, and shipping costs needed to collect and mail samples to Synergistic Pesticide Lab

[2/]Provide brief justification for travel requested. All travel must directly benefit project. Travel for professional development should come from other sources. If you request travel to meetings, state how it benefits project.

[3/]Justify equipment funding requests. Indicate what you plan to buy, how the equipment will be used, and how the purchase will benefit the growers. Include attempt to work cooperatively with others on equipment use and purchase.

[4/]Included here are tuition, medical aid, and health insurance for Graduate Research Assistants, as well as regular benefits for salaries and time-slip employees.

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1. Record information for active and pending projects.
2. All current research to which principal investigator(s) and other senior personnel have committed a portion of their time must be listed whether or not salary for the person(s) involved is included in the budgets of the various projects.
3. Provide analogous information for all proposed research which is being considered by, or which will be submitted in the near future to, other possible sponsors.

Name (List PI #1 first)	Supporting Agency and Project #	Total $ Amount	Effective and Expiration Dates	% of Time Committed	Title of Project
	Current				
Steven Seefeldt Carol Brown	Pacific Northwest Cooperative Ecosystem Studies Unit	$60,000	7/1/2018 – 6/30/2020	6	Vulnerability Assessment of Wetland Habitats to Reed Canarygrass (*Phalaris arundinacea*) along Ross Lake, North Cascades National Park Service Complex
Steven Seefeldt Chris Benedict	WSDA Specialty Crop Block Grant	$137,128	9/16/2018 – 9/29/2021	20	Integrated pest management of annual polygonum species in northwest Washington specialty crops: Working with plant biology
David Gang Doug Collins Wendy Hoashi-Erhardt Manuel Garcia-Perez B. Thomas Jobson Steven Seefeldt	Washington State Department of Ecology	$450,000	1/1/2018-12/31/2020	2	Integrating compost and biochar for improved soil health, crop yield, and air quality
Steven Seefeldt Carol Brown	Western Region IR-4	$38,500	9/1/2020-8/31/2021	6	Environmental Horticulture
	Pending				
Steven Seefeldt Chris Benedict	WA Blueberry Commission	$3,878	1/1/2021-12/31/2021	2	Will Chlorsulfuron Safely Manage Horsetail in Blueberries
Steven Seefeldt Chris Benedict	WA Raspberry Commission	$3,878	1/1/2021-12/31/2021	2	Will Chlorsulfuron Safely Manage Horsetail in Raspberries
Steven Seefeldt Chris Benedict	WA Blueberry Commission	$7,511	1/1/2021-12/31/2021	2	Preventing Wild Buckwheat Seed Production in Blueberries
Steven Seefeldt Chris Benedict	WA Raspberry Commission	$7,511	1/1/2021-12/31/2021	2	Preventing Wild Buckwheat Seed Production in Raspberries

CURRENT & PENDING SUPPORT

Name: Chris Benedict

Instructions:

Who completes this template: Each project director/principal investigator (PD/PI) and other senior personnel that the Request for Applications (RFA) specifies.

How this template is completed:

- Record information for active and pending projects, including this proposal.
- All current efforts to which PD/PI(s) and other senior personnel have committed a portion of their time must be listed, whether or not salary for the person involved is included in the budgets of the various projects.
- Provide analogous information for all proposed work which is being considered by, or which will be submitted in the near future to, other possible sponsors, including other USDA programs.
- For concurrent projects, the percent of time committed must not exceed 100%.

Note: Concurrent submission of a proposal to other organizations will not prejudice its review by CSREES.

NAME (List/PD #1 first)	SUPPORTING AGENCY AND AGENCY ACTIVE AWARD/PENDING PROPOSAL NUMBER	TOTAL $ AMOUNT	EFFECTIVE AND EXPIRATION DATES	% OF TIME COMMITTED	TITLE OF PROJECT
ACTIVE:					
Kruger, C., C. Benedict, M. Zhu	WSDA	$150,000	3/1/16 - 3/30/21	1%	Improving Soil Health for Whatcom County Raspberry Growers
S. Seefeldt, C. Benedict	WSDA SCBG	$120,000	9/16/18 - 9/29/21	5%	Integrated pest management of annual polygonum species in northwest Washington specialty crops: Working with plant biology
C. Benedict, B. Guindersen, T. Waters, D., McMoran	Northwest Potato Consortium	$24,000	7/1/19 - 6/30/21	5%	Controlling latent infections of black dot with early fungicide applications
G. LaHue, D. Griffin, L. DeVetter, C. Benedict	WA Blueberry Commission	$17,053	1/1/19 - 12/31/21	1%	Soil organic matter nitrogen mineralization
C. Miles, C. Benedict, M. Flury, H. Liu, L. DeVetter, S. Galinato	WSARE	$74, 054	6/1/19 - 5/31/21	1%	In-Service Training for Biodegradable Mulch
D. Collins, A. Bary, C. Benedict	NARF	$8,862	3/1/2020 - 2/28/2021	1%	Cover cropping, high-residue cultivation, and fertility for successful organic strip-till in Western Washington
Benedict, C. and Yorgey	WSA ARC	$49,967	01/01/2020-12/31/2021	5%	Evaluation of Nutrient Recovery from Undigested Dairy Waste Using a Dissolved Air Flotation System

S. Seefeldt and C. Benedict	WBC	$10,325	01/01/2020-12/31/2022	1%	Will Chlorsulfuron Safely Removed Manage Horsetail in Blueberries?
S. Seefeldt and C. Benedict	WRRC	$11,452	01/01/2020-12/31/2022	1%	Preventing Wild Buckwheat Seed Production in Raspberries
			Total % of Active:	**20.00%**	
PENDING:					
Benedict, C., D. I. Burke, D. LaHue, T. Potter, G. LaHue, N. Singh	WSU CSANR	$40,000	1/1/2021-12/31/2022	10%	Tracking the Tango Between Weeds, Soil Health, and Tillage.
Benedict, C., I. Burke, S. Galinato, G. Hoeheisel, S. Seefeldt	WA Blueberry Commission	$16,000	1/1/2021-121/31/2023	5%	Spot Spraying of Blueberry Herbicides
Smith-Pardo, A., Corona, M., G. Dively, C. Benedict, R. Danielsen, T.	USDA-APHIS	$52,628	1/1/2021-12/30/2021	3%	Use of a metal screen to prevent the attack of the Asian giant hornet, to honey bee colonies
DeVetter, L., H. Zhang, C. Miles, C. Benedict (this proposal)	WRRC	$39,785	1/1/2019-12/30/21	1%	Multi-season plastic mulches for improved weed management and crop growth
			Total % of Pending:	**19.00%**	

PHYSIOLOGY

Project Number: not yet assigned **Proposed Duration:** 1 year

Project Title: Are arbuscular mycorrhizal fungal propagules available in newly planted raspberry fields? (NEW)

PI: Rebecca A. Bunn
Organization: Western Washington University
Title:Associate Professor,
Dept. of Environmental Sciences
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Email: rebecca.bunn@wwu.edu
Address: 516 High St, MS-9181
City/State/Zip: Bellingham, WA 98225

Co – PI: Lisa W. DeVetter
WSU-NWREC
Associate Professor
Small Fruit Horticulture
360-848-6124
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Mount Vernon, WA 98273

Cooperators:
Dierdre Griffin, Assistant Professor, Soil Science, WSU-NWREC,
Undergraduate research interns from WWU Dept. of Environmental Sciences

Year Initiated: 2021 **Current Year**: 2021 **Terminating Year**: 2021

Total Project Request: $6,975 **Year 1**: WWU $6,975

Other funding sources: Yes, pending

Agency: WWU Research and Sponsored Programs

Amount Requested: WWU RSP: $500, undergraduate students would apply

Description

The objective of this study is to quantify any differences in the abundance and colonization potential of arbuscular mycorrhizal fungi between mature and newly planted raspberry fields. At the end of this study, producers will have data on arbuscular mycorrhizal fungi spore abundance (number of spores per gram of dry soil) and the colonization potential (percent colonization of roots of new plants) in paired fields that are managed similarly but differ in time since planting. This information will aid producers in determining if bio-inoculants are needed in newly planted fields.

Justification and Background

Field turnover in commercial raspberry fields typically includes tilling and soil fumigation; practices which can reduce populations of beneficial soil biota. Some producers apply bio-inoculants to aid in rebuilding these communities. However, commercial bio-inoculants are unregulated, and their efficacy is questionable (Maltz and Treseder 2015). Therefore, commercial bio-inoculant applications may not accomplish producers' goals of re-establishing beneficial soil biota communities. Furthermore, bio-inoculants may not even be necessary if beneficial soil biota are not substantially diminished during field turnover. Producers need data on beneficial soil biota communities in young fields to determine if bio-inoculants provide enough benefit to offset their expense.

Our recent work suggests that plant-symbionts, arbuscular mycorrhizal fungi (AMF), may be an important component of the beneficial soil biota communities in Washington raspberry fields. We found these fungi can increase the resilience of raspberries to the pathogen *Phytophthora rubi*, which causes root rot (Whitney, 2020). And although we found mature raspberry fields can support robust AMF communities (Whitney, 2020), we do not know if AMF are present in young fields. On one hand, we might expect AMF communities to be reduced or absent because of fumigation and tilling (An et al. 1993, Oehl et al. 2003). Conversely, AMF communities in young fields may be similar to those in mature fields if AMF propagules, such as spores, infected roots, or hyphal fragments, persist through field turnover. Furthermore, if AMF communities are diminished during turnover, it is also possible that the fungi may repopulate quickly from airborne spores (Chaudhary et al. 2020).

We will assess the presence and colonization potential of AMF communities in recently-planted fields from three to four producers in Whatcom County that have similar management practices. To control for variability in AMF communities due to external sources of fungi or environmental conditions; we will pair newly planted fields with the closest mature field managed by the same producer and all fields will be assessed for *P. rubi* infection prior to harvest.

When possible, we will coordinate our sampling effort with Deirdre Griffin and her colleagues by sampling from sites where their team will be measuring soil compaction and soil health. This coordination will leverage their data to also support our work. Soil health parameters like pH, organic matter concentrations, and availability of nitrogen and phosphorus can affect AMF abundance and these data will help us understand any variability in AMF abundance we observe across paired fields.

Relationship to WRRC Research Priorities

This project addresses the WRRC #2 priority of understanding soil ecology and soil-borne pathogens and their effects on plant health by quantifying how field turnover may alter the abundance and colonization potential of arbuscular mycorrhizal fungi, a group of beneficial soil biota which can increase the resilience of raspberry plants to *P. rubi*.

Objectives

1. Assess variation in AMF spore abundance in paired newly planted and mature fields
2. Quantify mycorrhizal colonization potential in paired newly planted and mature fields, which takes into account all propagules; viable spores, hyphal fragments, and root fragments with internal colonization.

Procedures

1. Summer 2021: We will collect soil samples from paired newly planted and mature fields managed by three to four different producers (n = 6-8 fields total). In each of the fields, ten soil sub-samples (6 cm wide, 15 cm deep) will be collected from

random locations within the field and combined into a single composite sample (~ 400 mL per sub-sample; ~ 4 L from each field). We will sample fields of representative cultivars (e.g., Meeker, WakeField, WakeHaven). Mature fields will be at least four years from planting. Newly planted fields will ideally be less than one year from planting (non-bearing). However, if first-year fields are unavailable, we will sample second-year fields. Prior to harvest, fields will be visually assessed for *P. rubi* infection and categorized as no, low, moderate, or highly infested by *P. rubi* (0, 1-10%, 11-40%, or >40% of surveyed plants exhibit *P. rubi* infection symptoms).

2. Summer - Fall 2021: To measure spore density, spores will be extracted from five 10 g replicates of each composite sample. We will use the sucrose gradient method and capture spores on 10-micron nylon filters. Viable spores will be identified by color, turgor, and texture and counted under a dissecting scope at 40X magnification. Counts will be reported as the number of spores per gram of dry soil. (6-8 fields x 5 replicates = 30-40 measurements)

3. Summer - Fall 2021: To measure colonization potential, we will grow corn (*Zea mays*) in 650 mL Deepots with field soil in the WWU greenhouse for six weeks with five replicates for each field and five additional control plants grown with sterilized soil (6-8 fields x 5 replicates + 5 controls = 35-45 pots). Corn is used in colonization potential studies because it forms mycorrhizae with a wide range of AMF species and it grows quickly, thus giving a good measure of primary colonization by field propagules, rather than measuring secondary colonization. At the end of six weeks, plants roots will be cleaned, cleared of pigment, and stained with a fungal specific dye. Root segments from each plant will be viewed under a compound scope at 200X magnification. The presence/absence of AMF structures will be recorded at 76 intersections. Colonization potential will be reported as the proportion of intersections with AMF structures.

4. Fall - Winter 2021: Analyze results, submit progress report to WRRC, and present results at the Small Fruit Conference

Anticipated Benefits and Information Transfer

This project will quantify the effects of field turnover on the abundance of one beneficial soil biota group. This information would help producers make informed decisions about the value of applying commercial bio-inoculants to newly planted fields. In addition, this study will fulfill a graduation requirement for two undergraduate students at Western Washington University.

Results will be shared with the raspberry industry at the Small Fruit Conference. Information will also be published online in the Whatcom Ag. Monthly (http://extension.wsu.edu/wam/), and shared on the WSU Small Fruit Horticulture Program website (https://smallfruits.wsu.edu/raspberry/), and the WWU Soil Ecology Lab website (https://wp.wwu.edu/soilecologylab/).

References

An, Z-Q Hendrix, DE. Hershman, RS. Ferriss & GT Henson. The influence of crop rotation and soil fumigation on a mycorrhizal fungal community associated with soybean. *Mycorrhiza* **3,** 171-182 (1993)

Chaudhary, VB, S Nolimal, SHA Moises, C Egan, J Kastens. (2020). Trait-based aerial dispersal of arbuscular mycorrhizal fungi. *New Phytologist*, 228(1), 238-252.

Maltz, MR, & KK Treseder. (2015). Sources of inocula influence mycorrhizal colonization of plants in restoration projects: a meta-analysis. *Restoration Ecology*, 23(5), 625–634.

Oehl, F, E Sieverdin, K Ineichen, P Mader, T Boller, and A Wiemken. 2003. Impact of land use intensity on the species diversity of arbuscular mycorrhizal fungi in agroecosystems of central Europe. *Applied and Environmental Microbiology* 69:2816–2824

Whitney, E. (2020) *Can arbuscular mycorrhizal fungi protect* Rubus idaeus *from the effects of soil-borne disease and parasitic nematodes?* MS Thesis. Western Washington University.

Budget

	WWU	WSU
Salaries	$6,000	$0
Operations (goods & services)	$230	$0
Travel	$140	$0
Benefits	$600	$0
Totals	**$6,975**	$0

Notes

1. <u>Salaries</u> - $6,000 for two undergraduate research interns (2 students x $15/hr x 200 hrs = $6,000)
2. <u>Operations</u> - Supplies for assessment of mycorrhizal fungal colonization in roots, spore abundance in soils, and mycorrhizal colonization potential of soils (tissue cassettes, slides, filter paper; $216) .WA state sales tax on supplies (.065 x $215 = $14). Funding for additional supplies will be requested via undergraduate proposal's to WWU Research and Sponsored Programs
3. <u>Travel:</u> Bellingham - Lynden, or location of raspberry farms, 30 miles round trip. (30 miles/trip x 9 trips x $0.535/mile = $145)
4. <u>Benefits:</u> undergraduate student at 10% ($6,000 x 0.10 = $600)

Current and Pending Support

Name: Rebecca Bunn

Instructions:

1. Record information for active and pending projects, including this proposal.
2. All current efforts to which project director(s) and other senior personnel have committed a portion of their time must be listed, whether or not salary for the person involved is included in the budgets of the various projects.
3. Provide analogous information for all proposed research which is being considered by, or which will be submitted in the near future to, other possible sponsors.

ACTIVE:

NAME (List.PI #1 first)	SUPPORTING AGENCY AND AGENCY ACTIVE AWARD/PENDING PROPOSAL NUMBER	TOTAL $ AMOUNT	EFFECTIVE AND EXPIRATION DATES	% OF TIME COMMITTED	TITLE OF PROJECT
NA					

PENDING:

Bunn, R. and L.W. DeVetter	WRRC	$6,975	1/2021-12/2021	5%	Are arbuscular mycorrhizal fungal propagules available in newly planted raspberry fields?

Name: Lisa Wasko DeVetter

Instructions:

1. Record information for active and pending projects, including this proposal.
2. All current efforts to which project director(s) and other senior personnel have committed a portion of their time must be listed, whether or not salary for the person involved is included in the budgets of the various projects.
3. Provide analogous information for all proposed research which is being considered by, or which will be submitted in the near future to, other possible sponsors.

NAME (List.PI #1 first)	SUPPORTING AGENCY AND AGENCY ACTIVE AWARD/PENDING PROPOSAL NUMBER	TOTAL $ AMOUNT	EFFECTIVE AND EXPIRATION DATES	% OF TIME COMMITTED	TITLE OF PROJECT
DeVetter, L., C. Miles, D. Griffin, M, Flury, M. Bolda, S. Wortman, S. Agehara, C. Benedict, H. Liu, T. Marsh, T. Chi, S. Galinato, K. Englund, M. Perez-Garcia, G. Yorgey, J. Goldberger, and L. McGowen	USDA SCRI	$49,234	9/2019-8/2020	10%	Planning grant: Implementation of new technologies and improved end-of-life management for sustainable use of agricultural plastics
Iorizzo, M., P. Munoz, J. Zalapa, N. Bassil, D. Main, D. Chagne, L. Giongo, K. Gallardo, E. Canales, A. Atucha, L.W. DeVetter	USDA SCRI	$7,900,000	9/2019-8/2023	5%	VacciniumCAP: Leveraging genetic and genomic resources to enable development of blueberry and cranberry cultivars with improved fruit quality attributes
DeVetter, L.W., T. Peever, S. Galinato, and S. Jung	Washington State Department of Agriculture Specialty Crop Block Grant (WSDA SCBG)	$249,963	10/2019-9/2022	5%	Novel production systems for improved production and disease management in strawberry
DeVetter, L.W.., C. Miles, C. Benedict, I.A. Zasada, H. Zhang, S. Ghimire	WSDA SCBG	$249,959	10/2018-9/2021	2%	Promoting productivity and efficiencies in red raspberry systems through application of biodegradable plastic mulches
DeVetter, L.W., F. Takeda, J. Chen, S. Korthuis, and W. Yang	WSDA SCBG	$178,328	10/2018-10/2021	2%	Improving machine harvest efficiency and fruit quality for fresh market

					blueberry
P. M Ndegwa, H. Tao, L. DeVetter	WSDA-SCBG	$249,973	10/2017-9/2021	3%	Concentrating and blending of manure nutrients to enhance sustainable production
Yang, W., F. Takeda, J. Chen, and S. Korthius	Oregon State Department of Agriculture Specialty Crop Block Grant	$172,630	5/2019-4/2021	1%	Improving fresh blueberry quality with innovative harvesting and sensor technology
Lukas, S., L.W. DeVetter, B. Strik, D. Bryla, J. Fernandez-Salvador, and S. Galinato	USDA ORG	$500,000	8/19-7/21	2%	Management techniques to optimize soil pH and nutrient availability in organic highbush blueberry grown east of the Cascade Rang
LaHue, G., D. Griffin, L.W. DeVetter, and C. Benedict	Washington Blueberry Commission (WBC)	$16,640	1/2020-12/2021	3%	Valuing nitrogen release from high organic matter soils
G. Hoheisel, L. DeVetter, L. Khot, and D. Gibeaut	WBC	$27,100	1/2020-12/2021	3%	Modeling blueberry cold hardiness in Washington
Miles, C., C. Benedict, M. Flury, H. Liu, L.W. DeVetter, and S. Galinato	WSARE PDP	$74,580	10/19-9/21	4%	In-service training for biodegradable mulch
Sankaran, S., A. Carter, K, Evans, K. Garland-Campbell, S. Ficklin, S. Gupta, A. Kalyanaraman, R. McGee, S. Serra,	National Science Foundation Research Experience for Undergraduates (NSF REU)	$389,170	1/2020-12//2022	2%	REU site: Phenomics Data integration and analytics in crop improvement
Isaacs, R., R. Mallinger, L. DeVetter, S. Galinato, P. Edgar, and A. Melathopoulos	USDA SCRI	$4 mil	10/2020-9/2024	10%	Optimizing blueberry pollination to ensure future yields
DeVetter, L.W., J. Davenport, G. Hoheisel, and G. LaHue	Northwest Center for Small Fruits Research	$141,258	9/2020-9/2023	4%	Optimizing nutrient management for organically grown blueberries east of the Cascade Range
M. Borghi and L.W. DeVetter	Utah State University	$5,000	1/2021-12/2021	1%	Harnessing the chemistry of flowers to increase yield via increased pollinator services: the case of blueberry crop

PENDING:

DeVetter, L.W., K. Englund, T. Marsh, J. Goldberger, S. Agehara, and S. Sistla	USDA SCRI	$8 mil	10/2021-9/2025	8%	Improving end-of-life management of plastic mulch in strawberry systems
Gramig, G., L.W. DeVetter, S. Galinato, D. Bajwa, and S. Weyer	USDA OREI	*Undetermined*	10/2021-9/2025	5%	MulcH2O: Biodegradable Composite Hydromulches for Sustainable Organic Horticulture
DeVetter, L.W. and W. Hoarshi-Erhardt	WRRC	$39,258	1/2021-12/2024	3%	Advanced machine harvest selection trials for raspberry grown in northwest Washington
Bunn, R., and L.W. DeVetter	WRRC	$6,975	1/2021-12/2021	2%	Are arbuscular mycorrhizal fungal propagules available in newly planted raspberry fields?
DeVetter, L.W., C. Miles, and S. Watkinson	WRRC	$15,002	1/2021-12/2021	2%	Evaluation of multi-season plastic mulches in mature raspberry production
DeVetter, L.W, C. Mattupalli, D. Brown, D. Harteveld, M. Cucak, and D. Brown	WBC	$20,766	1/2021-12/2022	2%	Optimizing the management of mummy berry using an online decision support tool
DeVetter, L.W., G. LaHue, M. Borghi, S. Watkinson, A. De La Luz	WBC	$25,795	1/2021-12/2022	4%	Pollinator attraction - Nectar, pollen, and assessment of new technologies

Project No: 3455-3222
Title: Multi-season plastic mulches for improved weed management and crop growth
Personnel:

- **PI:** Lisa W. DeVetter | Associate Professor of Horticulture | WSU NWREC | 16650 State Route 536, Mount Vernon, WA 98273 | phone: 360-848-6124 | lisa.devetter@wsu.edu
- **Co – PIs:**
- Huan Zhang | Former PhD Graduate Student | WSU-NWREC | 16650 State Route 536, Mount Vernon, WA 98273 | phone: 360-848-6129 | huan.zhang@wsu.edu
- Carol Miles | Professor of Vegetable Horticulture | WSU-NWREC | 16650 State Route 536, Mount Vernon, WA 98273 | phone: 360-848-6150 | milesc@wsu.edu
- Chris Benedict | Extension Educator | WSU Extension Whatcom County | 1000 N. Forest St. Ste. 201 | Bellingham, WA 98225 | phone: 360-676-673 | chrisbenedict@wsu.edu

Reporting Period:

- Jan. 1-Dec. 31, 2020. Please note that although this was originally a 2-year project, we are requesting an additional year of funding to continue to monitor treatments and observe root development. If the proposal for work in 2021 is not funded, we will submit a final project report within 60 days of the project's end (by March 1, 2021).

Accomplishments:

- The experiment was established and project data were collected according to plan. This project is providing continued information to growers, scientists, and crop advisors about mulching options in raspberry including their long-term effects on crop growth and productivity, weed management, and labor savings potential.

Results:

- The planting produced its first crop in 2021. Yield was greatest in plots grown with Weedmat, a mulch with durability that can last multiple years, and polyethylene (PE) mulch (**Fig. 1**).
- Weedmat produced the greatest primocane number and height , although primocane height was equal to PE (**Table 1**).
- Average volumetric water content (m^3/m^3) measured from sensors installed 4 inches deep, 4 inches from the drip emitters, and 2 inches from the crown averaged: 0.31, 0.35, 0.33, 0.34, and 0.4 for the bare ground, Bio360, Novamont, PE, and Weedmat plots, respectively.
- Soil temperature measured from the same sensors averaged: 56.4, 56.3, 57.7, 57.6, and 56.7 °F for the bare ground, Bio360, Novamont, PE, and Weedmat plots, respectively.
- Mulches effectively reduced weed number and biomass (data not presented). No differences in vole activity were detected (data not presented).
- Data suggest yield and growth gains under the conditions of the study are from improved weed management and soil moisture.

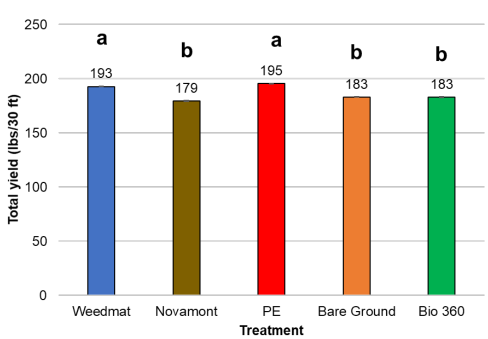

Figure 1. Yield of 'Meeker' raspberry grown with different mulches compared to bare ground (control), 2020. Letters denote significant differences.

Table 1. 'Meeker' primocane number and height, Sept. 2020. Different letters within a column denote statistical differences.

Treatment	Primocane #/hill	Primocane height (in)
Weedmat	**11 a**	**98 a**
Novamont (compostable)	8 b	86 bc
PE	9 b	**98 a**
Bare ground	**12 a**	80 c
Bio360 biodegradable	**11 a**	89 b
P-value	0.02824	0.000531

2020 WASHINGTON RED RASPBERRY COMMISSION
RESEARCH PROPOSAL

Project Number: 3455-3222 **Proposed Duration:** 3 years

Project Title: Multi-season plastic mulches for improved weed management and crop growth

PI: Lisa W. DeVetter
Organization: WSU NWREC
Title: Associate Professor, Small Fruit Horticulture
Phone: 360-848-6124
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Address: 16650 State Route 536
City/State/Zip: Mount Vernon, WA 98273

Co – PIs:
- Carol Miles, Professor of Vegetable Horticulture, WSU-NWREC, 16650 State Route 536, Mount Vernon, WA 98273, phone: 360-848-6150, milesc@wsu.edu
- Chris Benedict, Extension Educator, WSU Extension Whatcom County, 1000 N. Forest St. Ste. 201, Bellingham, WA 98225, phone: 360-676-673, chrisbenedict@wsu.edu

Year Initiated: 2019 **Current Year**: 2020 **Terminating Year**: 2021

Total Project Request: $39,785 **Year 1**: $12,625 **Year 2**: $14,563 **Year 3**: $12,607

Other funding sources: No

Notes: We have WSDA funding to continue our current work evaluating single-season plastic mulch application in raspberry. This project is separate from that work funded by WSDA.

Description:
Plastic mulches are widely used in annual vegetable and strawberry production systems due to their ability to manage weeds, modify soil temperature and moisture, and promote crop yield and quality. The benefits of plastic mulches in perennial systems such as floricane red raspberry (*Rubus idaeus*) is just starting to be explored. In a trial partially funded by the WRRC, we found polyethylene (PE) and biodegradable plastic mulches (BDMs) improved tissue culture (TC) plant establishment, managed weeds, and increased yield by 34% compared to our non-mulched control (Zhang et al., 2019). However, the PE and BDMs in this experiment are designed for single-season use and there may be a benefit to using mulches that have multi-year functionality. This project is exploring the application of thicker, non-degradable, compostable, and biodegradable plastic mulches designed for multi-season use in spring-planted TC raspberry and test both their application and suitability in floricane red raspberry production. Completion of this project will further inform growers about the benefits of mulching and additional mulch products suitable for the red raspberry system.

Justification and Background:
Mulching has the potential to increase both the productivity and efficiency of growing raspberry. Research conducted by this team showed that PE and BDMs controlled weeds and increased primocane number and height compared to growers' standard practice of herbicide application and hand weeding in a 'Wake^{TM}Field' spring-planted field (Zhang et al., 2019). Mulching provide adequate weed control, reducing the need to apply herbicides and hand-weed during the planting year, which saves costs and reduces labor needs. Furthermore, the increase in plant growth was manifested into a 34% yield increase among all mulched plants compared to the non-mulched ones during the first harvest year. Mulch benefits appear limited to spring-planted fields, as summer-planted raspberry did not demonstrate a yield increase when established with PE mulch (Zhang et al., 2020). However, improved weed management contributes to PE mulch adoption in both spring- and summer-planted systems. While research on mulch application in perennial systems is limited, findings to date highlight their benefits and justify further investigation.

Mulches with multi-year functionality may extend mulch benefits by providing weed management and promotion of crop growth through modified soil temperature and moisture conditions for several years. Harkins et al. (2013) and Larco et al. (2013) demonstrated the benefits of multi-year polypropylene and polyethylene mulch (i.e., "weedmat") in establishing organic blackberry (*Rubus ursinus*) and blueberry (*Vaccinium corymbosum*), respectively. In both trials, mulch improved weed management and crop growth compared to non-mulched plots and were considered more cost-effective than hand weeding. It is expected similar benefits will be observed in floricane raspberry planted as TC transplants. However, multi-year mulches are more costly and may interfere with and limit primocane emergence, which could decrease future yields. Additionally, voles (*Microtus* spp.) may find these mulches a suitable habitat and increase in their activity. Thus, there is a need to evaluate multi-year mulches in floricane raspberry and their viability in Washington.

This project builds upon previous work that demonstrated the benefits of single-season PE and BDM application in raspberry planted as TC transplants. We propose to investigate how multi-year mulches impact raspberry planted as TC transplants, including weed management, and plant productivity over three years. We will also evaluate incidence of vole activity, economics, and rooting patterns, as mulches can impact root growth and this has been requested by growers. Completion of this project will contribute to the development of recommendations on optimal mulch products and practices for Washington red raspberry.

Relationship to WRRC Research Priorities:
This project addresses labor saving practices (#1 priority), alternative management systems (#3 priority), and weed management (#3 priority).

Objectives:
Test the application of multi-year mulch materials in TC red raspberry and compare to bare ground cultivation (control; herbicide plus hand weeding) with consideration of the following: 1) Evaluate weed incidence; 2) Monitor surface degradation of the mulches; 3) Assess for vole incidence; 4) Evaluate growth and establishment of raspberry, including shoot and root

growth;5) Evaluate fruit yield and quality of raspberry; and 6) Assess economic impact of different mulches in Washington raspberry systems.

We assessed weed incidence, mulch surface degradation, plant growth, and vole incidence in 2019 and 2020. Yield and fruit quality were evaluated in 2020, when the planting produced its first crop. We propose to continue assessing weed incidence, mulch surface degradation, plant growth, yield, fruit quality, and vole incidence in 2021 but also plan to do a coarse evaluation of root growth and economic assessment as additional components to our research. Soil temperature and moisture will be monitored throughout the study.

Procedures:
This experiment was established at the Washington State University Northwestern Washington Research and Extension Center in Mount Vernon. Tissue culture 'Meeker' transplants were planted May 1, 2019, one day after mulch application. The experimental design is a randomized complete block with four treatments replicated four times. Plots are 1 row wide and 58 ft long. Treatments include: 1) Woven black polyethylene ("Weedmat") from Extenday; 2) Multi-year compostable plastic mulch from Novamont; 3) Bio360 (single season biodegradable plastic mulch); 4) PE mulch (positive control); and 5) bare ground (herbicide plus hand weeding using standard grower practices; negative control).

The following was completed in 2019 and 2020 and will be repeated in 2021 as indicated:

1. May 2019-2021- Install soil temperature and moisture probes, record temperature and moisture conditions every 15 minutes from May to Dec. 2019-2021.
2. May to Dec. 2019-2021 - Assess mulch surface degradation in a permanent 3 ft^2 area as percent soil exposure (PSE) on the 15^{th} and 30^{th} of every month throughout the duration of the experiment.
3. May to Oct. 2019-2021 - Count weeds and sample for above-ground biomass in a permanent 3 ft^2 area located in the middle of each plot. This was done once every two months in 2019 and 2020 and will be repeated in 2021.
4. July to Aug. 2020-2021 - Machine harvestable yield, average berry size, fruit total soluble solids, pH, and total titratable acidity will be measured.
5. Sept. 2019-2021 - Measure primocane number and height from 10 randomly selected representative plants per plot.
6. Sept. 2020-2021 - Estimate plant biomass using an unmanned aerial vehicle (UAV).
7. Oct. 2019-2020 - Visually assess vole activity as number of tunnels and holes in a permanent 30 ft^2 area in each plot. Lift mulches up from the side for assessment and rebury mulch sides immediately.
8. Oct. 2021 – Excavate 1 plant per plot for three blocks using a backhoe. Photograph and visually observe rooting patterns. If roots can be confidently separated from neighbor plants, we will measure dry root biomass.
9. Oct. 2021 – Conduct an economic assessment of all the mulch treatments relative to the control, including disposal fees, using the WSU Red Raspberry Enterprise Budget (Galinato and DeVetter, 2016).
10. Dec. 2021 – Final project report. Present project data, post project information on program website (see below) and submit newsletter article for publication in the *Whatcom Ag Monthly*.

Anticipated Benefits and Information Transfer:
Plastic mulches are promising tools that can enhance establishment, productivity, and efficiency of raspberry production. We expect multi-year mulches will manage weeds, increase plant growth and yields, reduce labor and pesticide needs associated with weed management, lower costs associated with mulch removal and disposal. Additionally, we anticipate benefits from multi-year mulches will last longer than single-season mulches. Project information will be presented at conferences. Additionally, we will post project results on the WSU Small Fruit Horticulture website (https://smallfruits.wsu.edu/plastic-mulches/). Results will also be shared through the *Whatcom Ag Monthly* and scientific publications.

References:

1. Galinato, S. and L.W. DeVetter. 2016. 2015 Cost Estimates of Establishing and Producing Red Raspberries in Washington. Washington State University Enterprise Budget. TB21.
2. Harkins, R. H., B.C. Strik, and D.R. Bryla. 2013. Weed management practices for organic production of trailing blackberry: I. Plant growth and early fruit production. HortScience 38:1139-1144.
3. Larco, H., B.C. Strik, B. C., D.R. Bryla, and D.M. Sullivan. 2013. Mulch and fertilizer management practices for organic production of highbush blueberry. I: Plant growth and allocation of biomass during establishment. HortScience 48:1250-1261.
4. Zhang, H., C. Miles, S. Ghimire, C. Benedict, I. Zasada, and L.W. DeVetter. 2019. Polyethylene and biodegradable plastic mulches improve growth, yield, and weed management in floricane red raspberry. Scientia Horticulturae 250:371-379.
5. Zhang, H., C. Miles, S. Ghimire, C. Benedict, I. Zasada, H. Liu, and L.W. DeVetter. 2020. Plastic mulches improved plant growth and suppressed weeds in late summer-planted floricane raspberry. HortScience. 55(4):1-8.

Budget:

	2019 (requested)	**2020** (requested)	**2021**
Salaries[1/]	$6,110	$7,456	$5,957
Timeslip[/2]	$960	$1,620	$1,680
Operations (goods & services)[3/]	$2,450	$2,235	$3,235
Travel[4/]	$450	$0	$0
Equipment	$0	$0	$0
Benefits[5/]	$2,655	$3,252	$2,735
Total	$12,625	$14,563	$13,607

1/ Scientific assistant (Sean Watkinson) at 1 month, 100% FTE (salary at $ 4,235/month) and Research Associate (Ed Scheenstra) at 0.5 month, 80% FTE (salary at $4,305) in 2021.
2/Timeslip in 2021 for field (i.e., harvest) and lab data collection: $14/hr x 20 hr/week x 6 weeks = $1,680.
3/Consumables (field work supplies) at $450; land-use fees at WSU NWREC at $585; field work equipment/rental at $1,200; backhoe rental $1,000.
4/No travel requested.
5/Benefits for Watkinson at 44.9% and Scheenstra at 39.1%; benefits for timeslip at 9.6%.
*Budget approved by Susan Cao on Nov. 23, 2020.

Miles, Carol A.

OMB Approved 0524-0039

UNITED STATES DEPARTMENT OF AGRICULTURE
COOPERATIVE STATE RESEARCH, EDUCATION, AND EXTENSION SERVICE
CURRENT AND PENDING SUPPORT

Instructions:

1. Record information for active and pending projects, including this proposal. (Concurrent submission of a proposal to other organizations will not prejudice its review by CSREES.)
2. All current efforts to which project director(s) and other senior personnel have committed a portion of their time must be listed, whether or not salary for the person involved is included in the budgets of the various projects.
3. Provide analogous information for all proposed work which is being considered by, or which will be submitted in the near future to, other possible sponsors including other USDA programs.

NAME (List/PD #1 first)	SUPPORTING AGENCY AND AGENCY ACTIVE AWARD/PENDING PROPOSAL NUMBER	TOTAL $ AMOUNT	EFFECTIVE AND EXPIRATION DATES	% OF TIME COMMITTED	TITLE OF PROJECT
Louws. et al.	USDA-NIFA-SCRI	$6,799,672	10/16-9/21	5%	Growing New Roots: Grafting to Enhance Resiliency in U.S. Vegetable Industries
Miles and Galinato	WSDA SCBG	$177,808	10/17-9/21	5%	Cost effective technologies for cider apple orchard mechanization and fruit quality evaluation
Walsh. et al.	USDA NIFA CPPM EIP	$837,000	10/17-9/21	2%	Washington state IPM extension implementation program 2017-2020
Miles. et al.	WSARE	$74,580	10/19-9/21	5%	In-service training for biodegradable mulch
DeVetter. et al.	WSDA SCBG	$249,960	10/18-9/21	2%	Promoting productivity and efficiencies in red raspberry systems through application of biodegradable plastic mulches
Miles and LaHue	WSU BIOAg	$39,200	5/19-12/20	2%	Evaluating regulated deficit irrigation in cider apple orchards for improved water use efficiency, reduced labor input, and improved fruit quality
Miles	WSDA Nursery	$25,829	7/20-6/21	2%	Establishing *Camellia sinensis* as a new crop for the Washington nursery industry
DeVetter et al.	USDA-NIFA-SCRI	$50,000	10/19-9/21	2%	New mulch technologies and improved end-of-life management
Grewell et al.	ND Corn Council	$10,000	1/21-12/21	2%	Field evaluation of new corn-based BDMs
Pending:					
Miles and Granatstein	WSU BIOAg	$14,907	5/21-4/22	2%	Tracking the Washington State Organic Sector

 Form CSREES-2005 (12/2000)

PATHOLOGY
VIROLOGY

Project Proposal to WRRC **Proposed Duration:** 3 Years

Project Title: Management of Fungicide Resistant Botrytis in Red Raspberry

PI: Alan Schreiber
Organization: Agriculture Development Group, Inc.
Title: Researcher
Phone: 509 266 4348 (office), 509 539 4537 (cell)
Email: aschreib@centurytel.net
Address: 2621 Ringold Road, Eltopia, WA 99330

Cooperators: Dr. Tom Walters-Walters Ag Research, Dr. Chakradhar Mattupalli, WSU

Year Initiated: 2019 **Current Year:** 2020 **Terminating Year:** 2021

Total Project Request: Year 1 $12,000 Year 2 $13,000 Year 3 $15,250

Other Funding Sources: I have submitted a parallel proposal to the Washington State Commission on Pesticide Registration. The WRRC funds are match for the Specialty Crop Block Grant on this topic.

Description: Resistance has been documented to four of five active ingredients historically used for control of botrytis in raspberry and other berry crops. Based on Dr. Peever's work, it is clear there is widespread resistance to Elevate, Pristine (boscalid), iprodione and Switch (cyprodonil), and the level of resistance appears to have increased during the time that he has screened for it. This project proposes to screen currently used products, other products that are registered but not commonly used, and products not registered inraspberry for control of botrytis. This project will be a standard efficacy trial that is modeled after the 2019 and 2020 trials, with some improvements based upon what was learned during the course of the previous trial. Data generated from 2016 supported a Section 18 for a new fungicide that was shown to be more effective than any currently available product used for botrytis control. Data generated in 2018 and 2019 resulted in yellow rust being added to the Fontelis fungicide label. This project will involve two trials: an efficacy program trial screening several fungicides and a program trial that evaluates all major raspberry botrytis programs. Additionally, a number of new fungicides have been registered on raspberry, most of which belong to the FRAC group 7 and belong to the same mode of action as boscalid (Pristine). These products need to be screened for their fit in a Washington raspberry disease program. A priority will be placed on finding new modes of action that are not in FRAC group 7.

Justification and Background: This project will generate conclusions on which fungicidal products are effective for controlling botrytis and which products are not. It is my expectation that WSU's Chakradhar Mattupalli will work cooperatively on this project. I am in the process of scheduling a meeting with him in December to discuss research needs and this project will be part of this discussion. I am submitting this proposal at the request of the WRRC to ensure that the necessary information is generated for the Washington raspberry industry. Dr. Tom Walters, of Walters Ag Research, will also assist with this project. This group of three scientists has a long history of working cooperatively and strongly together.

Botrytis cinerea, is a fungus that causes blossom blight, preharvest rot, postharvest rot and cane infections. On raspberry, it overwinters as sclerotia on canes, and as mycelia on dead leaves and mummified fruit. These sclerotia will produce conidia in spring, when a moist, humid environment provides the ideal conditions for the spread and sporulation of this pathogen. All flower parts except sepals are very susceptible. Initial infections of flowers are latent such that the fungus is dormant until fruit ripens. Fruit rot may be more prevalent in wet weather, in fields under overhead set irrigation systems, or where fruit ripens in the field for mechanical harvest. Conidia can infect mature or senescent leaves, resulting in primocane infections through petioles.

This is the most treated disease of berries in Washington State and the entire United States, with growers applying three to six applications per season, starting with a pre-bloom application and continuing until harvest. Raspberry growers who are applying only three or four applications are probably incurring significant economic losses from the disease. There is no economic or action threshold for this disease. If growers find it/think they have it, or are at risk of having it, then they have to start a treatment program. The PNW Small Fruit Research Center ranks it as the number one priority for research in blueberry and raspberry. Raspberry, blueberry, blackberry and strawberry fundamentally have the same disease issues, and are often planted adjacent to each other, using the same fungicides, and creating similar fungicide resistance issues. Raspberry has fruit that is susceptible earlier than blueberry and has heavier selection pressure. It is likely that spores which survived a raspberry fungicide programs will infect blueberry fields that mature later in the season, and are subsequently subjected to another fungicide program within the same year.

Despite aggressive treatment programs, growers will incur annual losses to this pest. Botrytis is well known for developing resistance to fungicides. Growers, crop advisors, researchers and extension representatives are concerned that genetic mutations facilitating resistance may be developing faster than new fungicide products that can be developed. The PNW Disease Management Handbook states this about Botrytis on raspberry: *"Fungal strains can become tolerant to a fungicide when it is used exclusively in a spray schedule. To reduce the possibility of tolerance, alternate or tank-mix fungicides that have different modes of action. Strains resistant to 5 different modes of action have been reported from Germany."*

Growers try using all four modes of action during a season for resistance management (although some can only use three products due to MRL limitations). Other issues occur due to label restrictions such as number of application restrictions, REI and PHIs. The loss of even one product could mean a significant problem; the loss of two products would cause a crisis in the industry. We will coordinate our efforts with OSU, USDA ARS, and BC disease research programs. Something especially concerning is that all new and pending registrations are for active ingredients in the same FRAC group 7 that is in the commonly used products including Pristine, Luna Tranquility, Kenja, Fontelis and Miravas.

Relationship to WRRC Research Priority: This project directly addresses the fruit rot priority.

Objectives: Our objective is to generate botrytis efficacy data for new products labeled for red raspberry. A secondary objective is to use this data and information provided by Dr. Peever to develop better botrytis control recommendations for raspberry.

Procedures: We plan to conduct efficacy trials in 2021 that are similar to the trials done in 2020. We feel we have a very good understanding of what products and patterns to test, but have not had adequate disease pressure to evaluate the proposed treatments. The testing techniques would be similar to what we have used in the past years, with some improvements. Although testing details have not been finalized, we expect to use a different site than in the past year. The trial site that we have used was one nearing the end of its productive life and had a weakened canopy. This may have exacerbated the lack of disease pressure that was predominately caused by weather conditions that were not conducive to a disease outbreak. A new location that has a crop canopy that is denser than the ones we have used in previous years will increase the likelihood of high disease pressure. One trial looked primarily at single ingredient programs to ascertain how that particular product worked against botrytis. The second trial evaluated several different programs used by the Whatcom County raspberry industry. The different programs covered the breadth of contract strategies used by growers as well as tested some new programs for controlling botrytis. Additionally, the second trial looked at more than 19 different active ingredients.

We propose to conduct two trials in 2021, one that would screen for new products and a second trial that would evaluate season long programs that are currently being used by growers controlling botrytis in raspberry. A commercial style applicator would be used and each treatment would be replicated four times.

Applications would start pre-bloom and would continue through harvest. The start and end dates, and the number of applications depends on environmental / weather conditions and disease pressure. Botrytis samples from the trial plots will be provided to Dr. Mattupalli to determine the degree of resistance to various fungicides. Dr. Tom Walters would be involved in applying fungicides and Schreiber would oversee the trial, collect and analyze the data to generate research reports.

The experimental design, including products and treatments, used in the previous trials will serve as the base for the 2021 trials. Scientists involved in this project will meet with raspberry industry members and discuss what adjustments should be made to improve the trial.

Anticipated Benefits and Information Transfer: We would provide a written report to the WRRC, make a presentation at the Small Fruit Conference, and work closely with WSU extension, crop advisors, and members of the raspberry industry to make sure the outcome of the research will be well known through the grower community.

Budget:	**2019**	**2020**	**2021**
Salaries	8,000	8,000	9,000
Operations	3,000	2,000	3,000
Travel	1,500	1,500	1,500
Benefits	1,500	1,500	1,750
Total	$14,000	$13,000	**$15,250**

These funds would be primarily used to cover the time of Schreiber and Walters spent on the project. It would cover the applicator's time, tractor/equipment usage, product purchases and other costs. WSCPR funds would be used to fund the effort to make applications and collect data. The funds would also cover partial travel costs that are related to traveling to the site and/or meeting with industry representatives.

Brief Summary of 2020 trials:

2020 Efficacy Trial

Field assessment of gray mold infection showed measurable infection incidence by July-9, where untreated check reached 19.3% infection incidence. Except for treatments including Meteor, Oxidate, Inspire, Orbit, and Vacciplant, most treatments resulted insignificantly lower incidence than untreated. While the typical grower standard Switch (with 6 applications) resulted in 7.8% incidence of disease, we found PhD (8%), Proline (4.8%), Kenja at higher rate (15.5 fl oz/a) (5.8%), Propulse (6.5 %), Experimental 1 all rates (around 7%), Experimental 2 (7.8%), and a rotational program of Luna Tranquility + PhD (7.5%) resulted in on par or even better (numerically) performance as Switch. Similar trend was observed on the July-14 where treatments showed statistically equal control efficacy, Switch with 6 applications, PhD, Proline, Propulse, Kenja high rate, Experimental 1 at all rates, Experimental 2, and Luna Tranquility + PhD rotation program resulted in the best control with 4.5 to 8 % incidence, suggesting 44 to 69% control efficacy compared to the 14.3% incidence in untreated check. Treatments include Luna Tranquility, Scala, Captan, Pristine, Kenja low rate, and Abound exhibited weakened effect by July-14 without significant difference compared to untreated. Meanwhile, Elevate, Fontelis, and Switch with 4 applications actually improved their levels of efficacy by July-14 with further reduced incidence of 6.3 to 8%, which is on par with the superior treatments at July-9. Results suggests good control efficacy on botrytis from Switch with 4 or 6 applications, PhD, Proline, Fontelis, Kenja at higher rate of 15.5 fl oz/a, Propulse, Experimental 1 at all rates, Experimental 2, and Luna Tranquility + PhD rotation program, without any noticeable phytotoxicity.

2020 Program Trial

The program trial also had good infection pressure with 9.5% gray mold incidence by July-9. Although all programs showed no statistical difference from the untreated check on July-9, three programs had only 4.5 to 6.5% incidence, suggesting 32 to 47% control efficacy compared to untreated. While botrytis incidence further increased to 13.8% in untreated check plots by July-14, one of the programs performed well on July-9 further reduced the incidence from 6.5% to 4.8% (July-14), indicating a very consistent control efficacy even when the pressure is increasing. Two of the previously (on July-9) performed well programs did not maintained their control efficacy, and had increased level of gray mold to 9.5% and 12.5%, respectively, indicating insufficient ability to control the disease in a higher-pressure situation. Additionally, another program also showed significantly lower disease incidence than the untreated with only 6% incidence, indicating its control effect eventually started with more applications. In summary, program with the tank mixture and rotation of Captan, Switch, Pristine, Kenja, and PhD exhibited the best and most consistent control efficacy on botrytis in this trial. Followed by a less complex program of Kenja, Captan, PhD, Meteor, and Switch with great potential towards later in a high-pressure timing. It is important to mention that two of the tested programs had very similar rotation/mixture regime as the best program yet did not perform as good. They both have an obvious difference from the best program, lack of Kenja in the rotation/mixture, indicating some superior enhancement from Kenja.

Research Report to the Washington Red Raspberry Commission

Principal Investigators: Alan Schreiber, Lisa Jones, Tom Walters

Title: Raspberry Cane Blight Efficacy Trial - 2020

Materials and Methods

A second-year raspberry cane blight trial was conducted in June 2020 by Agricultural Development Group, Inc. about 6 miles south of Lynden, WA to evaluate the effect of Luna Tranquility on raspberry cane blight and compare its efficacy with other fungicides. The experimental design was a RCB with 4 replications with the plot size of 10 ft x 30 ft. Applications A and B for this trial were made via drip with the A timing being 1 month pre harvest and B timing just before harvest. The rest of the applications for this trial were made by an over the row sprayer to apply treatment spray at 35 gallons/acre during harvest. Both sides of each plot's raspberries were simultaneously sprayed to ensure complete coverage with the experimental products used. The rows of raspberries established for this trial were not treated with any maintenance fungicides to prevent the possibility of interfering with the existing trial's objectives. The trial location was moved from the previous location due to the 2019 stand of raspberries being removed from production.

The raspberry variety was WakeField, a variety with known susceptibility to the disease. The applications were made on June 11 (A), July 5 (B), July 5 (C), July 12 (D), July 19 (E), July 27 (F), August 1 (G), and August 9 (H). The raspberry plots were harvested from June 8 to September 17. The evaluation for the total number of floricanes that collapsed was on August 27. The total number of damaged primocanes and the number of infected primocanes were counted on September 17. Then the incidence for new primocane infections was calculated using infected canes divided by the total damaged canes.

ANOVA means table

Rating Date				Aug-27-2020	Sep-17-2020
Rating Type				Tot col can	prim infect
Rating Unit				#	%
Number of Subsamples				1	1
Days After First/Last Applic.				77 18	98 39
Trt-Eval Interval				77 DA-A	98 DA-A
Trt No.	Treatment Name	Rate	Rate Unit	Appl Code	1	2
1	Untreated check				12a	69a
2	Velum Prime	6.5	fl oz/a	A	9a	57a
3	Velum Prime	6.5	fl oz/a	AB	6a	61a
4	Kenja	15.5	fl oz/a	CDEFGH	9a	52a
5	Luna Tranquility	16.42	fl oz/a	CDEFGH	9a	42a
6	Switch	14	oz/a	CDEFGH	9a	55a
7	Elevate 50 WDG	1.5	lb/a	CDEFGH	9a	55a
8	Tanos 50 DF	10	oz/a	CDEFGH	7a	51a
9	Actigard	0.75	oz/a	CDEFGH	6a	60a
10	Miravas	10.3	fl oz/a	CDEFGH	9a	51a
LSD P=.05					3.9	20.8
Standard Deviation					2.7	14.3
CV					31.35	25.85
Levene's F					0.667	1.831
Levene's Prob(F)					0.732	0.103
Skewness					-0.1937	-0.1945
Kurtosis					-0.4159	-0.9653
Replicate F					4.592	3.604
Replicate Prob(F)					0.0101	0.0261
Treatment F					1.698	0.984
Treatment Prob(F)					0.1383	0.4752

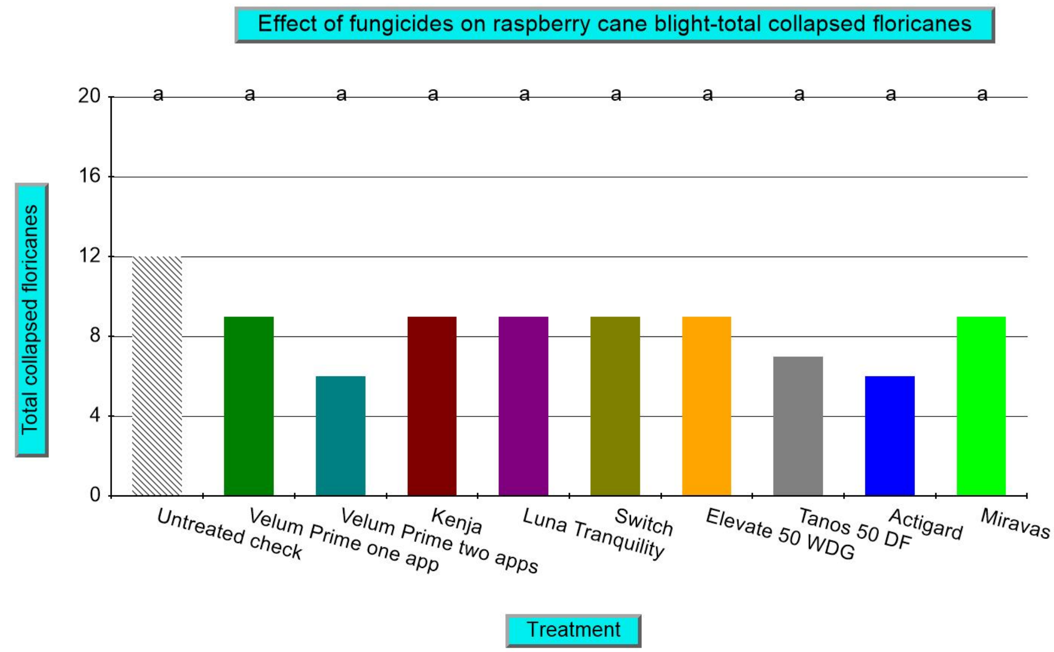
Results and Discussion

Although not statistically different, for the total number of collapsed floricanes, treatments of Velum Prime with 1 application, Velum Prime with 2 applications, Kenja, Luna Tranquility, Switch, Elevate, Tanos, Actigard, and Miravas showed 25%, 50%, 25%, 25%, 25%, 25%, 42%, 50%, and 25% numerically less number, compared to the untreated check, respectively. For new primocane infection incidence, treatments of Velum Prime with 1 application, Velum Prime with 2 applications, Kenja, Luna Tranquility, Switch, Elevate, Tanos, Actigard, and Miravas showed 12%, 8%, 17%, 27%, 14%, 14%, 18%, 9%, and 18% numerically less incidence, compared to the untreated check, respectively.

The results indicated that treatments of Velum Prime, Kenja, Luna Tranquility, Switch, Elevate, Tanos, Actigard, and Miravas can reduce total number of collapsed floricanes and reduce primocane infection of raspberry. We recommend repeating this trial next year to confirm the result and see if there will be significant differences among treatments. It would be important to repeat the exact treatments in the same plots as the previous year. According to Dr. Lisa Jones it is likely that a repeated program in 2021 is may show better impact based on year on year treatments.

This project was supported by the Washington Red Raspberry Commission and the Washington State Commission on Pesticide Registration.

Graph 1. Effect of fungicides on raspberry cane blight-total collapsed floricanes. The evaluation was on August 27, 2020.



Graph 2. Effect of fungicides on raspberry cane blight-primocanes infection incidence. The evaluation was on September 17, 2020.

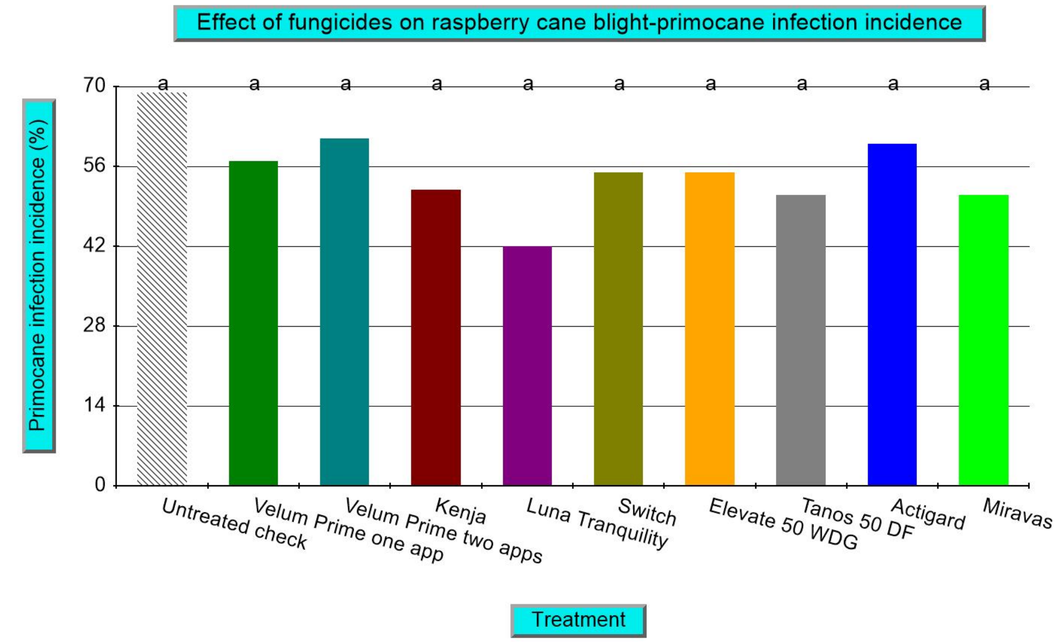


Photo 1. Trial overall photo taken on August 1, 2020.

Photo 2. Application A using drip on June 11.

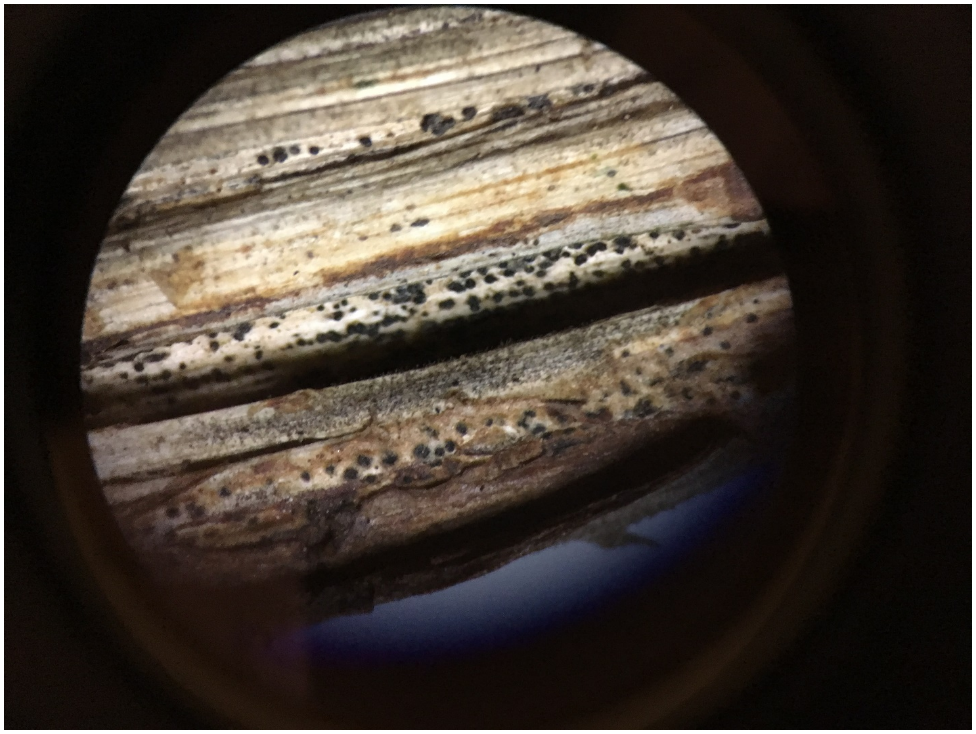
Photo 3. Application using over the row sprayer.

Photo 4. Raspberry plot photo taken on July 27 (left, application F) and August 1 (right, application G).

Photo 5. Cane blight lesions in the field.

Photo 6. Close-up photo for raspberry cane blight lesions.

Photo 7. Close-up photo for cane blight pycnidia.



Project Proposal to WRRC **Proposed Duration:** 3 Years

Project Title: Control of Cane Blight in Red Raspberries

PI: Alan Schreiber
Organization: Agriculture Development Group, Inc.
Title: Researcher
Phone: 509 266 4348 (office), 509 539 4537 (cell)
Email: aschreib@centurytel.net
Address: 2621 Ringold Road, Eltopia, WA 99330

Cooperators: Lisa Jones, Northwest Plant Company.

Year Initiated: 2019 **Current Year:** 2020 **Terminating Year:** 2021

Total Project Request: Year 1 Year 2 Year 3

Other Funding Sources: We have submitted a proposal to the Washington State Commission on Pesticide Registration.

Justification and Background: Cane blight, which is caused by the fungus *Kalmusia coniothyrium,* occurs on a wide range of crops including raspberry, blackberry and roses, and was only recently recognized as a major pest on Washington red raspberries. Cane blight infection requires a wound, such as those that occur during machine harvest, to infect a plant. Infections commonly originate on primocanes during summer. Shortly after infection the fungus colonizes vascular tissue. The fungus will produce small black pimple-like spore producing bodies in the fall and overwinter on the cane. The fungus will continue to grow in the spring and it will slowly girdle the cane. The girdled cane will start to wilt and collapse during early fruit development. Symptoms will develop quicker during hot and dry weather. Uninfected canes and roots are not affected. The fungus can also live on the dead tissue such as cane stubble or debris in the soil. Cane blight rarely is a problem in hand-harvested fields. Rain or overhead irrigation during harvest has increased disease incidence because spores are disseminated in splashing water. Young canes are more rapidly infected while older canes of raspberry are more resistant to infection in the fall.

Northwest Plant Company cultivars (WakeField, WakeHaven), Driscoll's cultivars and Chemainus appear to have a comparatively high level of sensitivity to this disease. In 2015, older WakeField plantings where cane blight had not been managed had up to 40% yield losses. WakeField represents about 30% of Washington's raspberry acreage and up to 50% of the state production. There are non-chemical control options that can reduce infections including pruning out infected canes, avoiding excess nitrogen, adjusting harvester catcher plates to reduce wounding, leaving cane stubble as short as possible and minimizing humidity during infection periods. However, despite the use of these tactics the disease has become a worsening problem.

The primary means of controlling the disease is expected to be fungicides. No other researchers have addressed this issue. Currently, the products recommended for control of cane blight are Tanos (famoxadone (Group 11), cymoxanil (Group 27)) and QuiltXcel (propiconazole (Group 3) and azoxystrobin (Group 11)), although cane blight is not on either label. Tanos requires rotation with fungicides containing different modes of action. The only products registered on caneberries that have cane blight on the label are copper and lime sulfur products (14 total products between the two types of products.) However, lime sulfur cannot be applied in season and copper is not thought to be very effective. One Washington raspberry grower found that alternating Tanos with Switch (Group 9 and 12) and Pristine (Group 7 and 11) seemed to reduce cane blight.

Lisa Jones, a Ph.D. plant pathologist with Northwest Plant Company, has carried out field and laboratory investigations on cane blight including the first identification of the disease on Wakefield raspberry in 2015. She has conducted lab bioassays screening selected fungicides against cane blight and found that Switch and Pristine were the most effective, with Kenja (isofetamid (Group7)) and Tanos being intermediate in effectiveness and Decree (fenhexamid (Group 17)) and PhD (polyoxin D) were relatively ineffective. A concern with applications of these products is that they occur during timings for *Botrytis*. Applications of products like Switch and Pristine have implications for resistance management. Dr. Jones and I propose to screen various fungicide use patterns for their ability to control cane blight in bearing raspberries in addition to collecting biological information on this disease. This is the only research being conducted against this disease on raspberries in the United States.

Research results in 2020 were mixed. All fungicidal treatments reduced cane blight with Luna Tranquility having the greatest impact reducing primocane infections by 42%. However, we believe that two years of treatments are needed to show impact. We believe that the infections may have originated in 2019 and that applications made in 2020 and in 2021 will show more effective control by the end of 2021.

Relationship to WRRC Research Priority: This project directly addresses the WRRC RFP Category “Foliar and Cane Diseases”.

Objective 1. Collect information on disease biology – including developing a growth curve of the cane blight fungus with respect to temperature to help us better understand disease progression since severity is much greater with warmer temperatures.

Objective 2. Generate data on fungicide efficacy against cane blight.

Procedures: A fungicide efficacy trial will be repeated in 2021 in the same location as 2020 in a WakeHaven field that has a significant infection of cane blight. The trial is set up as a randomized complete block design with four replications. Plot size would be approximately 10 feet by 30 feet. The treatments in the 2021 trial were Velum Prime applied a month before harvest by drip and a second treatment at one day before harvest by drip. Then Kenja, Luna

Tranquility, Switch, Elevate, Tanos and Actigard were applied as a directed spray to the base of the plant. The product choices were made in consultation with the Berry Pathology Technical Working Group that is made up of growers, crop advisors, university researchers and extension specialists, agrichemical companies and others with an interest in berry pathology. The Velum Prime treatment applied at one month before harvest begins to mimic an application made for root rot control. Actigard is a SAR product. Other than Miravis, all treatments are registered on raspberry. Miravis is in the process of being registered on raspberry.

We plan to largely do the same treatments in 2021 as in 2020 with some adjustments. We may start Actigard treatments earlier and also the applications would be made on the entire plants. The remaining foliar applications would be a directed spray towards the base of the plant. Foliar applications would start just prior to harvest, and a total of six applications would be made for the foliar fungicides until harvest is over. An over the row sprayer would be used to make the applications. The selection of fungicides for cane blight will have implications for *Botrytis* control. Therefore, in addition to cane blight, the trialists will evaluate for *Botrytis* and any other diseases, such as yellow rust, if appears. Application of products such as Pristine, Switch and Luna Tranquility for cane blight also has implications for *Botrytis* resistance management strategies.

Dr. Jones will have the lead on collecting information on the biology of this disease species. Funding this project is an excellent mechanism for harnessing the expertise of Dr. Jones for the greater benefit of the Washington raspberry industry.

Anticipated Benefits and Information Transfer:

Our goal is to develop a set of recommendations for control of cane blight on raspberry and assess the implications cane blight applications will have for *Botrytis* control programs. This information would be provided to growers through WRRC disseminated information, at the Washington Small Fruit Conference and at grower meetings.

Budget:	**2019**	**2020**	**2021**
Salaries	7,000	3,000	3,000
Operations	1,000	650	650
Travel	500	500	500
Contract Research	4,000	4,000	4,000
Contract Research	4,000	1,000	3,000
Benefits	1,250	850	850
Total	**$17,750**	$**10,000**	**$12,000**

The funds for Contract Research are for chemical applications by Tom Walters and for Lisa Jones' time to rate the plots and provide technical assistant to the project. Northwest Plant will donate travel expenses and lab capacity for the trial for Dr. Jones. Enfield Farms will donate the trial site and cooperate with coordinating applications in the field.

The Washington State Commission on Pesticide Registration has agreed to support this research project with $15,000 contingent on the WRRC supporting this project at the level of $12,000.

Project Title: Current State of Fungicide Resistance of *Botrytis cinerea* to Kenja and Luna Tranquility in Washington Raspberries.

PI: Lisa Jones
Organization: Pacific Berries LLC / Northwest Plant Company
Title: Plant Scientist
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Cooperators: Whatcom County raspberry growers

Year Initiated: 2020 **Current Year:** 2020 **Terminating Year:** 2020

Fungicide resistance is widely reported for *Botrytis*. Kenja (isofetamid, FRAC7) and Luna Tranquility (fluopyram, pyrimethanil, FRAC7,9) are relatively new products for control of *Botrytis* on raspberries. Efficacy of new fungicides generally starts out high and it is almost expected that fungi will eventually develop resistance; it is the rate and magnitude of developing this resistance that is in question. Providing growers with current fungicide resistance data from their fields could impact their fungicide management strategy for the better and possibly prolong the efficacy of products by providing data for more effective fungicide rotations. Cross resistance among FRAC7 fungicides exists but the specific mutation in the *sdhB* gene plays a large role in the magnitude and distribution of cross resistance. Pyrimethanil is not a new active ingredient for Whatcom county. Scala (a.i. pyrimethanil) has been used in the area on both berries and potatoes and some resistance in *Botrytis* has likely already developed in the area. The use of Luna Tranquility may have effects on other FRAC9 fungicides, primarily cyprodinil, an active ingredient in Switch, because there is strong cross resistance among the anilinopyrimidine fungicide group (Leroux et al., 1999). The state of efficacy of active ingredients such as isofetamid and fluopyram in raspberry after their first several years of use could provide information to help growers gain more effective *Botrytis* control.

Previous to this study fungicide sensitivity to Kenja and Luna Tranquility was tracked in 4 Whatcom County raspberry fields from 2017-2020. Data for field Z is shown in Figure 1. Field Z never received a direct application of Kenja or Luna Tranquility but was in close proximity to another grower's field where the products were used. Each consecutive year the *Botrytis* population showed less sensitivity to isofetamid. A similar trend for field Z was seen with Luna Tranquility as well (data not shown).

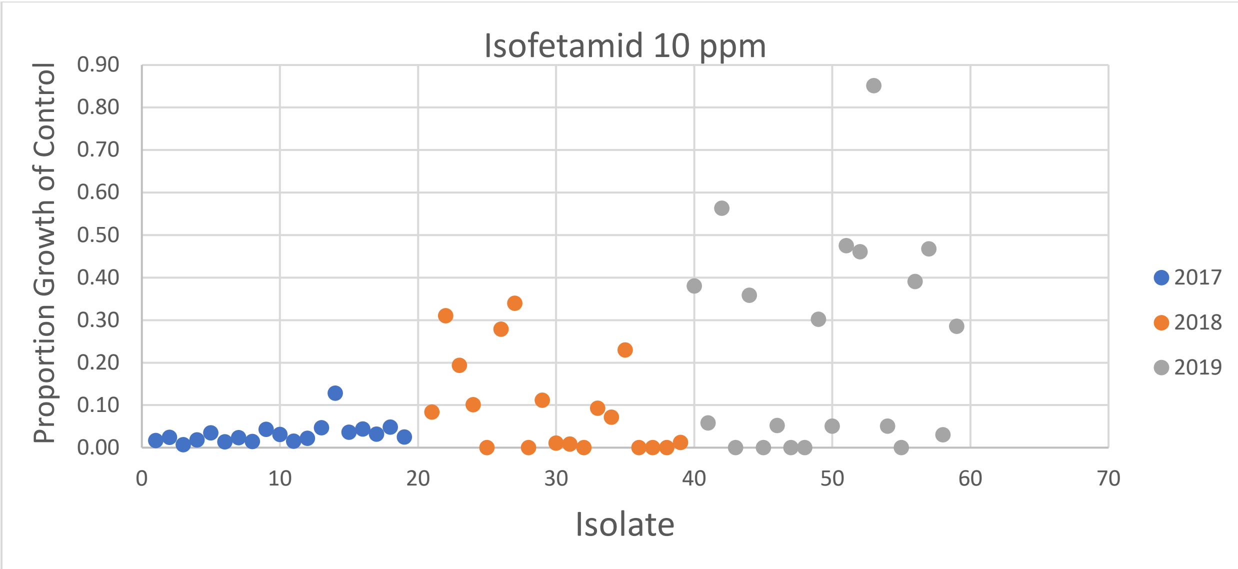

Figure 1. *Botrytis* sensitivity to isofetamid in field Z, 2017-2019.

To help understand the current state of fungicide resistance to the active ingredients in Kenja and Luna Tranquility a small *Botrytis* survey was conducted in red raspberry fields in Whatcom County, WA. Isolates were assessed for sensitivities to isofetamid, fluopyram, and pyrimethanil. Mutations in the *sdhB* (succinate dehydrogenase subunit B) gene were assessed for FRAC 7 fungicides and the EC_{50} values were estimated for isolates that showed the least sensitivities to the fungicides at the survey discriminatory doses.

Materials and Methods

During the winter of 2019-2020 *Botrytis* isolates were collected from 9 red raspberry fields designated as; A, B, C, D, H, J, R, S, and Z, throughout Whatcom County. These 9 fields included 4 different growers and 3 raspberry cultivars; WakeField, Cascade Harvest, and Meeker. Sclerotia were collected from cane scrapings on overwintering canes. Twenty isolates were collected from each field for a total of 180 isolates.

Figure 2. Trellised raspberry canes, with one cane to the right seen infected with *Botrytis* showing characteristic concentric ring growth pattern and the formation of small black sclerotia.

Cane scrapings were surface disinfested with 10% bleach and plated on potato dextrose agar for *Botrytis* growth and maintenance. Isolates were subjected to discriminatory doses of isofetamid (10ppm), fluopyram (2ppm), and pyrimethanil (2ppm) on yeast extract agar and proportion of growth was calculated from diameter of growth on fungicide amended media and compared to a no fungicide control. Twenty-eight isolates that showed a high proportion of growth to the control plates were subjected to a series of higher doses of the respective active ingredients to estimate their EC_{50} values. The *sdhB* gene was sequenced for 24 isolates to assess for mutations linked to resistance for FRAC 7 fungicides. Primers used for PCR and sequencing were Bc.SdhB-F1 (Amiri et al. 2014) and IpBecEnd2 (Leroux et a. 2010). Mega X (Kumar et al., 2018) software was used for sequence alignment and SNP (single nucleotide polymorphism) analysis.

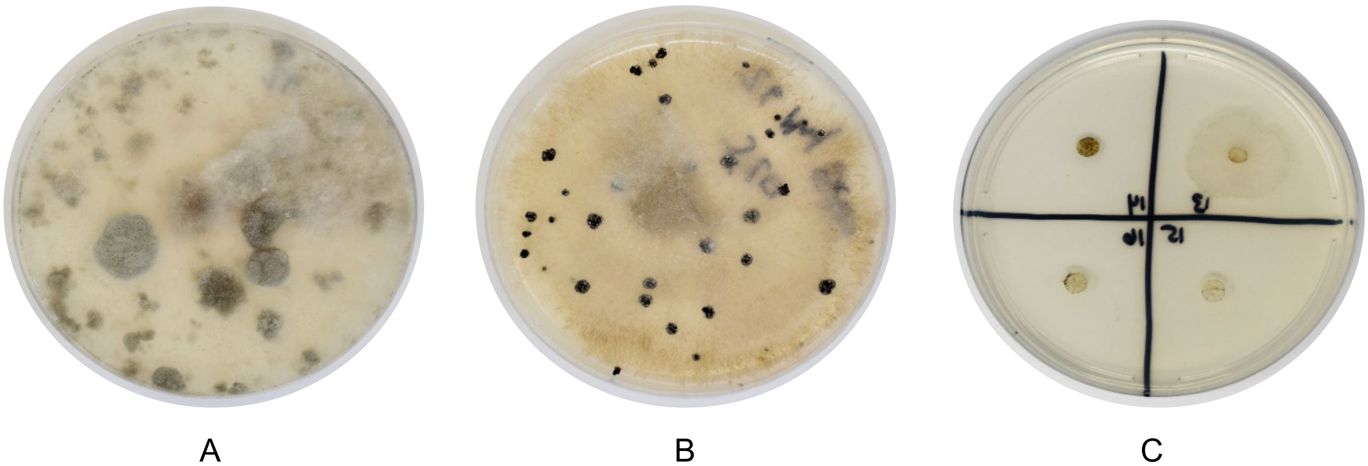

Figure 3. A and B. *Botyrtis* isolates growing on PDA; C. Four isolates growing on media amended with fungicide showing 3 sensitive and 1 less sensitive isolate.

Results and Discussion

Fungicide sensitivity survey of *Botrytis* isolates from Whatcom County red raspberry fields by active ingredient.

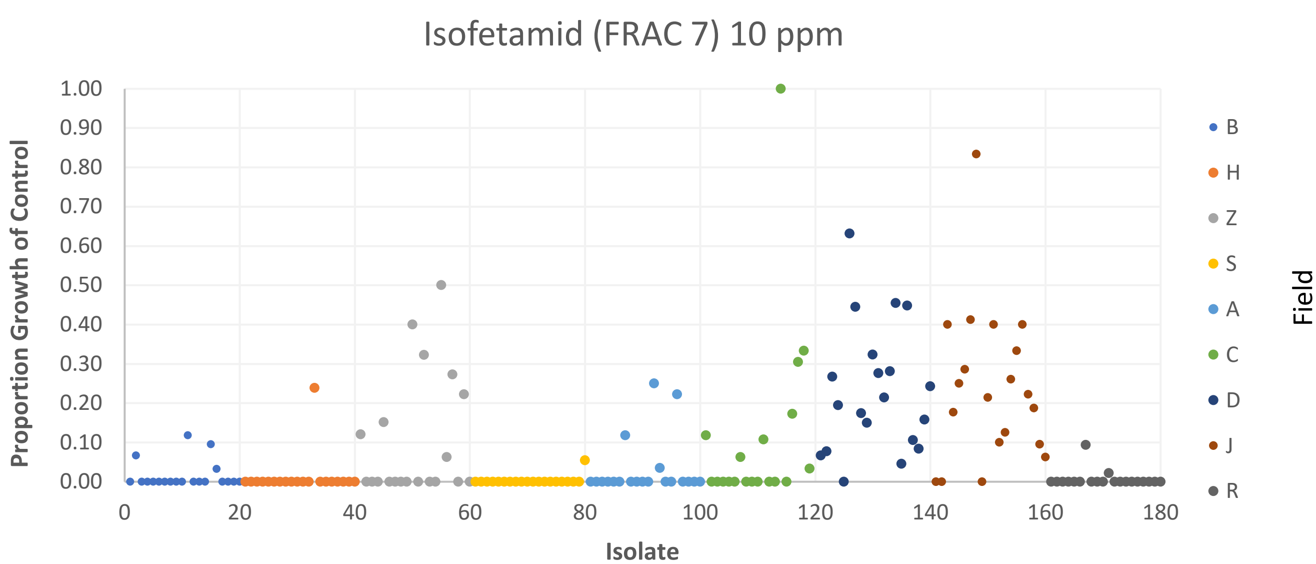

Figure 4. Isofetamid sensitivity of survey isolates at 10ppm.

Only 4 isolates (2.2%) with EC_{50} of 10ppm isofetamid or greater were found and further assessed. Field Z was the only field with an isolate that had an EC50 ≥ 10ppm that did not have a history of use. Field Z was in close proximity to field C which may explain why less sensitive isolates were present.

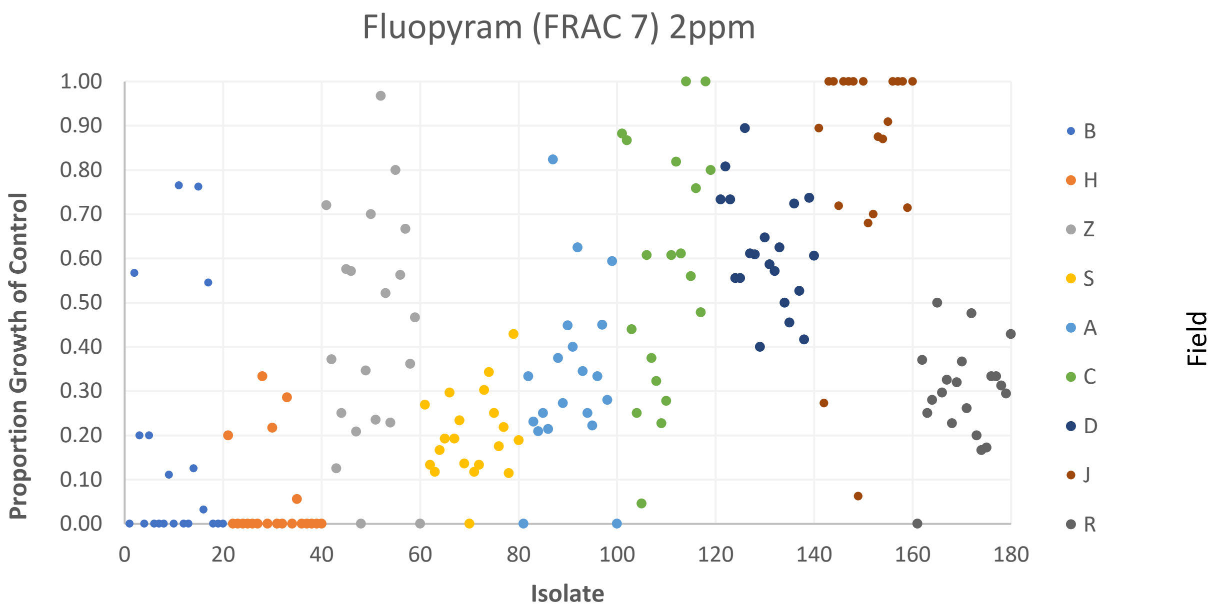

Figure 5. Fluopyram sensitivity of survey isolates at 2ppm.

Sixty-three isolates (35%) had and EC_{50} of 2ppm fluopyram or greater. Several isolates showing the least sensitivity to fluopyram were assessed further.

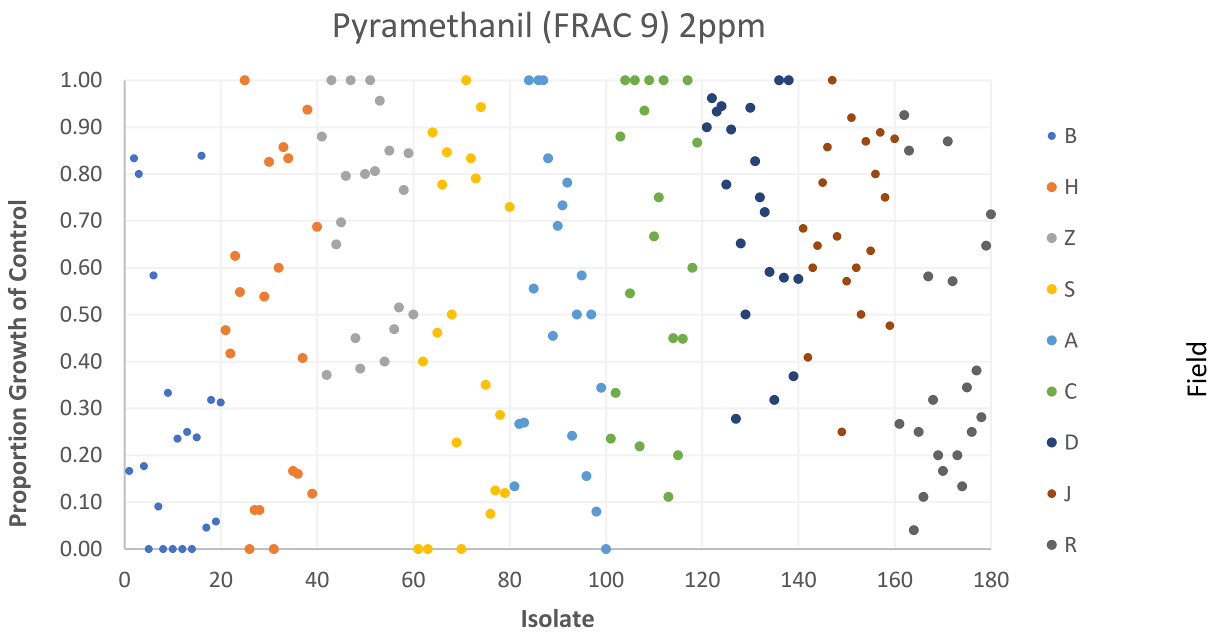

Figure 6. Pyrimethanil sensitivity of survey isolates at 2 ppm.

About 50 % of the survey isolates showed an $EC_{50} > 2$ppm. *Botrytis* has had exposure to pyrimethanil in the area longer than both isofetamid and fluopyram, this could partly explain the greater percentage of isolates with reduced sensitivity to the product. Another active ingredient in the same FRAC group, 9, cyprodinil has also been used for *Botrytis* control in berries for many years. Cross resistance among FRAC 9 fungicides has been widely reported and is likely to play a role in these data.

EC$_{50}$ of selected isolates with isofetamid, fluopyram, and pyrimethanil. Estimated respective EC$_{50}$ values can be found in Table 1.

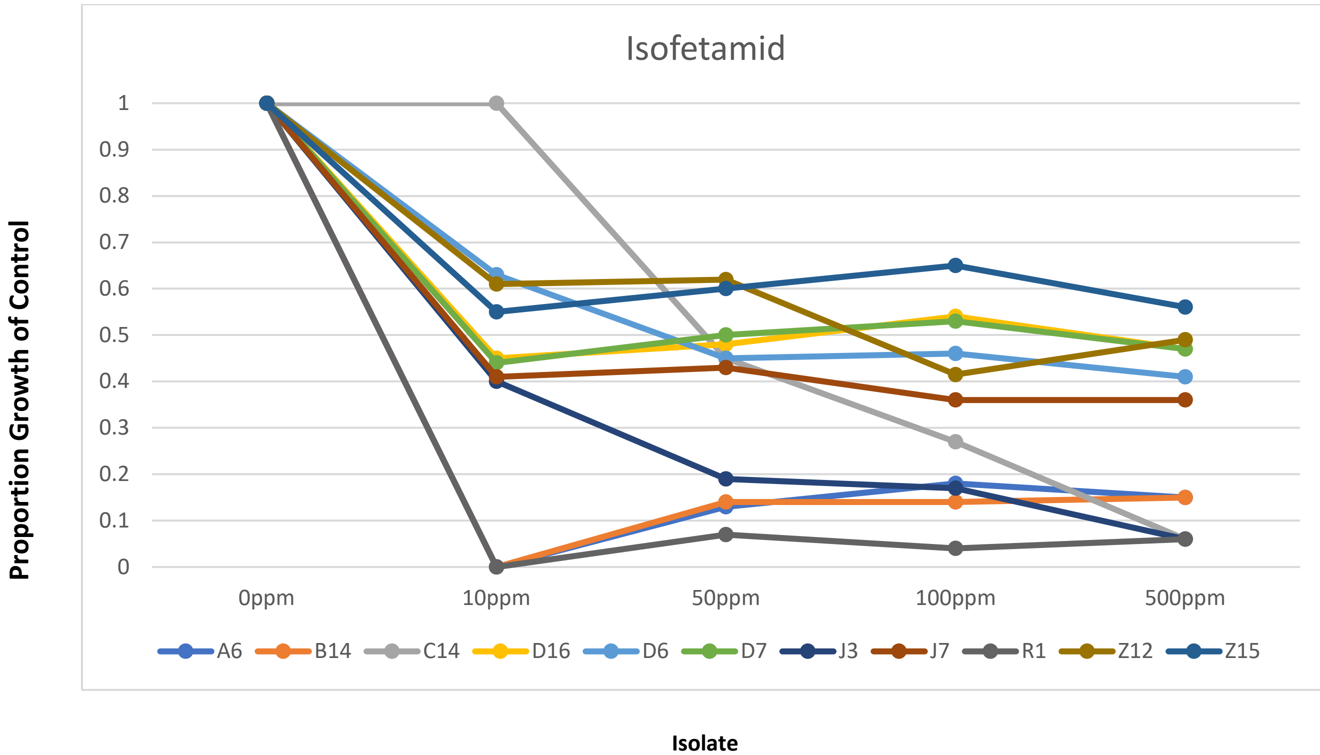

Figure 7. EC$_{50}$ curves for isofetamid of select survey isolates.

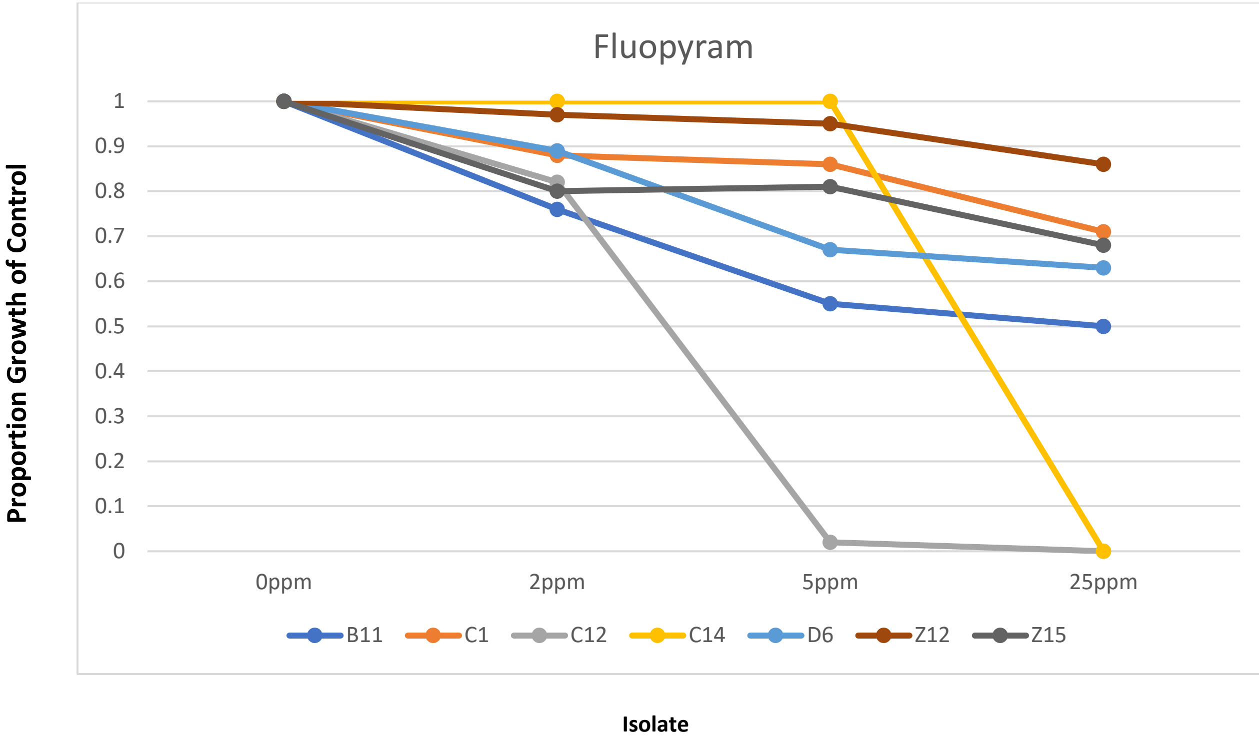

Figure 8. EC_{50} curves for fluopyram of select survey isolates.

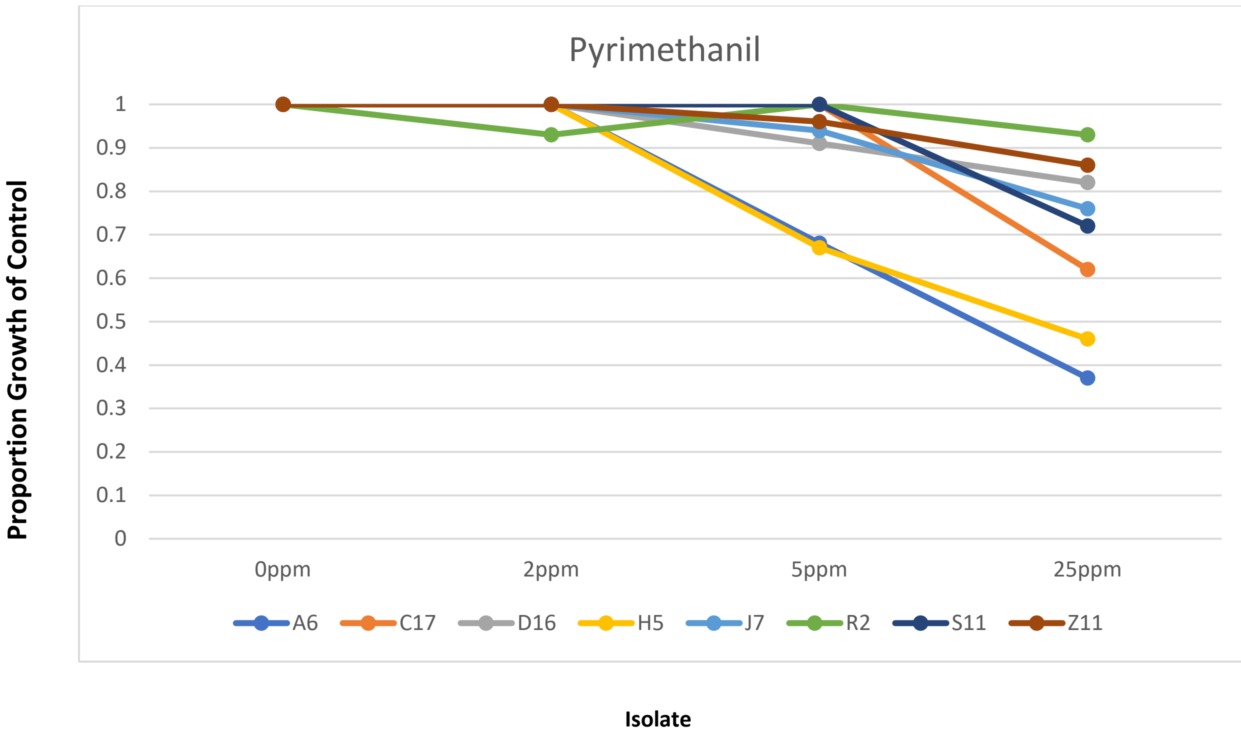

Figure 9. EC_{50} curves for pyrimethanil of select survey isolates.

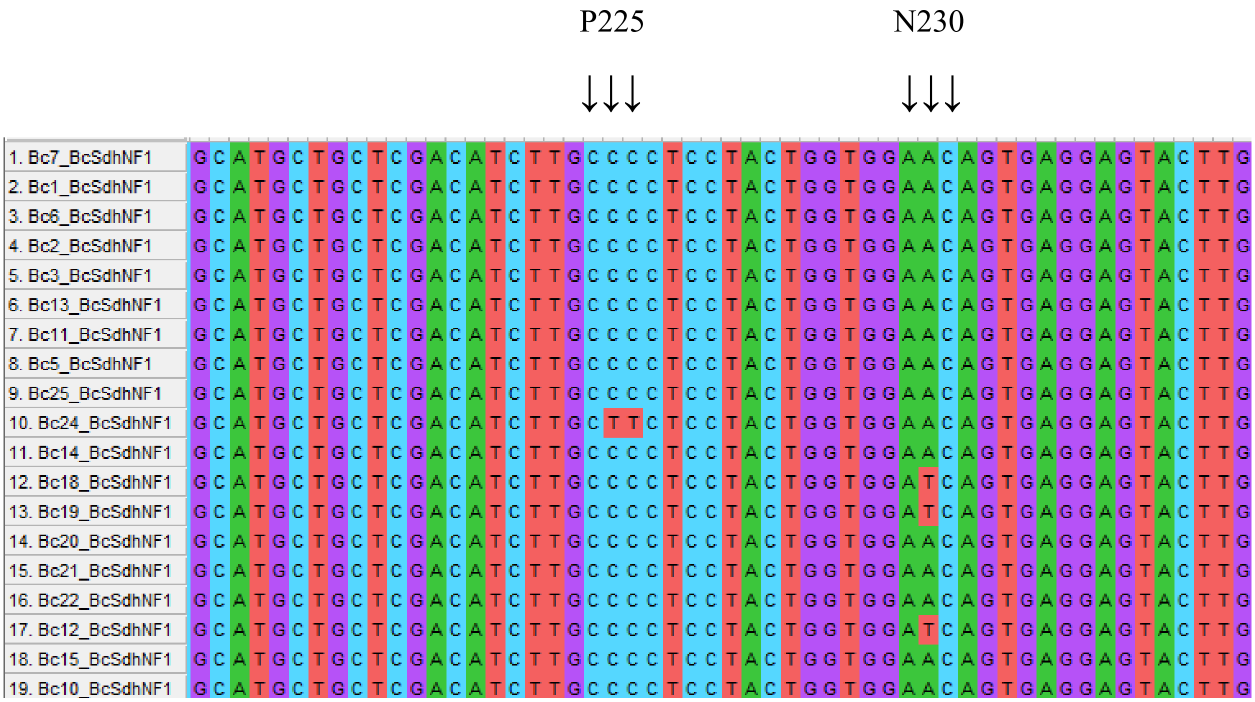

Figure 10. Alignment of survey isolates showing mutations for P225 and N230.

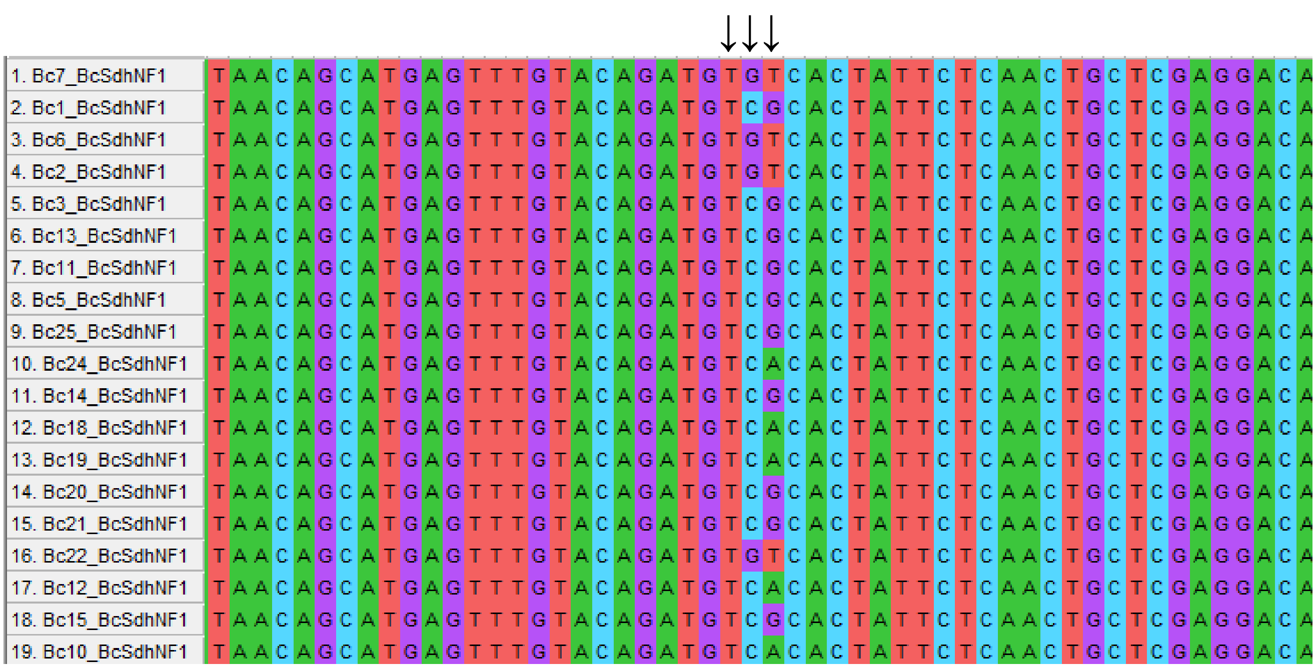

Figure 11. Alignment of survey isolates showing mutations for H272.

				EC$_{50}$		
	sdhB mutation			isofetamid	fluopyram	pyrimethanil
Isolate	N230 (WT)	P225 (WT)	H272 (WT)			
A6	NA	NA	NA	<10ppm		5-25ppm
A7	I	P	H			
B11	N	P	R		25ppm	
B14	N	P	R	<10ppm		
B16	N	P	R			
B6	N	P	R			
C1	I	P	H		>25ppm	
C12	N	P	R		2-5ppm	
C14	N	F	H	10-50ppm	5-25ppm	
C17	N	P	V			5-25ppm
D6	I	P	NA	10-50ppm	>25ppm	
D7	N	P	V	10-50ppm		
D16	NA	NA	NA			>25ppm
H5	N	P	R			5-25ppm
J10	N	P	H			
J18	N	P	R			
J20	N	P				
J3	N	P	V	<10ppm		
J7	NA	NA	NA	<10ppm		>25ppm
R1	N	P	R	<10ppm		
R2	NA	NA	NA			>25ppm
R16	N	P	V			
R19	N	P	R			
R2	N	P	H			>25ppm
S11	N	P	V			>25ppm
Z11	N	P	R			>25ppm
Z12	I	P	H	50-100ppm	>25ppm	
Z15	I	P	H	>500ppm	>25ppm	
Z7	N	P	R			

Table 1. Amino acid substitutions in the *sdhB* subunit and estimated EC$_{50}$ values, non wild-type mutations are highlighted in orange or red. WT = wild-type. NA = not available. I = isoleucine, N = asparagine, P= proline, F = phenylalanine, H = histidine, R = arginine, V= valine.

mutation confers a high level of resistance to one or more FRAC7 fungicides

mutation confers a moderate level of resistance to one or more FRAC7 fungicides

Previous to this study Peever et al. found one isolate with a H272V mutation in 2015 (BC). In this survey, at least 5 isolates were found to have the H272V mutation. In 2017, at the WSU Small Fruit Conference, Tobin Peever was concerned about this mutation increasing in the PNW, in one of his presentation slides he stated, "Mutation H272V appears to confer cross resistance to all new FRAC 7 fungicides– need to follow this mutation carefully in PNW". Personal communication with Olga Kozhar, PhD (WSU, Peever Lab) revealed that she found a single isolate with a P225F mutation just before graduation earlier this year. She did not find any isolates with the N230I mutation. In this survey, one isolate with P225F and five with the N230I were confirmed. The P225F mutation is reported be highly resistant to all FRAC 7 fungicides as well. P225F isolates are highly resistant to isofetamid, while H272V isolates are moderately to highly resistant. The one P225F isolate did show sensitivity to pyrimethanil (EC_{50} <2ppm). The N230I isolates show resistance to fluopyram and are moderately to highly resistant to isofetamid. The five N230I isolates found in this survey will be further assessed and the EC_{50} data with several FRAC7 fungicides and will be included along with Kozhar's graduate student work on FRAC 7 fungicide resistance of ***Botrytis*** on berry crops in the PNW.

Mutations P225F, N230I, H272V, showing resistance to isofetamid and fluopyram appear to be slowly increasing in the PNW berry population along with increased use of the products. Amiri et al. research from 2014 suggests that *Botrytis* isolates with P225F and N230I do not have a fitness cost. This finding stresses the need for proper use and fungicide rotation for Kenja and Luna Tranquility so that highly resistant isolates to these fungicides don't quickly increase in the population. I believe this is the first time the N230I mutation has been reported in raspberries, the mutation has previously been reported on other crops around the USA.

Reduced sensitivity to pyrimethanil was common among isolates with about 50% having an EC_{50} > 2ppm. It was determined that at least 6 of the survey isolates have an EC_{50} of > 25ppm. Pyrimethanil has been in use in the PNW longer than both isofetamid and fluopyram, it is not surprising that reduced sensitivity to this product is more common.

The take home message to growers is that resistance to both isofetamid and fluopyram is developing in the PNW *Botrytis* population on red raspberries. Some mutations have been found that make isolates highly resistant to isofetamid and/or fluopyram. The strongest resistance is associated in or near fields where the product is used most. Based off of this survey the resistant mutations appear to be at low frequencies in Whatcom County raspberry fields but further research will be necessary to monitor the situation.

This project was completed with the assistance of Amberose Kelley, Brooke Berendsen, T.J. VanderYacht, Kaarina Marttila, and Nancy Morado.

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Washington Red Raspberry Commission
Termination Report for 2019 Project

Project title: Refining the microbiome of developing red raspberry fruit tissues.
Personnel: Virginia Stockwell with Gayle McGhee and Brenda Shaffer. USDA-ARS Horticultural Crops Research Unit, Corvallis, Oregon

Reporting Period: January 2019 to December 2020

Accomplishments:

- Four red raspberry fields were sampled from floral bud emergence through ripe fruit in 2019. Culturable microorganisms and microbial DNA were isolated from each sample.
- For microbiome studies, we developed novel methods to block raspberry DNA from being amplified with PCR reactions. The amplification of red raspberry DNA for microbiome studies reduces the sensitivity of methods to identify all of the microorganisms present in each tissue.
- At the conclusion of the microbiome project, we will have a catalogue of which micro-organisms are commonly present on red raspberry. The data will represent the microbial communities present at different stages of berry development during two production years, on two cultivars, and in four locations. This microbial database will be useful for diagnosis of diseases or other conditions affecting plant health and for developing novel approaches towards disease management.
- Using molecular techniques, we determined that the Dry Berry pathogen, reported to cause significant crop losses in caneberries historically, is similar to modern day isolates from killed immature caneberries.

Results:

A) Microbiome of red raspberry: The microbiome is the collection of microorganisms present in or on a tissue. The interactions of microorganisms with plant tissues and interactions between microorganisms can influence plant health. Molecular methods are used to catalog microorganisms of microbiomes and culturing microorganisms provides representatives for downstream experiments.

We used the standard molecular methods to characterize the microbiome of red raspberry. We freeze-dried tissue samples individually, crushed them, and extracted DNA. We then used PCR to amplify genetic regions that are used to identify bacteria and fungi. We sequenced the PCR amplicons and compared the sequences to international DNA sequence databases to identify and count the bacteria, fungi, and yeasts in each raspberry sample.

We found that in addition to microbial DNA, that raspberry DNA in plant tissues and organelles (chloroplasts and mitochondria) also was amplified. This is a common result in microbiome studies on environmental or plant samples. Nonetheless, because ca. 95 to 99% of the sequence data was from the raspberry tissue, we could not obtain an in-depth account of the microorganisms present on each tissue.

To address this problem, we adapted a novel method to prevent the amplification of raspberry DNA. In preliminary tests, we found that the amount of ‘interference’ sequence data from raspberry was reduced dramatically and we had a corresponding significant increase in the amount of data cataloguing the microorganisms present on each tissue.

We are currently testing the fidelity of our methods on artificial fungal communities added to raspberry samples. We processed the samples and we now have the raw data from the sequencing reactions. After the raw data is processed, we will analyze the data to determine the fidelity of the novel method that is tailored to characterize the microbiome of red raspberry.

Once our improved methods are verified, we anticipate that we will be able to re-sequence the red raspberry microbiome samples of 2016 and 2019, hopefully, by the end of summer 2021.

B) Dry Berry disease of red raspberry: Dry berry is a fungal disease that was described in the 1950's in British Columbia by Dr. McKeen. The disease was observed on Loganberry and thimble berry and characterized as rapid death of developing green berries and necrosis extending down the berry stem (pedicel). We have observed the disease annually on red raspberry cultivars in northern Washington.

McKeen described periodic massive crop losses due to dry berry disease in BC. During his research on the disease, he deposited his isolate of the pathogen in a culture collection in The Netherlands in 1959. We purchased his isolate of the dry berry pathogen from the Netherlands collection. Using molecular techniques, we determined that they are closely related fungi and likely are a new species of *Monilinia*. *Monilinia* fungi are commonly plant pathogens; some species cause brown rots of stone fruits and other species infect flowers and cause diseases like mummy berry of blueberry. We suspect that the dry berry pathogen is a member of the flower-infecting *Monilinia* spp.

Follow-up research on dry berry disease and the pathogen will be done by a newly hired Post-Doctoral Scientist in our laboratory. The Post-Doc is funded with a grant from the USDA Agricultural Research Service to study this novel pathogen and the disease of red raspberry. His project involves analysis of whole genome sequences of three isolates of the dry berry pathogen from northern Washington and from McKeen's isolate from 1959. The genome sequence analysis will be used to determine the taxonomic identity of the pathogen and to develop molecular markers to study overwintering of the pathogen and to trace spores of the pathogen in raspberry fields for epidemiology studies.

Summary: The research that we had proposed is not complete at this time. The current Covid-19 pandemic has impacted our capacity to travel and to conduct research. We anticipate that we will remain in 'gating phase' or continued maximum telework for some time. Sequencing and molecular projects also are impacted and slowed by the coronavirus pandemic. Consequently, we are not submitting a proposal to the commission this year. Nonetheless, we anticipate that our research will move forward incrementally. We will provide an updated report to the commission in the future.

Publications: None at this time.

SOILS

The Future of Soil Fumigation for Washington Raspberry growers in 2020

Summary:
There are no immediate regulatory crises pending for soil fumigant use in Western Washington, and we anticipate a fairly stable regulatory environment for the next 3-4 years at least. In the longer term, 5-10 years, it is possible that regulatory tightening will occur for any or all of the commonly used soil fumigants, each for unique reasons. Using California strawberry production as a model, it is likely that as fumigant availability declines, the importance of disease resistance in plant breeding will become paramount. Viable crop rotation programs will also be important, as will postplant treatments for plant parasitic nematodes and soilborne diseases. New practices such as anaerobic soil disinfestation (ASD) may also be helpful.

Our group found no single silver bullet to replace soil fumigants. Nor did we see any promise yet for a "Grand Solution" to the problem through understanding the complex microbiome in the root zone. However, progress can be made by integrating multiple practices into systems that work together.

Current practices and regulation of existing fumigants:
Washington red raspberry growers currently fumigate nearly all ground prior to replanting. Many use a custom applicator to apply combinations of 1,3-D (Telone) and chloropicrin to either the whole field or to planting beds within the field. Application to the beds alone requires less fumigant and is less expensive than whole field (broadcast) fumigation. The difference is often about $400 per acre. In addition, buffer requirements are minimal for bed fumigation. For these reasons, bed fumigation has become more commonplace than broadcast fumigation in the past few years. A few growers also have the capability to apply metam products to the soil, and they do this in addition to or instead of the custom application of Telone and chloropicrin. We did not find any immediate regulatory challenges to any of these practices and anticipate that they will remain available for at least the next 3-4 years. However, each of the fumigants faces the potential of future regulation:

1,3-dichloropropene (Telone) provides control of plant parasitic nematodes and some weeds. Economically, the price of Telone is volatile, as its availability depends upon the production of certain types of plastics. Telone is still in EPA's reevaluation process, but indications are that it will not be dramatically affected. However, concerns about Telone's potential as a carcinogen and its contribution to VOC (Volatile Aromatic Compound) levels have led to increased regulation of this product in California. There, caps are placed on the amounts of Telone that may be used in a township. Air 1,3-D levels are monitored in areas of heavy use in California; these levels have been unacceptably high recently, and additional regulations are coming there. These could include a requirement for tarping with highly effective (but expensive) totally impermeable films (TIF), buffer increases or application block caps. Telone is heavily used in Central Washington, mostly on potatoes, and Washington could ultimately follow California's lead and similarly limit Telone use.

Chloropicrin controls soilborne fungi and *Phytophthora* species. Chloropicrin is highly volatile and is irritating to the eyes and mucus membranes. Current regulations on chloropicrin consequently include significant buffers, the size of which depends on the amount of chloropicrin used and the acreage involved. These buffers are currently minimized when bed fumigation is practiced. However, future regulations could require tarps over the beds (adding significant expense) or increase buffers for non-tarped applications. Because chloropicrin is so volatile, tarps both reduce emissions and enhance efficacy of chloropicrin applications. We highly recommend developing ways to tarp bedded chloropicrin applications.

Metam sodium or potassium are broad-spectrum products, having efficacy on many weeds, nematodes and soilborne pathogens like *Phytophthora* and *Verticillium*. Grower-applied metam is much less expensive than custom application of a Telone:chloropicrin combination. Metam is less volatile than Telone or chloropicrin, and is usually applied closer to the soil surface, within the upper 12 inches. The reduced volatility of metam products is helpful in reducing risk of offsite odors or drift. However, metam products are often applied by growers themselves, not by custom applicators. The growers using metam in Whatcom County have an excellent track record of safe use, but there have been incidents in Central Washington involving metam products. Although these incidents are relatively rare, they can be catastrophic. A single bad metam incident, or a cluster of incidents, could bring on increased regulation of this product at the state level.

Alternatives to soil fumigation:

We followed the California Strawberry Industry's experiences in identifying alternatives to soil fumigation. They have been looking hard for some time to identify simple replacements to existing soil fumigants, but there is no single "silver bullet" that will do this economically. However, their experiences do point the way to addressing these issues by integrating multiple practices within the raspberry production system. We identified several potential practices, each with its own attributes and problems:

Plant resistance. As California has shifted to bed fumigation without methyl bromide, new soilborne strawberry diseases (*Macrophomina*) have come up, and old diseases (*Verticillium, Fusarium, Phytophthora*) have surged. Plant breeders have re-focused breeding programs on disease resistance, with a significant boost to *Fusarium* resistance in new varieties. We recommend that the Commission fund breeding work focusing on resistance or tolerance to soilborne pathogens as a bulwark against future fumigant regulations. Breeding takes a long time, so it is important to focus on this area now, to make progress in the future. Critical areas are Phytophthora root rot resistance/tolerance (already very strong in the WSU breeding program), and resistance/tolerance to root lesion nematodes (no good sources identified yet). Resistant/tolerant varieties make other changes in the production system possible. For example, strawberry crop termination with drip-applied metam, followed by tilling bed tops and replanting was effective with resistant varieties, but not with susceptible ones.

Crop rotation. Research in California indicates that in areas where *Verticillium* is a problem, severity is reduced when strawberry can be grown in a two-year rotation with broccoli or a four-year rotation with lettuce. We have rotation with seed potatoes available in some areas and very short rotations with winter wheat, but clearly need other alternatives to replanting raspberries with raspberries. The Skagit valley has seen a recent mini-boom in brussels sprouts; perhaps some of those could be grown in Whatcom county as well. We recommend that researchers, growers and the Commission aggressively explore additional crop rotation options, especially those including *Brassica* crops.

Postplant nematode and disease control. Growers can currently use Vydate for postplant nematode suppression only in the establishment year, but some new fungicides (such as fluopyram) also appear to have some nematicidal activity. There is potential to improve on post-plant management of plant parasitic nematodes, if only to create a brief window of control during the critical year of plant establishment. Similarly, new products such as Orondis provide some hope to improve postplant control of raspberry root rot. Although finding a complete solution through postplant control is unlikely, moderate control could be readily integrated with plant resistance/tolerance and other measures. Treatments like these could be useful on their own in fields with low to moderate pathogen/nematode pressure, or they could be integrated with other measures in more challenging fields. We recommend evaluating proposals for postplant treatments on an individual basis, funding those which show exceptional promise or can be most easily integrated

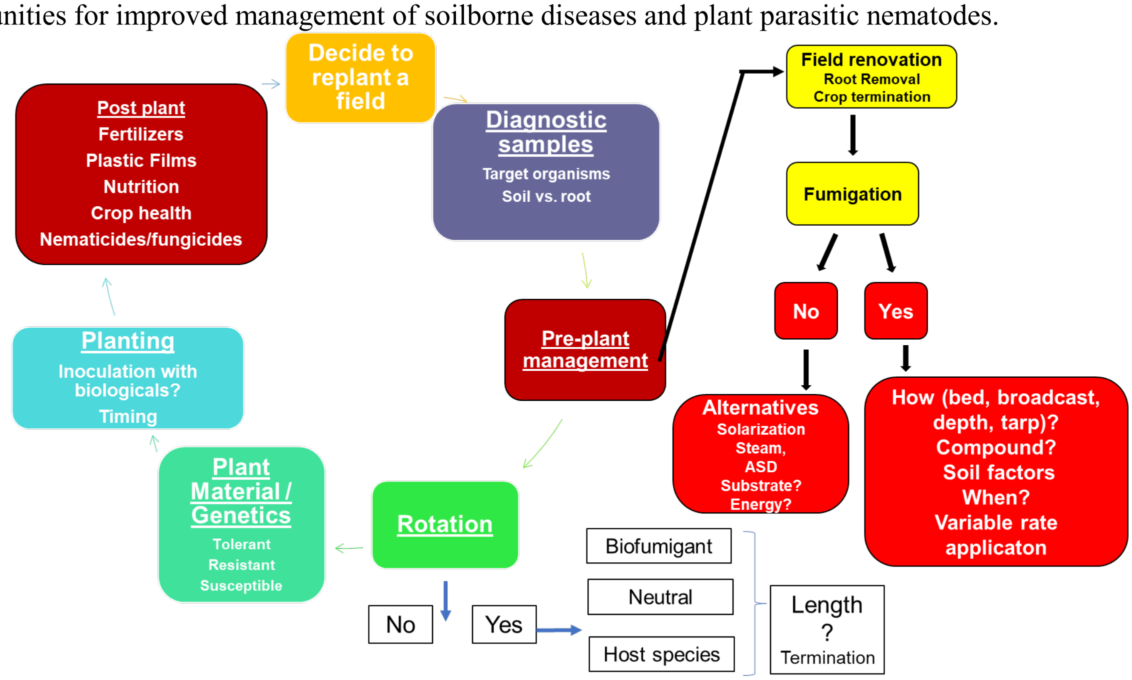
Steam can be used to pasteurize soil (maintain 158 °F for 20 minutes). This process is effective, but currently quite slow (less than 3 acres in 18 hours) and fuel-intensive. Costs in California have been brought down to as little as $4000/acre. It remains very expensive compared with fumigation.

*Anaerobic Soil Disinfestation (*ASD) is a process in which soil is subjected to acid fermentation in aerobic conditions. The soil is amended with a readily digestible carbon source (8 tons rice hulls/acre in California, possibly green chop grass in Whatcom County), fitted with drip lines and covered with a clear plastic film to raise soil temperatures and hold in moisture. The soil is then kept saturated for up to 6 weeks before the plastic film is removed. Elevating soil temperature to 86 °F for 460 hours under these conditions has been effective at suppressing common soilborne diseases of strawberry, and the technique has some promise. However, choice of carbon feedstock and planting time can impact which organisms are targeted. The prospect of using readily available green chop grass is enticing, but we do not know if it will be effective. Also, warming the soil to these temperatures is challenging in Northern California, and would be even more challenging in Whatcom County. ASD would need to take place late June to mid-August, when soil temperatures are highest, so land would likely be taken out of production for a year. There is also a risk of nitrate leaching from the saturated, amended soils during this process.

Here is a summary of our recommendations to the WRRC:

- Support projects that would increase the benefits or reduce the costs of fumigation tarps, especially when chloropicrin is applied.
- Fund breeding work focusing on resistance or tolerance to soilborne pathogens as a bulwark against future fumigant regulations.
- Aggressively explore additional crop rotation options, especially those including *Brassica* crops
- Evaluate proposals for postplant treatments on an individual basis, funding those which show exceptional promise or can be most readily integrated into raspberry production systems.
- Consider research with ASD if growers support it.

Below is a diagram our team created that shows the Washington raspberry planting system and opportunities for improved management of soilborne diseases and plant parasitic nematodes.



Team members:
Thomas Walters, Walters Ag Research; Lisa DeVetter, Washington State University; Inga Zasada and Jerry Weiland USDA-ARS HCRL; Randy Honcoop, Randy Honcoop Farms

Washington Red Raspberry Commission Progress Report for 2020

Project No: 4499-1208
Title: Measuring and Mitigating Soil Compaction in Raspberry Alleyways

Personnel:
Principal Investigator: Deirdre Griffin LaHue, Assistant Professor of Soil Quality and Sustainable Soil Management
Co-Principal Investigators:
Haly Neely, Chris Benedict, Gabriel LaHue
Other personnel: Dylan Mullins (M.S. Student with Dr. Neely), Betsy Schacht

Reporting Period: 2020, continuing in 2021 with existing funds

Accomplishments:
The objective of this project is to help raspberry growers and researchers better understand the extent to which compaction is an issue, including where in the alleyway compaction is highest, what equipment and practices are currently being used to manage it, and how drainage issues in alleyways are related to soil compaction. We made progress toward accomplishing this goal in 2020, though some equipment issues have caused delays in the measurements, as described below. We plan to continue this work into 2021 to complete the dataset and objective.

In summer 2020, we worked with 5 red raspberry growers in Whatcom County to identify field sites that represented the range of soil textures, planting ages, alleyway practices (e.g. cover cropping, tillage) and field histories of raspberry fields in the region. Though this initial observational study is not set up in a replicated and randomized design, we worked to select multiple fields to represent each soil type and management strategy.

In July 2020, we used a Geonics EM-38 apparent electrical conductivity (EC) device to map the soil in 10 fields in order to understand within-field variability in soil properties correlating with soil texture and moisture content. Assessing within-field variability allows us to make more informed choices when selecting sampling points to be able to capture that variability and also to compare compaction and field saturated hydraulic conductivity measurements within fields that have multiple soil texture but are otherwise managed the same (Figure 1).

In early August 2020, after harvests were complete but before alleyway tillage had occurred (maximum compaction), we began taking compaction measurements using a steel penetrometer mounted on a hydraulic ATV-mounted Giddings machine (Figure 2a). We set out to take measurements in the center and edge (near beds) of alleys at 10 points in each field along with soil cores to measure soil texture, moisture, and organic matter content. In addition, we conducted measurements of field saturated hydraulic conductivity (similar to infiltration) using SATURO machines (Figure 2b) at 2 locations per field and 3 measurements per location.

Unfortunately, the level of compaction was very high to the extent that the steel penetrometer began bending after several measurements. We tried several solutions, including taking measurements only in the center of the alley to avoid torqueing the penetrometer or taking compaction with a different method. However, we concluded that we would achieve the best dataset by redoing the measurements in winter and summer 2021 with a stronger penetrometer.

We communicated this plan with the grower collaborators, and they were comfortable with it. This method and equipment have been used extensively in other systems and we feel it is the best method to meet our objectives. A stronger penetrometer has now been built and will be used in winter and summer 2021. This timing will also allow us to assess the seasonal differences in compaction levels of raspberry alleys.

Our ultimate goal is that this assessment will inform future experiments to test and develop improved compaction management strategies, equipment, and recommendations for raspberry growers to mitigate issues that compaction may cause related to water drainage and plant health.

Preliminary Results:
As described above, we currently have limited data due to the equipment issues we experienced, but we will be collecting data in each field this winter and summer and will have full results next fall. Preliminary results from one field show that compaction in this field is concentrated in the upper 15 inches, with penetration resistance up to 730 lbs of force (Figure 3). For reference, 300 lbs is the point at which root growth is limited. We look forward to being able to collect measurements in all fields this year.

Publications:
This information was presented at the Washington Small Fruit Conference on December 1, 2020, and final results will be presented in 2021. Once we are able to complete measurements and analysis, we plan to publish results in a peer-reviewed journal, such as *Geoderma*.

Appendix

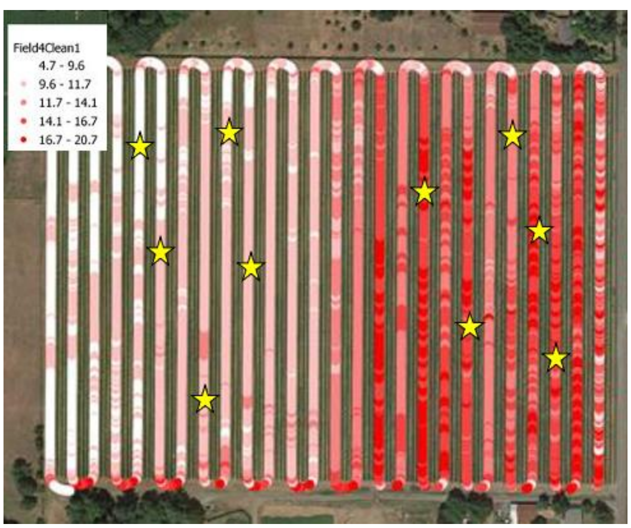


Figure 1. Results from electrical conductivity mapping in a selected field show a textural transition midway through the field. Sampling points (represented by yellow stars) are placed so that half fall in each textural zone.

Figure 2. Photographs showing how measurements were conducted for (a.) penetration resistance and (b.) field saturated hydraulic conductivity.

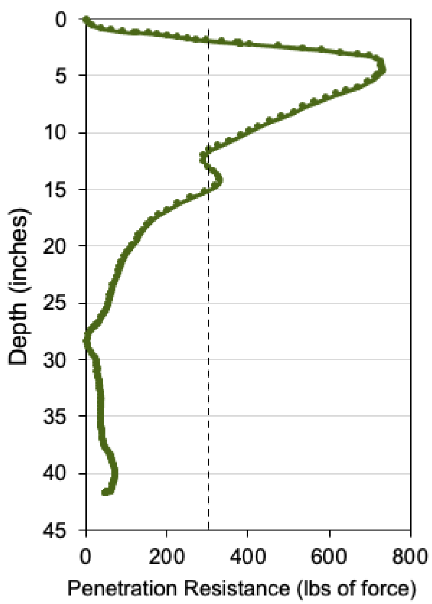


Figure 3. A depth profile of penetration resistance (lbs of force) from one field down to 42 inches. The dashed line at 300 lbs represents the point at which root growth is limited. This is an example of data that will be collected in the center and edges of alleyways across the 10 selected fields.