2020 Research Proposals

and

2019 Research Reports

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

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Research Priorities 2020

#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
- 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
- Maximum Residue Limits (MRL) – residue decline curves, harmonization
- Weed management – horsetail, poison hemlock, wild buckwheat, nightshade

#3 priorities

- Alternative Management Systems – fruit yield per linear foot of bed – planting densities, row spacing, trellising
- Soil fumigation techniques and alternatives to control soil pathogens, nematodes, and weeds.
- Nutrient Management – Revise OSU specs, Consider: timing, varieties, appl. techniques
- Irrigation management – application techniques including pulsing
- Viruses/crumbly fruit, pollination
- Cherry fruitworm, cutworm management
- 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

PAGE	PROJECT TITLE	RESEARCHER (S)	REQUEST	Draft #1	Other $	Source	Approved
PLANT BREEDING			47.61%	0.00%			0.00%
4	Cooperative raspberry cultivar development	Finn	$11,782		$38,420	ORBC	
18	Red Raspberry Breeding, Genetics and Clone Evaluation	Hoashi-Erhardt	$81,265		$32,299	NWCSFR	
25	Coordinated Regional on-farm Trials	Walters, NWBF	$9,572		$1,800	propagators	
32	Red Raspberry Cultivar Development	Dossett	$10,000				
ENTOMOLOGY			16.72%	0.00%			0.00%
41	Managing SWD with Reduced Insecticide Residues	Schreiber					
45	Attract and Kill, New Strategy for SWD Control	Schreiber	$10,000		$10,000	WBC	
49	Long-term management of BMSB	Gerdeman					
51	Factors affecting spider mite outbreaks	Gerdeman					
53	Improved Management of lepidopteran pests	Gerdeman	$9,936		$9,941	WSCPR	
58	Plastic mulches for management of spotted wing drosophila	Guédot, Wisconsin	$9,627		$11,987	SARE	
62	Development of Biologically-based RNAi Insecticide	Choi	$10,000		$30,000	other Com.	
WEEDS			4.63%	0.00%			0.00%
70	Preventing Wild Buckwheat Seed Production in Raspberries	Seerfedt	$9,132				
74	Will Chlorsulfuron Safely Manage Horsetail in Raspberries?	Seerfedt	$1,823				
PHYSIOLOGY			6.16%	0.00%			0.00%
79	Impacts of Mycorrhizal Fungal Colonization	Bunn/DeVetter					
82	Comparison of Alternate- and Every-Year Production	DeVetter					
84	Multi-season Plastic Mulches for weed mangement and crop growth	DeVetter	$14,563				
PATHOLOGY/VIROLOGY			17.37%	0.00%			0.00%
	Biology and control of *Botrytis* fruit rot	Peever				SCBG	
93	Management of Fungicide Resistant Botrytis in Raspberries	Schreiber	$13,000		$13,000	WSCPR	
117	Control of Cane Blight in Red Raspberries	Schreiber/Jones	$10,000		$10,000	WSCPR	
129	Fungicide Resistance of *Botrytis cinerea* to Kenja and Luna Tranquility	Jones	$6,950		$3,510	NWP	
133	Refining the microbiome of developing red raspberry fruit tissues	Stockwell	$11,152		$180,000	USDA	
SOILS			7.51%				0.00%
140	Reducing alleyway tillage to decrease costs and improve soil health	Griffin/LaHue					
144	Measuring and Mitigating Soil Compaction	Griffin/LaHue	$14,664				
154	Fumigant Study Group	Walters/Zasada	$3,100				
	Total Production Research		**$236,566**	**$0**	**$340,957**		**$0**
	Research Related	WRRC expenses	$3,500	$3,500			$3,500
	Small Fruit Center fee		$2,500	$2,500			$2,500
	TOTAL		**$242,566**	**$6,000**			**$6,000**
	2020 Research Budget		$179,415		report only	applied	

PLANT BREEDING

Project No:
Title: Cooperative raspberry cultivar development program

Personnel: Chad Finn, Research Geneticist
USDA-ARS, HCRL; 3420 NW Orchard Ave. Corvallis, OR 97330

Reporting Period: __2019__

Accomplishments: Our goal is develop raspberry cultivars that are improvements over the current standards or that will complement them. In addition, the information generated on WSU and BC advanced selections is available and can aid in making decisions on the commercialization of their materials. Multiple floricane selections are in grower and machine harvest trials in Washington. ORUS 4373-1, identified in Puyallup as having good root rot tolerance, ORUS 4600-3, and ORUS 4607-2 have been in small grower trials and, along with ORUS 4371-4, ORUS 4600-1 and ORUS 4462-2, are being propagated for more extensive trials. All floricane trials in Oregon were harvested with a Littau machine. We supported the WSU release of 'WSU 2166'. Primocane fruiting types have been released and are being adopted for commercial fresh market; ORUS 4716-1 will be named in 2020.

Results: In 2019, we made 35 crosses, 45 selections (22 floricane, 23 primocane), and planted ~2,500 seedlings. Not surprisingly, the most commercially promising selections or cultivars were among the most commonly used parents and were common parents in the selections. We are now regularly using a Littau machine on our floricane yield trials and, while not perfect, it has worked well. Rose stem girdler unexpectedly destroyed our primocanes in 2017. As a result, the 2016 planted trial had its's first harvest in 2019 instead of 2018. This year's results are presented in Tables RY1-RY8. Machine trials in Lynden have pointed to a few promising selections (Table RY3). In the Lynden machine harvest trial ORUS 4371-4, ORUS 4462-2, ORUS 4600-1 and ORUS 4607-2 have been promising enough to put into grower trial. In addition, ORUS 4373-1 has had outstanding root rot tolerance in Puyallup in addition to good yield and fruit quality. ORUS 4371-4, ORUS 4640-1, and ORUS 4641-3 had less bud kill in Lynden than 'Meeker' or 'Wakefield'. Based in part on results from our trials, WSU released 'WSU 2166'. Multiple ORUS selections were identified as having excellent root rot resistance in Puyallup and were used in WSU crosses. While indirectly related to red raspberry, our efforts in black raspberry have identified verticillium wilt and aphid resistance (that should translate into virus resistance for the aphid transmitted viruses).

Publications:

Moore, P.P., W. Hoashi-Erhardt, C.E. Finn, R.R. Martin, and M. Dossett. 2019. 'WSU 2166' red raspberry. HortScience 54:564-4567. https://doi.org/10.21273/HORTSCI13652-18

Appendices

Table RY1. Fruit size and yield in 2019 for floricane fruiting raspberry genotypes at OSU-NWREC planted in 2016. Would normally have been harvested in 2018, two years after harvest, however, due to rose stem girdler damage in 2017, we cut floricanes to the ground and had no crop in 2018. **Harvested by Littau Harvester**.

Genotype	Berry size (g)[z]	Yield ($tons \cdot a^{-1}$)
Replicated		
ORUS 4371-4	4.1 a	5.93 a
WSU 2130	3.2 d	5.28 ab
ORUS 4692-1	4.3 a	4.74 a-c
WSU 2088	3.5 b	4.68 a-c
WSU 2191	3.2 cd	4.53 a-c
ORUS 4690-1	3.7 b	4.49 a-c
Meeker	**2.8 e**	**4.02 bc**
ORUS 4715-1	3.5 bc	3.99 bc
ORUS 3959-1	3.5 bc	3.56 bc
WSU 2162	3.2 cd	3.04 cd
ORUS 4707-2	3.6 b	3.01 cd
ORUS 4089-2	3.0 de	1.55 d
Nonreplicated		
ORUS 4692-2	4.8	6.75
ORUS 4641-3	3.0	5.00
ORUS 4692-4	3.4	4.98
WSU 2087	3.8	4.73
WSU 2299	2.9	4.61
ORUS 4713-1	3.3	4.44
ORUS 4690-3	3.8	4.39
ORUS 4715-2	4.0	3.96
ORUS 4707-1	3.3	3.52
ORUS 4694-1	2.8	3.20
ORUS 4715-3	4.8	3.14
ORUS 4713-2	3.9	2.63

[z] Mean separation within columns by LSD, $p \leq 0.05$.

Table RY2. Fruit size and yield in 2019 for floricane fruiting raspberry genotypes at OSU-NWREC. Planted in 2017 and **harvested by Littau Harvester**.

Genotype	Berry size (g)[z]	Yield (tons·a^{-1})
Replicated		
WSU 2188	4.4 a	5.30 a
ORUS 4600-1	3.6 b	4.76 a
Wakefield	**2.9 c**	**4.75 a**
Meeker	**2.8 c**	**4.35 a**
WSU 1914	3.5 b	4.13 a
Nonreplicated		
WSU 2234	3.1	7.57
WSU 2088	4.0	5.56
Georgia	**3.2**	**5.47**
WSU 2421	3.5	5.09
WSU 2298	2.4	4.70
WSU 2123	3.3	4.36
WSU 2366	3.3	4.33
WSU 2299	2.6	4.31
ORUS 4851-2	3.5	4.23
ORUS 4837-2	3.3	4.17
WSU 2205	3.0	3.94
WSU 2195	4.3	3.58
ORUS 4837-1	4.1	3.53
ORUS 1154R-3	2.5	3.53
ORUS 4851-1	3.2	3.47
ORUS 3702-3	4.5	3.06
ORUS 4840-1	2.6	2.85
ORUS 4846-1	4.3	2.73
WSU 2202	2.9	2.29
ORUS 4373-1	4.0	1.93

[z] Mean separation within columns by LSD, $p \leq 0.05$.

Table RY3. Performance of standards and ORUS selections in **machine harvest trials** in Lynden, Washington at commercial grower fields. Planted in 2017 and 2018.

Genotype	Total yield (tons/acre) 2018	Total yield (tons/acre) 2019	Total yield (tons/acre) 2018-19	Berry weight (g) 2018	Firmness (g/mm) 2018	Firmness (g/mm) 2019	Firmness (g/mm) 2018-19	Brix (%) 2018	Brix (%) 2019	Brix (%) 2018-19	Acidity (%) 2018	pH 2018	Winter injury 2019
Lynden Grower 2017 Planted													
Meeker	**7.91**	**7.62**	**7.76**	**3.85**	**17.7**	**19.4**	**18.5**	**11.6**	**9.4**	**10.5**	**1.4%**	**3.53**	**Med-High**
ORUS 4371-4	7.46	6.98	7.22	5.83	26.0	27.0	26.5	11.3	9.0	10.2	1.9%	3.75	Med
Cascade Harvest	**6.74**	**7.52**	**7.13**	**5.86**	**21.4**	**35.8**	**28.6**	**10.1**	**9.4**	**9.8**	**1.1%**	**3.64**	**Low**
Wakefield	**3.90**	**9.64**	**6.77**	**4.10**	**33.9**	**30.6**	**32.2**	**10.7**	**10.2**	**10.5**	**2.3%**	**3.21**	**Low-Med**
ORUS 4851-1	7.46	5.23	6.34	6.54	22.8	20.6	21.7	10.6	8.4	9.5	1.4%	3.42	Med
ORUS 4607-2	6.50	5.13	5.81	4.86	21.5	23.4	22.5	10.8	8.9	9.9	1.8%	3.30	Low
ORUS 4465-3	**4.98**	**5.55**	**5.26**	**4.71**	**17.5**	**20.7**	**19.1**	**10.1**	**8.3**	**9.2**	**1.4%**	**3.48**	**Med**
Squamish	3.72	6.63	5.18	4.67	24.5	25.3	24.9	11.0	9.1	10.1	1.8%	3.27	Low
Wakehaven		11.49				41.9			9.9				Med-High
Lynden Grower 2018 Planted													
Wake®Haven		**5.7**				**40.8**			**9.8**				**Low**
Cascade Harvest		**4.8**				**30.3**			**9.7**				**Low**
Meeker		**4.5**				**19.9**			**9.5**				**Med**
Wake®Field		**4.5**				**33.2**			**10.2**				**Med**
Squamish		**3.5**				**24.0**			**8.7**				**Low-Med**
ORUS 4640-1		3.0				17.8			9.0				Low
ORUS 4641-3		2.2				19.9			9.8				Low
ORUS 4283-2		1.6				21.3			8.6				Med
ORUS 4783-3		1.4				-			9.0				Med
ORUS 4961-1		0.2				18.2			9.0				High

Table RY4. Mean yield and berry size in 2018-2019 for primocane fruiting raspberry genotypes at OSU-NWREC planted in 2016. Not harvested in 2017 due to rose stem girdler infestation.

Genotype	Berry size (g) 2018-2019	Yield (tons·acre^{-1}) 2018	2019	2018-19
Non replicated				
ORUS 4858-2	3.3	4.59	4.19	4.39
Imara	**3.4**	**4.17**	**4.33**	**4.25**
Kweli	**3.5**	**3.71**	**3.31**	**3.51**
ORUS 4874-1	3.3	4.50	2.24	3.37
Heritage	**2.2**	**2.71**	**3.55**	**3.13**
Kokanee	**3.0**	**2.57**	**2.94**	**2.76**
ORUS 4723-2	4.0	2.79	1.03	1.91
ORUS 4722-2	3.6	1.87	1.79	1.83
Vintage	**2.6**	**2.08**	**1.41**	**1.75**
Kwanza	**4.0**	**1.32**	**1.60**	**1.46**

Table RY5. Mean yield and berry size in 2018-2019 for primocane fruiting raspberry genotypes at OSU-NWREC planted in 2017

Genotype	Berry size (g) 2018-2019	Yield (tons·acre^{-1}) 2018	2019	2018-19
2018	2.5 b			1.8 b
2019	3.2 a			2.9 a
Replicated				
ORUS 4716-1	3.2 a	2.65 a	4.05 a	3.35 a
Heritage	**2.3 b**	**1.86 a**	**2.43 a**	**2.15 b**
ORUS 5005-2	3.1 a	0.92 a	2.08 a	1.50 b
Non replicated				
ORUS 5005-1	4.1	1.70	4.14	2.92
ORUS 4990-1	3.8	2.19	2.07	2.13
ORUS 4989-1	4.4	0.89	3.23	2.06
ORUS 4988-5	3.2	1.47	1.55	1.51
ORUS 5004-3	3.4	0.42	2.48	1.45

Mean separation within columns by LSD, $p \leq 0.05$.

Table RY6. Mean yield and berry size in 2019 for primocane fruiting red raspberry genotypes at OSU-NWREC planted in 2018.

Genotype	Berry size (g)		Yield (tons·a^{-1})	
Replicated				
Polka	**3.4**	**a**	**4.68**	**a**
ORUS 4487-1	2.4	b	4.44	a
Kokanee	**3.2**	**a**	**1.42**	**b**
Non replicated				
ORUS 4858-1	2.9		4.71	
ORUS 5114-1	4.0		4.13	
ORUS 5243-3	3.6		3.96	
ORUS 5118-1	3.1		2.71	
ORUS 5114-2	3.1		2.49	
ORUS 5109-2	3.4		2.04	
ORUS 5243-1	4.6		1.79	
ORUS 5243-2	2.6		1.78	
ORUS 4985-1	3.5		1.68	
Vintage	**3.2**		**1.30**	
ORUS 4291-1	3.2		1.20	

Mean separation within columns by LSD, $p \leq 00.05$.

Table RY7. Ripening season for floricane fruiting red raspberry genotypes at OSU-NWREC. Planted in 2016-17 and harvested by Littau Harvester in 2019.

Genotype	Year planted	Harvest season 5%	50%	95%	No. years in mean	Rep/ Obsv
ORUS 4837-2	2017	11-Jun	24-Jun	8-Jul	1	Obsv.
ORUS 4692-1	2016	18-Jun	24-Jun	8-Jul	1	Rep
ORUS 4837-1	2017	11-Jun	28-Jun	15-Jul	1	Obsv.
WSU 2130	2016	18-Jun	28-Jun	15-Jul	1	Rep
WSU 2298	2017	20-Jun	28-Jun	15-Jul	1	Obsv.
ORUS 4846-1	2017	24-Jun	28-Jun	15-Jul	1	Obsv.
WSU 2191	2016	18-Jun	1-Jul	15-Jul	1	Rep
WSU 2299	2016	18-Jun	1-Jul	15-Jul	1	Obsv.
Georgia	**2017**	**20-Jun**	**1-Jul**	**15-Jul**	**1**	**Obsv.**
WSU 2299	2017	20-Jun	1-Jul	15-Jul	1	Obsv.
ORUS 4692-2	2016	24-Jun	1-Jul	15-Jul	1	Obsv.
ORUS 4713-1	2016	24-Jun	1-Jul	15-Jul	1	Obsv.
ORUS 4715-2	2016	24-Jun	1-Jul	15-Jul	1	Obsv.
WSU 1914	2017	24-Jun	1-Jul	15-Jul	1	Rep
WSU 2205	2017	24-Jun	1-Jul	15-Jul	1	Obsv.
WSU 2421	2017	24-Jun	1-Jul	18-Jul	1	Obsv.
WSU 2123	2017	20-Jun	4-Jul	18-Jul	1	Obsv.
Meeker	**2016**	**24-Jun**	**4-Jul**	**18-Jul**	**1**	**Rep**
Meeker	**2017**	**24-Jun**	**4-Jul**	**18-Jul**	**1**	**Rep**
ORUS 1154R-3	2017	24-Jun	4-Jul	18-Jul	1	Obsv.
ORUS 3702-3	2017	24-Jun	4-Jul	18-Jul	1	Obsv.
ORUS 3959-1	2016	24-Jun	4-Jul	18-Jul	1	Rep
ORUS 4371-4	2016	24-Jun	4-Jul	18-Jul	1	Rep
ORUS 4600-1	2017	24-Jun	4-Jul	18-Jul	1	Rep
ORUS 4641-3	2016	24-Jun	4-Jul	18-Jul	1	Obsv.
ORUS 4690-1	2016	24-Jun	4-Jul	18-Jul	1	Rep
ORUS 4692-4	2016	24-Jun	4-Jul	18-Jul	1	Obsv.
ORUS 4707-1	2016	24-Jun	4-Jul	18-Jul	1	Obsv.
ORUS 4713-2	2016	24-Jun	4-Jul	18-Jul	1	Obsv.
ORUS 4715-1	2016	24-Jun	4-Jul	18-Jul	1	Rep
ORUS 4851-2	2017	24-Jun	4-Jul	18-Jul	1	Obsv.
WSU 2087	2016	24-Jun	4-Jul	18-Jul	1	Obsv.
WSU 2188	**2017**	**24-Jun**	**4-Jul**	**18-Jul**	**1**	**Rep**
WSU 2202	2017	24-Jun	4-Jul	18-Jul	1	Obsv.
WSU 2234	2017	24-Jun	4-Jul	18-Jul	1	Obsv.
WSU 2366	2017	24-Jun	4-Jul	18-Jul	1	Obsv.
ORUS 4373-1	2017	24-Jun	8-Jul	18-Jul	1	Obsv.
ORUS 4690-3	2016	24-Jun	8-Jul	18-Jul	1	Obsv.
ORUS 4694-1	2016	24-Jun	8-Jul	18-Jul	1	Obsv.
ORUS 4707-2	2016	24-Jun	8-Jul	18-Jul	1	Rep
ORUS 4715-3	2016	24-Jun	8-Jul	18-Jul	1	Obsv.
ORUS 4851-1	2017	24-Jun	8-Jul	18-Jul	1	Obsv.
Wakefield	**2017**	**24-Jun**	**8-Jul**	**18-Jul**	**1**	**Rep**
WSU 2088	2016	24-Jun	8-Jul	18-Jul	1	Rep

WSU 2088	2017	24-Jun	8-Jul	18-Jul	1	Obsv.
WSU 2162	2016	24-Jun	8-Jul	18-Jul	1	Rep
WSU 2195	2017	24-Jun	8-Jul	18-Jul	1	Obsv.
ORUS 4840-1	2017	28-Jun	15-Jul	18-Jul	1	Obsv.

Table RY8. Ripening season for primocane fruiting red raspberry genotypes at OSU-NWREC. Planted in 2016, 2017 or 2018 and harvested 2018-19.

Genotype	Year planted	Harvest season 5%	50%	95%	No. years in mean	Rep/ Obsv
ORUS 4291-1	2018	30-Jul	14-Aug	20-Aug	1	Obsv.
ORUS 4988-5	2017	3-Aug	14-Aug	27-Aug	2	Obsv.
ORUS 5005-1	2017	3-Aug	14-Aug	3-Sep	2	Obsv.
ORUS 5005-2	2017	3-Aug	17-Aug	4-Sep	2	Rep
Polka	**2018**	**6-Aug**	**20-Aug**	**11-Sep**	**1**	**Rep**
Imara	**2016**	**6-Aug**	**20-Aug**	**11-Sep**	**2**	**Obsv.**
Heritage	**2017**	**14-Aug**	**20-Aug**	**11-Sep**	**2**	**Rep**
ORUS 4858-2	2016	3-Aug	24-Aug	11-Sep	2	Obsv.
Kweli	**2016**	**6-Aug**	**24-Aug**	**11-Sep**	**2**	**Obsv.**
ORUS 4874-1	2016	10-Aug	24-Aug	7-Sep	2	Obsv.
Heritage	**2016**	**10-Aug**	**24-Aug**	**7-Sep**	**2**	**Rep**
ORUS 4858-1	2018	6-Aug	27-Aug	11-Sep	1	Obsv.
ORUS 5118-1	2018	6-Aug	27-Aug	11-Sep	1	Obsv.
ORUS 4487-1	2018	6-Aug	27-Aug	24-Sep	1	Rep
ORUS 5114-1	2018	14-Aug	27-Aug	11-Sep	1	Obsv.
Vintage	**2016**	**7-Aug**	**27-Aug**	**11-Sep**	**2**	**Rep**
ORUS 4716-1	2017	14-Aug	27-Aug	15-Sep	2	Rep
Kokanee	**2016**	**10-Aug**	**31-Aug**	**18-Sep**	**2**	**Obsv.**
ORUS 4990-1	2017	14-Aug	31-Aug	22-Sep	2	Obsv.
Kwanza	**2016**	**17-Aug**	**31-Aug**	**15-Sep**	**2**	**Obsv.**
ORUS 5109-2	2018	14-Aug	3-Sep	11-Sep	1	Obsv.
Kokanee	**2018**	**14-Aug**	**3-Sep**	**19-Sep**	**1**	**Rep**
ORUS 5114-2	2018	14-Aug	3-Sep	19-Sep	1	Obsv.
ORUS 5243-1	2018	14-Aug	3-Sep	19-Sep	1	Obsv.
Vintage	**2018**	**14-Aug**	**3-Sep**	**19-Sep**	**1**	**Obsv.**
ORUS 4985-1	2018	20-Aug	3-Sep	19-Sep	1	Obsv.
ORUS 4723-2	2016	24-Aug	4-Sep	18-Sep	2	Obsv.
ORUS 4722-2	2016	24-Aug	10-Sep	22-Sep	2	Obsv.
ORUS 5243-3	2018	20-Aug	11-Sep	24-Sep	1	Obsv.
ORUS 5243-2	2018	27-Aug	11-Sep	24-Sep	1	Obsv.
ORUS 4989-1	2017	3-Sep	14-Sep	22-Sep	2	Obsv.
ORUS 5004-3	2017	3-Sep	14-Sep	22-Sep	2	Obsv.

Project Title: Cooperative raspberry cultivar development program

PI: Chad Finn,
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Year Initiated __2013___ **Current Year** 2020-2021__ **Terminating Year** _Continuing__

Total Project Request: Ongoing.

Other funding sources:
Current pending and support form attached

I receive and apply for funding each year with Bernadine Strik from the Oregon Raspberry and Blackberry Commission towards the cooperative raspberry and blackberry breeding program. This funding is complementary not duplicative.

Description describing objectives and specific outcomes

The Northwest is one of the most important berry production regions in the world. This success is due to a combination of an outstanding location, top notch growers, and a strong history of industry driven research. The USDA-ARS berry breeding programs in Corvallis have a long history of developing cultivars that are commercially viable. New cultivars that are high yielding, machine harvestable, and that produce very high quality fruit are essential for the long term viability of the industry. Cultivars that replace or complement the current standards, primarily 'Meeker' or 'Wake®field' would help towards that goal. The breeding programs in the region have a long history of cooperation exchanging parents, seedlings, and ideas and thoroughly testing and evaluating each other's selections. Cultivars developed by these integrated programs will benefit the entire northwest industry. The specific objectives include developing:

- 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).
- Fresh market cultivars will be pursued that provide season extension: improve viability of fresh marketing through floricane or primocane fruiting types (#3 Priority).

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

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.
- Foliar & Cane Diseases – i.e. spur blight, yellow rust, cane blight, powdery mildew, etc.
- Soil fumigation techniques and alternatives to control soil pathogens, nematodes, and weeds.
- Viruses/crumbly fruit, pollination

Objectives:

- To 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 Commission Research Priority).
- New fresh market cultivars will be pursued that provide season extension: improve viability of fresh marketing through floricane or primocane fruiting types (#3 Priority).
- To 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:

This is an ongoing project where cultivars and current 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. All of the steps are taking place every year i.e. crossing, growing seedlings, selecting, propagating for testing, and testing.

Thirty to forty crosses will be done each year. Seedling populations are grown and evaluated in Corvallis, Ore. Selections are made and propagated for testing at the Oregon State University - North Willamette Research and Extension Center (Aurora, Ore.). Washington State University and Agriculture and Agri-Food Canada selections, in addition to the USDA-ARS selections, that looked outstanding as a seedling or that have performed well in other trials, are planted in replicated trials (4, 3 plant replications). Selections that we are less sure of are generally planted in smaller observation trials (single, 3 plant plot). Fruit from replicated and observation plots are machine harvested and weighed, and plants and fruit are subjectively evaluated as well for vigor, disease tolerance, winter hardiness, spines, ease of removal, color, firmness, and flavor.

Fruit from the best selections are processed after harvest for evaluation in the off season.

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

Anticipated Benefits and Information Transfer:

This breeding program will develop raspberry cultivars that are improvements over the current standards or that will complement current standards. In addition, the information generated on advanced selections from the WSU and B.C. programs will be made available and aid in making decisions on the commercial suitability of their materials.

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

Budget:

Amount allocated by Commission for previous year: $__5,000____

Funds from the USDA-ARS will be used to provide technician support and the bulk of the funding of the overall breeding project.

Salaries: Student labor (1 student GS-2, 4 months)	$8,282
Operations (goods & services)	1,000
Travel[1]	1,500
Other: "Land use charge" ($3,500/acre)	1,000
Total	**$11,782**

[1]To visit Puyallup, Lynden, and/or grower trials, field days and small fruit conferences in Washington

Current & Pending Support					
Chad Finn					
Name(List PI #1 first)	Supporting Agency and Project #	Total $ Amount	Effective and Expiration Dates	% of Time Committed	Title of Project
Current:					
Finn, C.E.	Washington Red Raspberry Commission	$6,000	7/2019-6/2020	2	Cooperative raspberry cultivar development program.
Strik, BC, and Finn, C.E.	Oregon Blueberry Commission	$6,240	7/2019-6/2020	1	Establishing a New, Replacement, Cultivar & Selection Evaluation Block – Cooperative Blueberry Breeding Program, NWREC
Strik, BC, and Finn, C.E.	Oregon Blueberry Commission	$18,520	7/2019-6/2020	2	Cooperative Blueberry Breeding Program - Cultivar and Selection Evaluation, NWREC
Finn, C.E.	Oregon Blueberry Commission	$11,966	7/2019-6/2020	4	Developing PNW Cultivars That May Resist Blueberry Shock Virus
Strik, B.C. and C.E. Finn	Oregon Raspberry and Blackberry Commission	$38,420	7/2019-6/2020	4	Production System/Physiology Research and Cooperative Breeding Program- Raspberries and Blackberries
Strik, B.C. and C.E. Finn	Oregon Strawberry Commission	$16,500	7/2019-6/2020	4	Cooperative Breeding Program - Strawberries
Finn, C.E.	Washington Blueberry Commission	$8,147	7/2019-6/2020	4	Developing commercial blueberry cultivars adapted to the Pacific Northwest with an emphasis on tolerance of Blueberry shock virus (BlShV)
Worthington, M. et al.	Specialty Crop Research Initiative Competitive Grants Program	$50,000	2019-2020	1	Research and extension needs assessment for the U.S. blackberry industry

Iorizzo, M. et al.	USDA-ARS, SCRI	$7,200,000	10/2019-9-2024	3	VacciniumCAP: Leveraging genetic and genomic resources to enable development of blueberry and cranberry cultivars with improved fruit quality attributes
Pending:					
Finn, C.E.	Washington Red Raspberry Commission	$11,782	7/2020-6/2021	2	Cooperative raspberry cultivar development program.
Strik, BC, and Finn, C.E.	Oregon Blueberry Commission	$26,220	7/2020-6/2021	2	Cooperative Blueberry Breeding Program - Cultivar and Selection Evaluation, NWREC
Strik, B.C. and C.E. Finn	Oregon Raspberry and Blackberry Commission	$38,420	7/2019-6/2020	4	Production System/Physiology Research and Cooperative Breeding Program- Raspberries and Blackberries
Strik, B.C. and C.E. Finn	Oregon Strawberry Commission	~$16,500	7/2020-6/2021	4	Cooperative Breeding Program - Strawberries
Finn, C.E.	Oregon Blueberry Commission	$26,513	7/2020-6/2021	4	Developing commercial blueberry cultivars adapted to the Pacific Northwest with an emphasis on understanding the heritability of abiotic stress (heat/UV and cold) tolerance in populations grown in multiple Oregon and Washington locations. Split funding OBC and WBC.
Finn, C.E.	Washington Blueberry Commission	$26,513	7/2020-6/2021	4	Developing commercial blueberry cultivars adapted to the Pacific Northwest with an emphasis on understanding the heritability of abiotic stress (heat/UV and cold) tolerance in populations grown in multiple Oregon and Washington locations. Split funding OBC and WBC.
Fernandez, GE and multiple co-PIs	Foundation for Food and Agricultural Research	$51,947	1/2020-6-2022	2	*Rubus* uncovered: Tapping into the genetic potential of more than 100 wild *Rubus* species to improve fruit quality and plant resilience of raspberry, blackberry and black raspberry crops

Project No.: 13C-3755-5641
Title: Red Raspberry Breeding Genetics and Clone Evaluation
Personnel: Patrick P. Moore, Professor
Wendy Hoashi-Erhardt, Senior Scientific Assistant
WSU Puyallup Research and Extension Center
Reporting Period: 2019

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:
Release. **WSU 2166** was released as a new cultivar and successfully patented under Plant Patent Number PP 30,980 on October 29, 2019. Certified plants are available to growers. WSU 2166 ('Cascade Premier') is an early season cultivar with large, firm, good flavored fruit that machine harvests very well. It has good levels of root rot tolerance though not completely resistant to the disease. **WSU 2188** was also advanced toward release stage and is a very promising potential cultivar. WSU 2188 needs extensive large-plot commercial evaluations for IQF processing before the cultivar committee can recommend it for release. Those evaluations are pending and new funding for this stage of evaluation is being sought from the WSDA Specialty Crop Block program.
Crosses/selections. Crosses made in 2016 were planted at the Goss Farm in 2017 and selections made in 2019. The crosses emphasized parents that are machine harvestable and root rot resistant. Forty-seven of the fifty-two selections had a root rot resistant parent. 'Cascade Premier' was a parent of 20 of the selections and WSU 2188 was a parent of 12 of the selections. Selections that were parents of several selections were Cascade Harvest (12), Killarney (10), Cascade Bounty (8) and Chief (7). Many of the crosses had at least one parent that has root rot resistance in its background.
Machine Harvesting Trials. A new machine harvesting trial was planted in 2019. This planting will be harvested in 2021 and 2022. The 2016 and 2017 planted machine harvesting trials were harvested in 2019 and subjectively evaluated.
Grower Trials**.** Seven WSU selections appear promising and are either in Grower Trials or will be planted in Grower Trials in the near future. These selections are WSU 2001, WSU 2068, WSU 2069, WSU 2087, WSU 2088, and WSU 2130. There are an additional 13 selections that have promise, but need to be evaluated further before they might be included in Grower Trials.
Selection Trials**.** Raspberry selections were planted at the Goss Farm in 2016 and harvested in 2018 and 2019 (Table 1). Yields and fruit size were smaller than normal for this field. There were problems with the irrigation system that probably caused the lower yield and smaller fruit. WSU 2087, WSU 2130 and WSU 2088 had the highest yields and largest fruit among WSU selections.
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. Four plants of each selection were planted in 2016 and in 2017 scored for survival. In 2018 and 2019, the plants were evaluated for vigor from 0 (plant dead) to 5 (plants vigorous). WSU 2298 (WSU 1499 x WSU 1715) had the highest score in 2019 and Cascade Harvest had the highest score among cultivars.

Results

Table 1.

	Yield (t/a)			Fruit wt (g)		Fruit rot (%)		Firmness (g)		Midpoint of harvest	
clone	2018	2019	total	2018	2019	2018	2019	2018	2019	2018	2019
WSU 2087	4.83	2.19	7.01	3.00	2.67	0.247	0.139	315	158	7/1	7/5
WSU 2130	4.55	1.68	6.23	2.73	2.59	0.140	0.157	247	138	6/27	7/4
WSU 2088	4.02	1.76	5.78	2.77	2.36	0.223	0.224	295	162	7/4	7/9
WSU 2162	2.01	1.28	3.30	2.56	2.27	0.181	0.168	185	127	7/5	7/7
WSU 2191	2.31	0.81	3.12	2.07	1.78	0.144	0.140	212	99	6/29	7/3
WSU 1962	1.71	0.83	2.54	2.92	2.14	0.173	0.200	208	103	7/4	7/8
WSU 2195	1.05	0.68	1.73	2.95	2.44	0.274	0.241	271	156	7/7	7/10
Casc.Harvest	3.38	1.54	4.92	3.51	2.75	0.177	0.203	234	110	6/30	7/4
Meeker	1.79	1.45	3.24	2.52	1.72	0.300	0.178	171	82	6/29	7/5
Willamette	2.37	1.54	3.91	2.44	2.20	0.145	0.152	192	83	6/27	7/1

Table 2.

Root rot evaluation	2019	2018
WSU 2298	5.00	4.50
C Harvest	4.75	4.00
WSU 2377	4.35	3.50
WSU 2069	3.25	3.00
WSU 1962	3.00	3.50
WSU 2363	2.50	2.00
Meeker	2.25	3.50
WSU 2190	2.25	2.50
WSU 2278	2.25	1.50
WSU 2123	2.00	2.75
WSU 2162	1.75	2.50
WSU 2366	1.75	2.25
WSU 2068	1.00	2.25

Publications/Presentations

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. In press.

North Willamette Horticultural Society, Canby, OR. January 16, 2019

Strawberry and Raspberry Cultivar Development at Washington State University. Lower Mainland Horticultural Improvement Association, Abbotsford, BC. January 23, 2019

Machine Harvesting Field Day Lynden, WA July 12, 2019

"Comparison of Selection for Root Rot Tolerance and Machine Harvestability", December 3, 2019. Northwest Center for Small Fruit Research, Ferndale, WA.

Raspberry Breeding, December 5, 2019. Small Fruit Conference. Lynden, WA.

PROJECT: 13C-3755-5641
TITLE: Red Raspberry Breeding, Genetics and Clone Evaluation
CURRENT YEAR: 2019

PI:	Wendy Hoashi-Erhardt	**Co-PI:**	Patrick P. Moore
Organization:	WSU Puyallup Research and Extension Center (WSU-PREC)	**Organization:**	WSU-PREC
Title:	Senior Scientific Assistant	**Title:**	Professor
Phone:	253-445-4641	**Phone:**	253-445-4525
Email:	wkhe@wsu.edu	**Email:**	moorepp@wsu.edu
Address:	2606 W Pioneer Ave. Puyallup, WA 98371	**Address:**	2606 W Pioneer Ave. Puyallup, WA 98371

Cooperators: Northwest Berry Foundation, Chad Finn, Michael Dossett, Tom Walters, Northwest Plant, Randy Honcoop, other regional growers

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

Project Request: **$81,265** for 2020-2021

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: Washington State Department of Agriculture Specialty Crop Block Grant
Amt. Requested: to be determined
Notes: Funds from the WRRC will also be leveraged via a supporting grant process to WSDA in collaboration with the Northwest Berry Foundation (NBF) and Walters Ag Research, and on behalf of the Washington red raspberry industry. The concept proposal's objectives are to 1) complete cultivar development evaluations on 4-6 elite red raspberry selections, and 2) assess IQF performance of upcoming cultivars and establish and disseminate guidelines on IQF processing of two new cultivars (WSU 2166 and WSU 2188). Pending a successful concept proposal, the PI will submit a full proposal in spring 2020.

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. Selections will be evaluated for adaptation to machine harvestability by planting selections with cooperating growers. Promising selections will be propagated for grower trials and superior selections will be released as new cultivars. The year 2020 will be the first year of Wendy Hoashi-Erhardt acting as interim PI. Special focus will be directed at comprehensively evaluating several promising advanced selections in the breeding pipeline that have machine harvestability, desired fruit quality, and high yield. Other special interim emphasis will be placed on root rot assessments, IQF processing evaluation of advance clones, and germplasm preservation.

Justification and Background: The Pacific Northwest (PNW) breeding programs have been important in developing cultivars that are the basis for the industry in the PNW, and have made excellent progress in incorporating machine harvestability, productivity, and root rot resistance into breeding populations and advanced selections. Washington's growers are leaders in the production of high quality processed red raspberries. As the top producers of processed red raspberry in the U.S., 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: the breeding program has an unusually large number of promising selections and cultivars; the cooperation between growers, processors, and researchers is strong; and Washington raspberry growers critically need a competitive edge.

New cultivars emerge through a continuity of effort of yearly processes 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 across the region. The program proposes intensive evaluations of elite red raspberry selections with a view to accelerating their release as cultivars for Washington's red raspberry industry. This project will rigorously evaluate this plant material for root rot response, yield, and fruit quality in commercial-scale managed grower trials

Additionally, to enhance the competitiveness of the state's raspberry growers in the valuable Individually Quick Frozen (IQF) domestic and international market, the program will compete for and potentially leverage new funding from the WSDA Specialty Crop Block grant program. IQF evaluations are currently not performed as part of cultivar development because of the expense of growing enough fruit for processing in commercial IQF facilities.

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. The top 6-8 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. Funding will be sought from WSDA Specialty Crop Block Grant program to include an assessment of IQF processing for new cultivars.
2. Advanced selections from partnering breeding programs and WSU will be evaluated in replicated plots planted in 2017, 2018, and 2019 for Phytophthora root rot resistance. A new planting of new selections and regional cultivars will be planted in 2020.

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 planted in spring 2020. The goal will be to plant 108 plants in the field for each cross.
5. Selections will be made among the seedlings planted in 2018. 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 2017 and 2018 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 2018 and 2019 will be planted in a second machine harvesting trial, in replicated plantings at WSU Puyallup for collection of hand harvest data and screened for root rot tolerance and RBDV resistance (if potentially resistant based on parentage).
10. The replicated plantings established in 2017 and 2018 at WSU Puyallup will be hand harvested for yield, fruit weight, fruit rot and fruit firmness.

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		2020-2021
Salaries - 00		$ 34,619
Scientific Asst (0.50 FTE)	$ 19,542	
Ag Res Tech 2 (0.30 FTE)	$ 15,077	
Time-slip Wages - 01		$ 8,100
Goods/Services - 03		$ 17,000
Machine harvest trials	$ 13,000	
Land use fees	$ 2,000	
Supplies	$ 2,000	
Travel - 04		$ 1,500
Benefits - 07		$ 20,046
Total Direct Costs		**$ 81,265**

Budget Justification

Salaries and Wages:
Scientific assistant. Sci. Asst. 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 ($19,542).
Agricultural Research Technologist 2. ART2 Smith will maintain selections in the greenhouse, treat seeds, sow and rear seedlings, maintain germplasm, treat pest problems, and process fruit post-harvest. This equates to 0.3 FTE ($15,077).
Student and temporary worker. Seasonal workers will harvest fruit, collect data under supervision of PI, maintain plots, and do field work. This equates to 600 hours at $13.50/hr (minimum wage in 2020), equivalent to 2 workers at full time for 7.5 weeks ($8,100).

Benefits. Scientific assistant benefits are $10,217 for 0.5 FTE. Agricultural Research Technologist 2 benefits are $9,069 for 0.3 FTE. Temporary employee benefits amount to $760.

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. Honcoop Farms is contractor for MH trials established in 2017 ($3,000), 2018 ($3,000), and 2019 ($3,000). A suitable grower will be identified for the preparation and planting of the 2020 MH trial ($4,000). Total is $13,000.
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 ($2,000).

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 = 287 miles) in one year. (9 trips x $0.58/mile x 287 miles = ~$1,500).

Current Support

Name	Supporting Agency and Project #	Total $ Amount	Effective-Expiration Dates	% effort	Title of Project
Moore, P.P., Hoashi-Erhardt, W.	Northwest Center for Small Fruit Research	$32,299	2017-18	5%	Small Fruit Breeding in the Pacific Northwest
Moore, P.P. and Hoashi-Erhardt, W.	WSDA	$110,401	2017-20	15%	A thriving fresh market strawberry industry through breeding, horticultural systems, grower resources, and nursery expansion

Pending Support

Name	Supporting Agency and Project #	Total $ Amount	Effective - Expiration Dates	% effort	Title of Project
Hoashi-Erhardt, W., Peerbolt, T; Walters, TW	WSDA SCB	Un-determined.	Oct 2020 – Sept 2023	10%	The finishing touch: rigorous evaluations of potential new cultivars of red raspberry for Washington growers

2019 WASHINGTON RED RASPBERRY COMMISSION RESEARCH Report

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

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

PI:
Tom Peerbolt
Organization: Northwest Berry Foundation
Title: Executive Director
Phone: 503-289-7287
Email: tom@peerbolt.com
Address: 5261 North Princeton St.
City/State/Zip: Portland, OR 97203

Co PIs
Chad E. Finn – USDA-ARS-HCRU, Corvallis, OR
Patrick Moore – Washington State University, Puyallup, WA
Julie Enfield – Northwest Plant/Enfield Farms, Lynden, WA

Cooperators
Eric Gerbrandt, Sky Blue Horticulture, Ltd., Chilliwack, B.C.
Tom Walters, Walters Ag Research, Anacortes, WA.

Year Trials Originally Initiated_2012__Current Year 2018 Terminating Year_2019__

Background
From 2012-18 the we have been organizing a commodity commission funded pilot program for on-farm evaluations of caneberry selections and cultivars. Using the knowledge gained over this period, The 2019 project incorporated a number of changes that included:

- Improve regional coordination by:
  - Adding Tom Walters as supervisor for the NW Washington onfarm trials and to help facilitate communication between Northwest Plants, the growers and the other project participants.
- Improve data collection and dissemination by:
  - Increased site visits.
- Increase budget efficiencies by:
  - Minimizing travel time & mileage cost by eliminating reliance on Tom Peerbolt needing to drive to NW Washington to conduct site visits.

Notes on 2019 season project:

- Due to the revisions being made to improve this program in the long run no new plantings were done in the spring of 2019.
- Work in 2019 was evaluating the plantings now in the ground as well as implementing revisions.

Description: Maintain an ongoing network of regional on-farm grower trials for evaluating red raspberry advanced selections and newly released cultivars from the USDA-ARS/OSU breeding program in Corvallis, the WSU breeding program in Puyallup and the British Columbia raspberry breeding program combining public and private resources in ways that would 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.

Table of Raspberry Advanced Selections in Onfarm Trials including those planned for 2020

Note (d) indicates that the selection was dropped from further consideration following evaluation.

2017 planted	# planted	2018 plantings	# planted	2019 plantings	2020 selections	# ordered	List of potential selections beyond 2020
WSU 1914 (d)	**900**	**WSU 1962 (d)**	**500**	**None**	**WSU 2088**	**500**	**ORUS 4373-1**
WSU 1962 (d)	**14**	**WSU 2068**	**500**		**WSU 2130**	**500**	**ORUS 4465-3**
WSU 2010 (d)	**725**	**WSU 2069**	**500**		**WSU 2188**	**500**	**WSU 2130**
WSU 2162 (d)	**908**				**ORUS 4607-2**	**500**	**WSU 2087 (virus hold)**
WSU 2166	**511**						**WSU 2088**
WSU 2188	**575**						**WSU 2601**

Justification and Background:

The northwest caneberry breeding programs have been a cornerstone of the industry's success. Its ability to produce cultivars of commercial value is crucial to continued success. Global competition is increasing and public funding for these programs at our land grant institutions is under increasing budget constraints.

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:

- Maintain and improve the established network of regional on-farm grower trials for evaluating caneberry advanced selections issuing from the USDA-ARS/OSU breeding program in Corvallis, the WSU breeding program in Puyallup and the British Columbia raspberry breeding program.
- Evaluate trials established over the past years on farms located in a variety of regional growing conditions.:
  - 1) Improving the quality and breadth of information available on advanced selections,
  - 2) Improving the efficiency of this information's distribution to the grower/processor base.
- Establish new trials in of new advanced selections.

- Develop list of draft selections to be included in onfarm trials in future years.

The overall goal of the project is to combine public and private resources in ways that would accelerate the commercialization of our genetic resources.

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.

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:
Tom Peerbolt
Organization: Northwest Berry Foundation
Title: Executive Director
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Co PIs
Chad E. Finn – 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.
Tom Walters, Walters Ag Research, Anacortes, WA.

Year Initiated_2020__Current Year_2020 Terminating Year_2021__

Total Project Request: 2020 $9,572 2021: $10000

Other funding sources:

In-kind contributions: $1800 (estimated 1200 plants for trials in 2019. 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 possibly other) raspberry breeding program in Whatcom county growers' fields. The program will evaluate existing trials in growers' fields, 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 (NBF) 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 2020, we will:

- Evaluate 2017 and 2018 on-farm trials, with an emphasis on repeated evaluation of fruit quality and yield potential.
- Establish 2-3 new advanced selection trials as well as a 2-4 A IQF trial.

- 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 evaluate plants and fruit in the 2017 and 2018 (Minaker and Dhaliwal) trials. Selections in these trials include: Cascade Premier, WSU 2188, WSU 1914, WSU 2162, WSU 2010, WSU 1914, WSU 1962, WSU 2068, 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.

One grower has already expressed interest in a field-scale (4A) evaluation of WSU 2188. 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 Fall 2020. Fruit quality in this trial will be evaluated in 2022 and 2023.

Two growers have expressed interest in smaller-scale "row" trials of 50-150 plants/selection. One of these wants to plant spring 2020, the other fall 2020. Selections available for spring trial include WSU 1962, WSU 2068, WSU 2069, WSU 2130, WSU 2088. These will also be available for fall planting; there may be some ORUS selections available for fall planting as well. If possible, we will also attempt to establish a row trial in a field with root rot pressure.

Project guidelines
- Tissue culture plants.
- Maximum of 5 red raspberry selections each year.
- Minimum of 3 grower sites each year.
- 50-1000 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
Salaries[1/]	**$4,224**
Travel[2/]	**648**
Outreach[3/] `	**1,500**
Other (Propagator payments**)**[4/]	**1,200**
Offices costs (including AgReports**)**	**2,000**
Total	**$9,572**

Budget Justification

[1/] **Salaries**

Tom Walters—7 days a year at 8 hours per day at $50/hour including benefits = $2,688
Tom Peerbolt---4 days a year at 8 hours per day at $50/hour including benefits = $1,536

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

Tom Walters—5 trips a year at 120 miles per day at $ .58 per mile = $348
Tom Peerbolt---2 round trips per year between Portland and Lynden 600 at $ .50 per mile = $300

[3/]**Outreach**

Outreach will be accomplished by 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) $1200

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

Washington Red Raspberry Commission
Progress Report Format for 2019 Projects

Project No:

Title: Red raspberry cultivar development

Personnel:
Michael Dossett
C/O Agriculture and Agri-Food Canada
Agassiz Research and Development Centre,
PO Box 1000, 6947 #7 Hwy.
Agassiz, BC, Canada, V0M 1A0
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Reporting Period: 2019

Accomplishments:

- In 2019 we established ~4700 new seedlings in the field from crosses made in 2018 and made 87 new selections from crosses made in 2016. We also established 120 selections into a new yield trial

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- 160 BC and WSU selections were evaluated as machine-picked fruit in 5-plant trial plots at the Clearbrook station. 'Cascade Premier' looked outstanding in the 2016 and 2017 plantings, BC 11-110-11 and BC 7-17-7 continued to look good as well, with both picking very well, but also slightly softer than desirable.

- Overall, yield in most selections was down somewhat this year compared to the past two years. While many things showed no obvious winter injury, the program used this last season as an opportunity to cull material that had either been previously either on it's last stay of execution, or which had looked good before but had excessive winter injury. A total of 253 selections were eliminated from the program for subpar performance. On average the, number of berries per lateral was up, but fruit size was down about 0.5g from last year

- Three selections identified last year from the MH plots continued to look good and are being propagated for larger-scale grower trials. One seedling from 2016 crosses with outstanding potential also continued to look good and is being propagated for grower trials:

    - BC 10-79-33 had the highest three-year combined yield in our 2015-planted trial at the Clearbrook. Quality has not been as consistent as I'd like, but we are alternating between 3 and 4-day picks most of the season and it looked very good on a 2-day cycle. It might be on the light side but has received a tremendous amount of interest from growers who have visited the Clearbrook site and seen it. It starts a few days later than Meeker

- BC 10-84-9 is very large and vigorous. Yield was down again in 2019, but much of this looks to be due to spur blight in our plots, which receive no fungicide sprays. Fruit looks good on a 2-day pick, but may not be IQF quality on longer intervals. Nice color, very pretty.

- BC 10-71-27 is very firm and has beautiful fruit in the MH tray. Although it picks exceptionally well, it has mainly received the attention of a couple of fresh-market growers because of its somewhat earlier season and lighter color. While it has only had yields similar to Meeker in previous years, the yield was up considerably in 2019 over previous seasons.

- BC 1653.7 is a seedling selection that had large, very firm, easily harvested fruit with nice flavor. Laterals were strong and had a high number of berries (average 25-30). The plant clearly has yield potential and looks like it will machine-pick OK. Its father (ORUS 1025-10) has a good degree of root rot tolerance. Because this one has so much potential, we have made the decision to bulk this up for grower trial while we establish it in a yield trial at Clearbrook, so that we can evaluate it on a variety of sites as soon as possible.

Results:

Fig 1. Fruit of BC 1653.7; BC 1653.7 was identified in its first fruiting season as having outstanding fruit firmness and productivity, as well as having the potential for machine-harvestability. Its father, ORUS 1025-10 has good root rot tolerance.

Fig 2. Fruit of BC 10-79-33, which had the highest combined yield over the last three seasons in the 2015 planting. BC 10-79-33 is a couple days later than Meeker and perhaps softer than desired, but machine-harvested fruit is still in decent shape. Fruit color is borderline but may be acceptable.

Table 1: Combined yield data from the 2015 raspberry planting harvested in 2017 and 2018. Selections in bold are currently being propagated for grower trial. We will plan to evaluate this field for one more season.

Name	Avg. fruit weight 2019 (g)	Yield 2017 (t/a)	Yield 2018 (t/a)	Yield 2019 (t/a)	Combined Yield (t/a)	Comments
10-79-33	**3.9**	**8.1**	**7.4**	**6.2**	**21.7**	**Soft, but holds shape OK, bit lumpy, color? Might be acceptable? Season?**
10-73-19	3.8	10.1	4.5	5.5	**20.1**	Soft, poor quality, large drop in yield from '17-18
1-64-3	2.5	6.4	6	5.5	**17.9**	Very light color, extremely soft.
10-84-9	**6.0**	**7.3**	**5.5**	**4.8**	**17.6**	**V. Large, dark, firm. Beautiful on 2-day pick. - spur blight?**
Chemainus	2.8	6.1	6.2	5.3	**17.6**	Good, firm, consistent
10-52-68	2.7	5.3	6.5	5.1	**16.9**	Good color, bit lumpy, large opening, softish?
96-2R-1	2.8	7.1	6.3	3.1	**16.5**	Round, 1/4 wild, but V good for this.
96-38R-31	2.9	6.7	4.9	4.9	**16.5**	Beautiful, but very soft. 1/4 wild.
10-84-45	3.9	7.1	4.4	4.8	**16.3**	softish and light colored
K02-15	2.6	6.4	4.7	4.8	**15.9**	Beautiful with good flvr and color, but susceptible to root rot and late
10-71-27	**2.9**	**4.5**	**4.8**	**6.3**	**15.6**	**Firm. A few days before Chemainus, not as early as previously hoped, MH but light**
10-84-10	3.4	6	5.1	4.1	**15.2**	Good quality, especially on 2-day pick
1-86-21	3.4	6.2	4.2	4.5	**14.9**	Nice but soft, flvr?
3-19-5	2.6	6	4.3	4.4	**14.7**	rough and soft, nice flvr.
1-86-11	2.6	5.8	5.6	2.4	**13.8**	Early, looks nice, poor flavor
4-36-17	2.5	5.5	5.7	2.6	**13.8**	cohesive but soft
10-83-22	5.7	7.4	3.5	2.6	**13.5**	Very large chunky druplets, uneven.
10-84-42	3.5	7.6	3.8	1.9	**13.3**	chunky, softens quickly at ripening, probably too light
1-9-11	3.9	7.7	3.9	1.5	**13.1**	Very light and very soft
10-84-76	3.5	4.8	5.1	3.2	**13.1**	Firm, doesn't pick until very ripe
10-80-9	2.3	5.1	4.3	3.7	**13.1**	Poor color, many orangey
10-79-61	2.6	6.5	4	2.5	**13.0**	Lumpy, glossy, bit soft
93-26-25	3.3	6.3	3.8	2.7	**12.8**	Bit light? Lots of overripes,
10-71-23	3.3	5.3	4.4	3.1	**12.8**	Firm, picks very nice
10-78-40	3.1	6	3.8	2.1	**11.9**	Good color, in good shape, but significant crumbles
10-80-100	2.2	5.2	3.3	3.3	**11.8**	Dark, very nice. Probably best of 10-80s
1-11-15	3.4	6.5	3.8	1.3	**11.6**	Soft, crumbly. Eliminate
10-84-14	3.2	5.5	3.4	2.2	**11.1**	Good budbreak, healthy plant, tart, firm
10-65-1	3.1	5.3	3.6	2.0	**10.9**	Very light, picks well, bit lumpy, but looks V good. Parent for MH
Meeker	2.5	4.4	3.9	2.2	**10.5**	

Table truncated - 30 additional selections not presented

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:				

2020 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
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City/State/Zip: Agassiz, BC V0M 1A0

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

Cooperators: Chad Finn, Pat Moore, Wendy Hoashi-Erhardt

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

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

Other funding sources:
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, and the Washington Blueberry Commission, to support the blueberry and strawberry portions of our work).

Amt. Requested/Awarded: *(retain either requested or awarded and delete the other)*
Notes: We recently received approval of our 5-year proposal from the federal government. 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've 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: 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 good yield and we are adjusting our selection techniques to more readily identify seedling selections with high 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. This is in collaboration with Pat Moore, and Nahla Bassil, testing new markers, and then validating those markers across breeding populations to assess their utility. 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. The populations have already been screened for aphid resistance. Screening for root rot resistance has started in the greenhouse and will continue over the next few winters in addition to planting in a field with heavy pressure in Puyallup, WA (field screen in Puyallup has been completed and data are being analyzed). 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.

ENTOMOLOGY

Project Title: Managing SWD in Red Raspberry with Reduced Insecticide Residues

PI: Alan Schreiber
Organization: Agriculture Development Group, Inc.
Title: Researcher
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Cooperators: Tom Walters-Walters Ag Research

Year Initiated: 2017 **Current Year:** 2019 **Terminating Year:** 2020

Materials and Methods

During the summer of 2019, the staff of the Agriculture Development Group, Inc. conducted a research trial near Lynden, WA to look at the efficacy of multiple insecticide residue reducing programs for the control of spotted wing drosophila (SWD) in primocane managed red raspberry produced for the fresh market. The experimental design for this trial was a RCB with 4 replications and plot sizes of 10 ft x 30 ft. Applications for this trial were made with an over-the-row sprayer calibrated to apply treatment sprays at 84 gallons per acre (Photo 1). SWD pressure in this trial was very high towards the harvesting.

Six applications were made on Aug-13 (A), Aug-20 (B), Aug-31 (C), Sep-7 (D), Sep-13 (E), and Sep-25 (F) for rotations of different insecticides programs. Amount of SWD larvae in 50 randomly selected berries per plot were assessed using salt water soaking method (30 minutes soaking before examination of the larva in a tray) on Aug-31, Sep-6, Sep-13, Sep-23, and Oct-1. Berry samples were also collected at 2 DAT C, D, and E then sent to the Synergistic Pesticide Lab in Portland, OR for insecticide residue test.

Photo 1. Treatment application made by an over-the-row sprayer.

Results and Discussion

Obviously, SWD population did not start heavy reproduction until the 3rd application (C on Aug-31) with only 2 larvae found in 50 untreated berries at the first sampling event. By application D (Sep-6), the larvae population increased dramatically where the untreated check had an average 43 SWD in 50 berries. Meanwhile, program 3 and 4 only had 15 and 11 counts, leading to a relative 65 and 74% control. Programs 2, 5, and 6 also reduced the SWD larvae population with 31, 27, and 24 larvae, respectively, a relative control range from 39% to 44%. With the same treatments at application A, B, and C as program 5 and 6, program 7, however, had 40 larvae, although the results are statistically the same. The reason for the high pressure mid trial is that the grower concluded harvest part way through this project and stopped SWD maintenance applications in the rest of the field. Shortly thereafter SWD numbers in the trial increased sharply.

By Sep-13 (before application E), all treatments showed reduced SWD compared to untreated. Program 4 continue to perform the best with 26 larvae per 50 berries, a relative 72% control compared to untreated (94 larvae), followed by program 2 (66 larvae), 3 (43 larvae), 5 (59 larvae), and 6 (64 larvae) with very similar control efficacy around 33% to 54%. Program 7 still had the highest larvae population at 76 counts, leading to only 19% control. SWD population started natural decreasing at Sep-23 (before application F) and showed no obvious differentiations among programs after that.

Overall, same trends were observed for the study total larvae data. Program 4 resulted in the lowest total counts of 48, a relative 71% control compared to untreated (167 larvae). Programs 2, 3, 5, and 6 resulted in total 112 (33% control), 72 (57%), 101 (40% control), and 108 (35%) SWD larvae, followed by program 7 at 133 (20% control) total larvae. Results suggested on-par (programs 5 and 6) or even better (programs 3 and 4) control efficacy from the tested residue reducing programs than the conventional malathion dependent program 2.

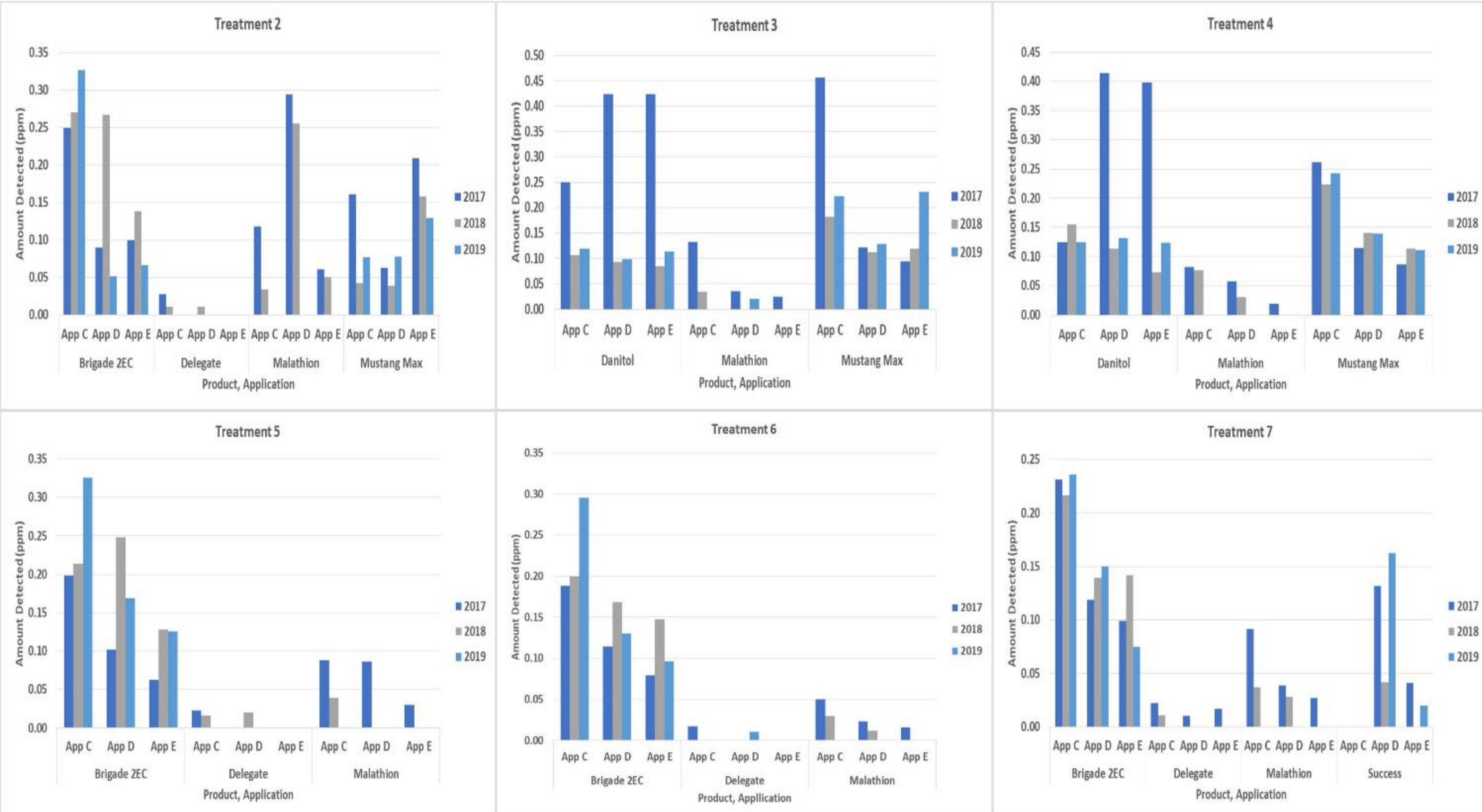
Generally, the residue data (Figure 1) showed that program 3 and 4 resulted < 0.15 ppm Danitol, <0.05ppm Malathion, <0.25ppm Mustang Max for samples collected at all 3 timings (2 days after application C, D, and E). Program 5 and 6 also achieved <0.15 ppm Brigade, nearly 0 ppm Delegate, and <0.05 ppm Malathion by the last sampling (2 days after application E). With similar setup as program 5 and 6 but addition of Success, program 7 had the same residue performance yet slight Success (<0.05ppm) by 2 days after application E.

In summary, programs 5 and 6 had statistically the same control efficacy as program 3 and 4 at most rating dates but also lower and less overall residues. However, if control efficacy is the top priority, program 4 is recommended as it showed the best control and very low pesticide residues. Program 3 can also be used as an alternative to program 4 with the similar pesticide residues yet slightly lower SWD efficacy. If this effort is to continue, we would recommend moving this project to a commercial floricane raspberry field. It is expected that one year of data in a commercial floricane raspberry field would be needed to complete this project.

Table 1. ANOVA mean separation table for the SWD larvae population at different rating dates.

Pest Name	Spotted wing d>	Spotted wing d>	Spotted wing d>	Spotted wing d>	Spotted wing d>	Spotted wing d>
Crop Name	Red raspberry	Red raspberry	Red raspberry	Red raspberry	Red raspberry	Red raspberry
Rating Date	Aug-31-2019	Sep-6-2019	Sep-13-2019	Sep-23-2019	Oct-1-2019	
Rating Type	count	count	count	count	count	total
Rating Unit	#	#	#	#	#	#
Days After First/Last Applic.	18 11	24 6	31 6	41 10	49 6	
Trt No. Treatment Name / Rate RateUnit / Appl Code	1*	2*	3*	4*	5*	6*
1 Untreated	2a	43a	94a	10a	19a	167a
2 Delegate 170g/a A	0a	31abc	66a	8a	8a	112abc
Malathion 20fl oz/a B						
Brigade 2EC 6.4fl oz/a C						
Malathion 20fl oz/a D						
Mustang Max 4fl oz/a E						
Malathion 20fl oz/a F						
Switch 14oz/a CDEF						
3 Danitol 1pt/a A	0a	15cd	43a	6a	9a	72cd
Malathion 20fl oz/a B						
Mustang Max 4fl oz/a C						
Grandevo 3lb/a D						
Corn Syrup 3% v/v D						
Jet Ag 1.2% v/v D						
Venerate 6qt/a E						
Corn Syrup 3% v/v E						
Jet Ag 1.2% v/v E						
Grandevo 3lb/a F						
Corn Syrup 3% v/v F						
Jet Ag 1.2% v/v F						
Kenja 15.5fl oz/a CDEF						
4 Danitol 1pt/a A	1a	11d	26a	4a	7a	48d
Malathion 20fl oz/a B						
Mustang Max 4fl oz/a C						
Venerate 6qt/a DF						
Jet Ag 1.2% v/v DEF						
Grandevo 3lb/a E						
Miravis Duo 10.5fl oz/a CDEF						
5 Delegate 170g/a A	1a	27a-d	59a	5a	9a	101bcd
Malathion 20fl oz/a B						
Brigade 2EC 6.4fl oz/a C						
Grandevo 3lb/a DEF						
Jet Ag 1.2% v/v DEF						
Corn Syrup 3% v/v E						
Miravis 5.13fl oz/a CDEF						
6 Delegate 170g/a A	2a	24bcd	64a	4a	15a	108bc
Malathion 20fl oz/a B						
Brigade 2EC 6.4fl oz/a C						
Grandevo 3lb/a DEF						
Corn Syrup 3% v/v DF						
Jet Ag 1.2% v/v DEF						
Miravis 6.84fl oz/a CDEF						
7 Delegate 170g/a A	1a	40ab	76a	5a	12a	133ab
Malathion 20fl oz/a B						
Brigade 2EC 6.4fl oz/a C						
Success 6fl oz/a DF						
Jet Ag 1.2% v/v DF						
Grandevo 3lb/a E						
Jet Ag 1.2% v/v E						
Miravis 10.2fl oz/a CDEF						
LSD P=.05	1.7	18.7	40.2	6.7	9.4	58.5
Standard Deviation	1.2	12.6	27.0	4.5	6.3	39.4
CV	131.24	46.56	44.42	77.52	56.62	37.21
Replicate F	4.257	4.564	11.155	5.445	0.428	8.494
Replicate Prob(F)	0.0194	0.0151	0.0002	0.0077	0.7351	0.0010
Treatment F	1.509	3.617	2.623	1.055	1.775	3.864
Treatment Prob(F)	0.2314	0.0157	0.0525	0.4244	0.1610	0.0118

Figure 1. Residue test for the concentration of different products found on the berries collected at 2 days after treatments C, D, and E.



Project Proposal to WRRC **Proposed Duration:** 2 Years

Project Title: A New Strategy for SWD Control in Raspberry; Attract and Kill

PI: Alan Schreiber
Organization: Agriculture Development Group, Inc.
Title: Researcher
Email: aschreib@centurytel.net
Address: 2621 Ringold Road, Eltopia, WA 99330

Cooperators: Tom Walters, Walters Ag Research and ISCA Technologies

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

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

Other Funding Sources: None. A proposal was submitted to the Washington Blueberry Commission to conduct a similar trial on that crop.

Description, Justification and Background:

Control of the soft fruit pest *Drosophila suzukii*, or spotted wing drosophila (SWD), is based largely on calendar sprays of organophosphate, carbamate, neonicotinoid, and pyrethroid insecticides with some reliance on other products. These programs create several problems for growers, including high costs, difficulty abiding maximum residue limits (MRLs) for export of affected produce, secondary pest problems (i.e., flare-ups of aphid and mite infestations), delays due to preharvest intervals, and some concerns regarding human health and the environment. In some cases, environmental conditions such as rain and wind can cause problems with application, ultimately reducing the efficacy of these pesticides.

A relatively new technology, called SPLAT (Specialized Pheromone and Lure Application Technology) has been applied for control of SWD. SPLAT is a base matrix from which a large variety of products have been developed, utilizing a range of strategies, including attract-and-kill, mating disruption, and repellence. This technology has been used for the controlled release of sex pheromones to disrupt mating in pink bollworm, fall armyworm, and carob moth (pests of cotton, corn, and dates, respectively), of anti-aggregation pheromones to repel mountain pine beetles from vulnerable forest trees, and of potent parapheromones to attract and kill fruit flies that might otherwise attack and infest tropical fruits, among other applications. The company that developed SPLAT, ISCA Technologies, has developed a new formulation called Hook SWD, specifically targeting SWD using an attract-and-kill strategy. The active ingredient (AI) in Hook SWD is spinosad. Hook SWD is applied to the base of berry plants, ensuring that none of the incorporated pesticide comes into contact with the fruit. Application of Hook SWD therefore has the potential to deliver control of SWD while also producing insecticide residue-free fruit, assuming it is effective.

ISCA Technologies has recently teamed up with the IR-4 Project and Driscoll's to evaluate the efficacy of this product on fresh raspberries and blackberries grown under tunnels in California.

UC Cooperative Extension Agent Mark Bolda is conducting this trial. Rutgers University's Cesar Rodriguez-Saona and University of Florida's Oscar Liburd are conducting trials with this product in blueberries.

ISCA Technologies provided the following information on their product. "*In a raspberry farm in Watsonville, CA, Hook SWD significantly outperformed the grower's conventional pesticide applications. Weekly evaluations showed that areas treated with Hook SWD maintained low fruit damage. At the peak of SWD pressure, the conventional program had 4.5 times higher larval damage than the Hook SWD*."

Additional considerations regarding the use of Hook SWD include cost of the product and its application, number of applications required per season, ease of use, irrigation, and rain fastness. Because the product is not registered, the final cost of Hook SWD is not yet known but based on the costs of other formulations with this AI, the registrant has approximated a potential material cost of $22.50 per acre per application.

A model that might be similar to the the Hook SPLAT program is codling moth mating disruption. Almost all apple growers use mating disruption to manage codling moth, but few rely exclusively on this approach, which allows them to reduce insecticide use and have insecticide residues that allows them to enter more export markets.

This year was the first year of our investigation with this technology. The results were not favorable, but we did not receive product in time to initiate treatments at the appropriate time (see our WBC blueberry trial report for more information on this). Of the two trial sites, one had virtually no SWD pressure and the second site had very high SWD pressure. Arrangements have been made with ISCA Technologies to address these issues.

Relationship to WRRC Research Priority:

This project addresses a #1 priority -- Management options for control of the Spotted Wing Drosophila

Objectives:

Develop efficacy data on whether Hook SWD will provide commercially acceptable levels of control of SWD in raspberry in WA State. Determine cost of Hook SWD control program for WA growers.

Procedures:

We have followed the advice of ISCA Technologies' Biology Manager on how to set up this trial. The minimum plot size should be at least 2 acres (approximately 210 x 206 feet), and a minimum of four replicates should be established, meaning the trial would require 8 acres per treatment. We are proposing three treatments, meaning the field to be used for this trial would need to encompass at least 24 acres. We would like to conduct this trial in two locations. The ideal grower to participate in this trial would have lower SWD standards that would have some SWD present in fruit with the use of the grower standard program.

The treatments evaluated at these sites would be 1) growers' standard SWD program; 2) growers' standard program plus Hook SWD, applied at 1.5 liters per acre every 7 days; and 3) grower standard program plus Hook SWD, applied at 1.5 liters per acre every 14 days with Hook SWD would be applied in a band to the base of the crop canopy in 1-yard strips every 4 to 5 yards. Applications would start at approximately 50% first blue or whenever the grower starts their SWD program. The ideal grower would have lower SWD standards that would have some SWD present in fruit with the use of the grower standard program. The efficacy of the three treatments would be evaluated on the basis of how much additional control the Hook SWD programs provided to the program. Depending upon SWD pressure, 200–800 fruit would be collected from each plot each week and examined for the presence of SWD larvae using the salt dunk method. Results would be analyzed by analysis of variance. Once efficacy of SWD control has been established for Hook SWD, future trials might include Hook SWD-only treatments.

We have potentially identified cooperators for 2020. One challenge to using this technology is the time (and therefore cost) of applying the product. One option that we will consider to reduce application costs is the use of a drone to apply the bait. A drone company, City Drones UAV has expressed a willingness to cooperate on this project. They have an existing contract to apply Mediterranean fruit fly bait commercially and are looking for other applications for their technology.

Anticipated Benefits and Information Transfer

This project, if successful, would provide growers with a way to control SWD, not flare secondary insect pests such as aphids or mites without or with lower insecticide residues which would increase the number of export markets to which Washington red raspberry growers could access. If this product could replace current conventional insecticide programs it could have substantial benefits associated with reduced insecticide use. Alternatively, this treatment may be able to supplement existing SWD programs, allowing growers to use softer products more often, making it easier to meet MRL requirements and reducing applicator exposure to organophosphates, neonicotinoids, carbamates and pyrethroids. Finally, if this technology fails in this trial, then Washington raspberry growers will save money by not using a product that won't work.

We believe we can figure out this technology in two years as we have one year of experience already with blueberries. By doing this working in both blueberry and raspberry over the next two year, we will know whether it will bring any value to a Washington Red Raspberry grower.

Budget:

	2020	2021
Salaries[1/]	$4,000	$4,000
Time-Slip	$	$
Operations	$	$
Travel[2/]	$1,000	$1,000
Meetings	$	$
Other	$	$
Other – Contract Research	$4,000	$4,000
Benefits[4/]	$1,000	$1,000
Total	**$10,000**	**$10,000**

Salary is for the Ag Research Manager

Travel is for travel expenses to and from research plots

Contract research is for the cost of Tom Walters contribution.

Washington Red Raspberry Commission
2019 Final Project Report

Project No: 13C-3443-3275

Title: Longterm Management of BMSB

Personnel: Beverly Gerdeman & Charles Coslor

Reporting Period:

- January – December 2019

Accomplishments:

- Searched for Brown Marmorated Stink bug, BMSB, in Skagit and Whatcom counties
- Maintained a BMSB colony to support the *Trissolcus. japonicus* colony
- Maintained a *T. japonicus* colony
- Made releases of *T. japonicus* at the end of growing season
- The *T. japonicus* founder population will help provide longterm management of BMSB in Skagit and Whatcom Counties.

Results:

Ten scouting sites were selected based on host plants and captures in previous years. Most locations were in Skagit County and two were in Whatcom County. Sites were visited between 1 and 3 times between May and September. One adult was found in May on a holly tree in west Mount Vernon. Nymphs were found multiple times on a Catalpa tree in south Mount Vernon, in August and September. A pyramid trap was placed at this site to monitor for nymphs and the majority of captures were during August and September. BMSB were not found at other host plant sites despite checking multiple times during the peak season (August and September).

Our BMSB colony went into diapause during the 2018-2019 winter. An attempt to break the diapause using methods described in the literature was unsuccessful and the colony failed. Because no eggs were being laid, the *Trissolcus japonicus* colony from 2018 was unable to propagate and also collapsed. A new BMSB colony was slow to establish because in late winter and early spring, no wild BMSB were available. In order to collect more BMSB for a founder population, multiple trips to southwestern WA were made in the spring and summer. In the meantime, we reached out to multiple labs in Washington state and found one that could spare fresh *Trissolcus* wasps.

The colony was reestablished in July and *Trissolcus* wasps were ready by the end of the season. Despite setbacks, *T. japonicus* releases were made on 27 September 2019. Approximately 30 wasps across 2 sites were released. Release sites were based on host plant proximity and BSMB observations.

Additional parasitized egg masses are anticipated this fall from a *T. japonicus* colony in Yakima. These egg masses will be placed directly into the field to allow the wasps to acclimatize and overwinter. Each egg mass will release approximately 25-30 adult wasps. This work will continue next season with BMSB monitoring and more parasitoid releases at no extra cost to WRRC. Sentinel egg masses from our

BMSB colony will be set out to confirm successful *T. japonicus* establishment.

Publications:
Details of the project were presented at the Western Washington Berry Workshop on 8 March 2019. Additional BMSB information was presented to the South Whidbey Garden Club on 15 March, 2019. The project was also presented at the NWREC Field Day on 11 July 2019.

Figure 1. A: Releasing *Trissolcus japonicus* wasps onto wild hazelnut at one site in Skagit County, September 2019. B: Two *T. japonicus* adults on the surface of a hazelnut leaf. *(photos C. Coslor)*

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

Washington Red Raspberry Commission
2019 Final Project Report

Project No: 10A-3093-4918

Title: Determination of bifenthrin and bifenazate resistance in red raspberry spider mite populations

Personnel: Beverly Gerdeman & Charles Coslor and Lydia Tymon

Reporting Period:

- January – December 2019

Accomplishments:
- Approximately 40 adult mites were slide-mounted/location for identification.
- Insecticide resistance bioassays using two products (Acramite and Brigade), were performed using a Precision Potter Spray Tower, on spider mites collected from four Whatcom County red raspberry fields.
- DNA was extracted from 288 spider mites from the bioassays.
- DNA from the 156 spider mites surviving the high field-rate concentration of Brigade (bifenthrin) in the bioassays was amplified and completely sequenced using the following primer sets: KdrIIF1-R1 and KdrIIF2-R2.
- Raw sequence reads are currently being analyzed.

Upon completion of the analysis, we will be able to calculate resistance incidence/location to determine baseline levels resistance in the different raspberry growing regions

Results:
Results of the Probit Analyses from each of the 4 sites were combined for each insecticide because of the similarity in % mortality (Figs. 1 & 2). The results of the research indicate:
- Widespread resistance to bifenthrin in all 4 localities.
- Acramite at 1 locality outperformed (78% mortality) the three remaining sites (36%, 42% and 44% mortality).
- All mites from all locations were identified as *Tetranychus urticae*, twospotted spider mite based on Pritchard and Baker (1955) and http://treefruit.wsu.edu/crop-protection/opm/mites/

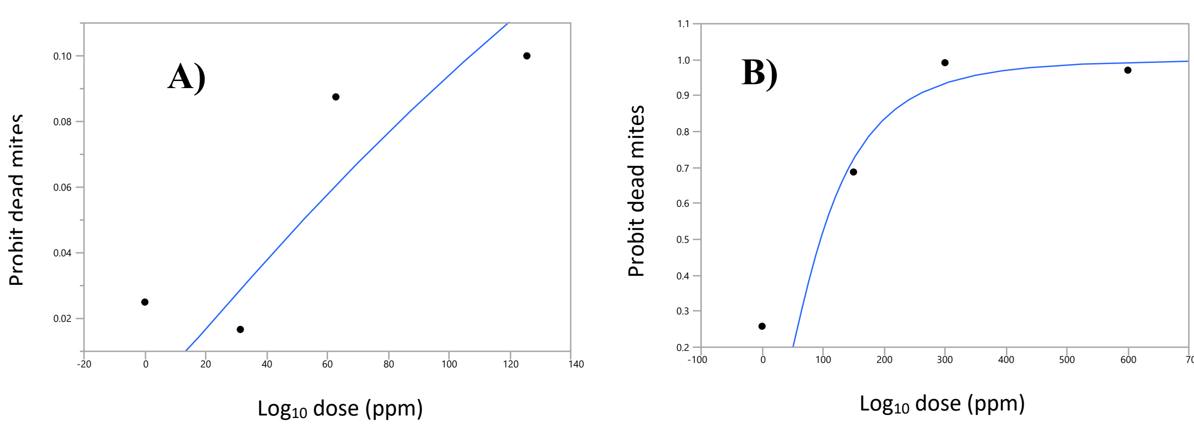


Figure 1. Probit of percentage lethality on twospotted spider mites was plotted against $\log_{10}$ concentration of two acaricides, A) Brigade 2EC and B) Acramite 50WS.

In Figure 1A, 100% mortality was never reached for the full field rate of bifenthrin, which indicates resistance in the twospotted spider mite populations surveyed at 4 locations in Whatcom County red raspberries. The LC_{50} of bifenthrin could not be determined, since the maximum % mortality even at the high field rate was only 5.8%.

In Figure 1B, 90% mortality was reached with the half field rate and 100% was reached with the full field rate. The LC_{50} of bifenazate was 95.8 ppm, which is lower than the ¼ rate. At full rate this product is more than sufficient to reach 100% mortality.

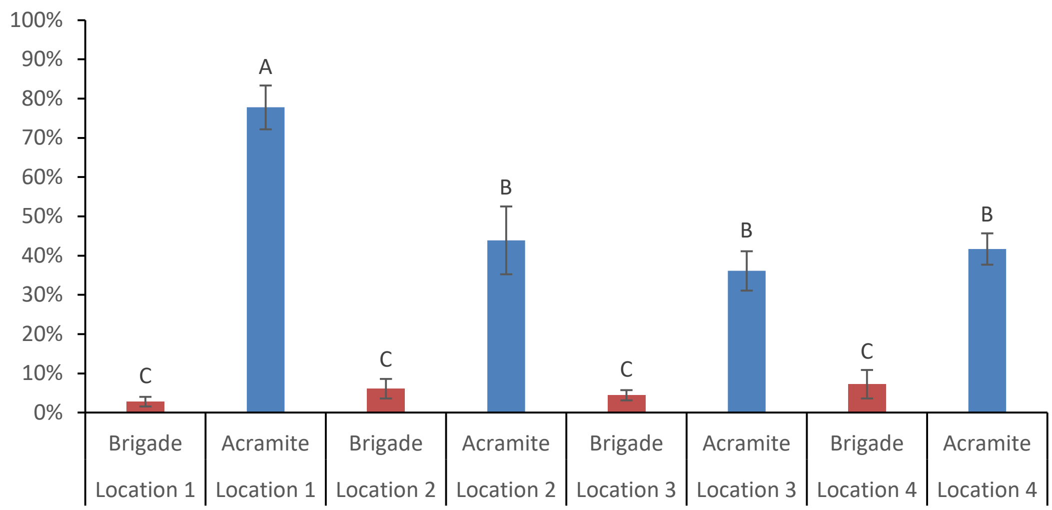


Figure 2. Mortality of twospotted spider mites in bioassays using Brigade (bifenthrin) and Acramite (bifenazate). Bars with the same letter are not significantly different based on an alpha of 0.05.

There was no difference in performance of the full rate of bifenthrin at the four different localities in 2019. Compared to 2018, average percent mortality for bifenthrin full rate has fallen from 18.9% to 5.8% in 2019. Acramite exhibited an average of 74.2% mortality for the full field rate in 2018 and one year later it had dropped to 56.2%. These results clearly indicate that Whatcom County red raspberry spider mites have developed widespread resistance to bifenthrin and the 18% drop in performance by Acramite from 2018 to 2019 suggests resistance is developing for bifenazate as well. Pending results of the molecular analysis, we will be able to determine the incidence of mutations and potential risk to growers. Meanwhile, growers in Whatcom County should exercise careful resistance management to slow its development.

2020 WASHINGTON RED RASPBERRY COMMISSION RESEARCH PROPOSAL

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

Project Title: Improved Management of lepidopteran pests in Washington State Red Raspberry

PI: Beverly Gerdeman	**Co-PI:**
Organization: WSU NWREC	**Organization:**
Title: Assistant Research Professor	**Title:**
Phone: 360-848-6145	**Phone:**
Email: bgerdeman@wsu.edu	**Email:**
Address: 16650 State Route 536	**Address:**
Address 2:	**Address 2:**
City/State/Zip: Mt. Vernon, WA 98273	**City/State/Zip:**

Cooperators: Lynden growers to be determined

Year Initiated __2019__ **Current Year** __2020__ **Terminating Year**

Total Project Request: **Year 1 $9,936** **Year 2 $** **Year 3 $**

Other funding sources:
Agency Name: Requesting funds from Washington State Commission on Pesticide Registration
Amt. Requested: $9,941
Notes: The Washington State Commission on Pesticide Registration provides a match for this research.

Agency Name: Requesting funds from Northwest Ag. Research Foundation
Amt. Requested: $4,039
Notes: These funds maintain the red raspberry experimental field plot at WSU NWREC where untreated leaves will be collected for the insecticide bioassays for detection of resistance described in the objectives of this research proposal.

Description: (less than 200 words) describing objectives and specific outcomes

Small fruit production (caneberries and blueberries) in Western Washington is estimated at $21.5 million. Several moths are serious pests of red raspberries in Western Washington, including two leafrollers, Obliquebanded leafroller, *Choristoneura rosaceana*, OBLR, and Orange Tortrix, *Argyrotaenia franciscana*, OT. Several cutworms including *Xestia c-nigrum,* the spotted cutworm and *Noctua pronuba*, the winter cutworm can be found in red raspberry fields along with the Bertha armyworm, *Mamestra configurata* (PNW Insect Mgmt Handbook). The caterpillars of these moths can damage buds, defoliate and become significant harvest contaminants. Larval feeding on blossoms may also contribute to botrytis. For the past three years Whatcom County berry growers have increasingly reported difficulty in controlling OBLR, which are prone to resistance (Dunley et al 2006), which could be promoted by the aggressive insecticide program for spotted wing drosophila, SWD. This research will establish a colony of OBLR from Whatcom red raspberry then perform bioassays using Mustang Maxx, zeta cypermethrin and malathion to determine if resistance may be developing in red raspberry populations. Light traps will be used to survey for moths and identify their flight periods. Specimens will be pinned and serve as a reference collection of lepidoptera associated with red raspberry.

Justification and Background: (400 words maximum)

Since 2018, red raspberry growers have been reporting an increase in lepidopteran pests despite the aggressive SWD spray program which includes insecticides equally effective against lepidoptera. The cutworms climb high enough in the raspberry canopy to be picked up by the harvesters, while leafrollers are dispersed within the canopy. The obliquebanded leafroller, OBLR, is prone to resistance (Dunley et al 2006). Resistance studies performed by Dunley et al (2006) on OBLR in tree fruits, indicated presence of resistance and cross-resistance in populations with some developing even prior to insecticide registration and field use. Red raspberry growers practice a similar aggressive spray schedule due to the presence of the invasive direct pest, spotted wing drosophila, SWD. Whatcom red raspberry growers could be facing loss of control of these moths if resistance develops. There is a need to determine the susceptibility of red raspberry populations of OBLR to insecticides used for their control and to return to a resistance management program, including insecticide rotations among insecticide classes to prevent resistance. Whatcom County is not the only location where leafrollers, cutworms and armyworms are a growing concern. These moths know no borders. A similar increase in leafroller populations has been reported in British Columbia and the Raspberry Industry Council of British Columbia has accurately ranked leafrollers and caterpillars a high priority for 2020 research, second only to spotted wing drosophila. To address the growing regional concern, Tracy Hueppelsheuser, BC Ministry of Ag, and myself will be co-presenting on these moth outbreaks at the Lower Mainland Horticultural Improvement Association and Horticulture Growers' Short Course in Abbotsford, BC in January 2020. This proposed research will investigate the susceptibility of Whatcom County red raspberry OBLR populations to raspberry insecticides, using bioassays. Testing multiple concentrations of each insecticide requires hundreds of even-aged larvae/test, which are only available from a laboratory colony. Although OBLR is polyphagous, it is not known whether there are genetic differences between populations infesting blueberry and red raspberry, so developing a colony specifically from red raspberry is necessary and could provide these answers.

Relationship to WRRC Research Priority(s): While the Washington Red Raspberry Commission ranks moths as 3rd in priority, this position does not reflect increasing grower concern which I experienced regarding these moth outbreaks and subsequent harvest contamination in the past 2-3 years.

Objectives:

This study will be performed during a single season in 2020 and will focus on the following objectives:

1. Determine moth species infesting Western Washington red raspberry.
2. Establish an OBLR colony from Whatcom County populations.
3. Perform leaf bioassays to determine evidence of OBLR resistance to 2 common insecticides: malathion and Mustang Maxx (subject to grower input).

Procedures – The project is anticipated to require at least one year to accomplish, dependent on results.

1). To determine the moth species infesting Western Washington red raspberry, four fields will be sampled for presence of lepidoptera using light traps. Light traps will be monitored weekly throughout the entire season. Specimens collected will be identified to species, prepared and pinned to serve as a reference collection.

In addition to light traps, pheromone traps including OBLR, OT, Spotted cutworm and Bertha armyworm will be placed in the 4 locations, checked weekly and monitored throughout the season to determine flight periods.

2). To establish an OBLR colony for bioassays, OBLR larvae from the overwintering generation will be collected from Whatcom County infested fields in the spring using a beat tray and placed on the leafroller diet for rearing. Alternatively, larvae or pupae will be collected when foliage is sufficient to observe web nests making it easy to collect specimens. Following emergence, adult moths will be placed into rearing cages for oviposition. Egg masses will be removed and placed on Stonefly Heliothis Diet (Ward's Science) and allowed to feed and molt to subsequent instars. Following eclosion, adult moths will be removed and placed into cages for oviposition and colony expansion.

3). The following procedure will be used to perform bioassays to detect levels of resistance in Whatcom red raspberry populations of OBLR. A leaf disk bioassay will be used to expose leafroller larvae to insecticide residues. Methods are based on those developed by Dunley et al (2006). Treatments will consist of various concentrations of malathion and Mustang Maxx (zeta cypermethrin) with a wetting agent added to the stock solution to promote even coverage. The control will consist of water plus the wetting agent.

Leaves will be collected from untreated red raspberry (var. 'Meeker') at WSU NWREC. Whole leaves will be dipped in the selected insecticide concentrations and allowed to air dry. Leaf disks will be punched and four leaf disks will be placed on cotton dampened with di-ionized water in covered Petri dishes. Five 1 to 2-day-old leafroller larvae will be placed at random on the leaf disks in each dish. A total of 10 dishes (50 larvae) will be prepared for each insecticide concentration. Petri dishes will be held at 23 ± 2°C and 16:8 (L:D). Mortality will be evaluated after 1DAT, 3DAT and 7DAT. Caterpillars failing to respond to gentle probing with a camel's hair brush will be considered dead. Results will be analyzed using appropriate statistics.

Anticipated Benefits and Information Transfer: (100 words maximum)

- Red Raspberry growers will be provided with information on the status of resistance development in Whatcom County OBLR populations.
- Knowledge of lepidopteran species and their flight periods will assist growers in better managing these pests and assist in preventing bud damage and harvest contaminants.

Results of this research will be provided at the 2020 NWREC Summer Field Day. Growers will receive information at the Lynden Small Fruit Conference in 2020 and other grower meetings.

References:

Dunley, J., J. Brunner, M. Doerr and E.H. Beers. 2006. Resistance and cross-resistance in populations of the leafrollers, *Choristoneura rosaceana* and *Pandemis pyrusana*, in Washington apples. 7pp. Journal of Insect Science 6:14, available online: insectscience.org/6.14

PNW Insect Management Handbook. https://pnwhandbooks.org/insect

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

	2020
Salaries[1/]	$972
Time-Slip	$5,440
Operations (goods & services)	$
Travel[2/]	$487
Meetings	$
Other	$1,699
Equipment[3/]	$
Benefits[4/]	$1,338
Total	**$9,936**

Budget Justification

[1/] .5 month Ag Tech III @ .25 FTE ($578)

.5 month Plant Technician, .25 FTE ($394)

Timeslip Non-student wages @ $16/hour ($2,560) and @ $18/hour ($2,880) at 16 hours/week for 10 weeks

[2/] Travel - 7 trips @ 120 miles/trip (840 miles) @ $0.58/mile to grower fields in Lynden, WA. To check light traps, pheromone traps and moth damage.

[3/]

[4/] Benefits Ag Tech III @ 42.08% ($243)

Plant Tech I @ 54% ($214)

Timeslip $16/hour @ 9.39% ($240)

Timeslip $18/hour @ 22.5% ($641)

Gerdeman Current and Pending

Current		
USDA - FAS TASC	2017 - 2019	Develop Caneberry Pesticide Degradation Curves to Avoid MRL Violations in Foreign Markets, Increase Exports, Prepare Growers for Canada's Proposed Low Default MRL and Overcome the Canadian/Cypermethrin Trade Issue.
USDA - FAS TASC	2019 - 2021	Eliminating pest-related trade barriers for the Alaska grown peony trade industry
WSDA Specialty Crop Block Grant K2545	2018- 2020	Investigating impacts of insecticides on pollinators in a biennial seed crop
Northwest Agricultural Research Foundation (NARF)	2019	Lygus Beet Seed Efficacy Trial
NARF, WSCPR and WRRC	2019	Trickle releases of *Trissolcus japonicus* for managing Brown Marmorated Stink Bug.
Western SARE	2018 - 2020	Trap cropping and surveying introduced wireworms (*Agriotes* spp.) in Western Washington
Washington Blueberry Commission and WSCPR	2019	Leafrollers in Washington State Blueberry
Washington Red Raspberry Commission and WSCPR	2019	Determination of bifenthrin and bifenazate resistance in red raspberry spider mite populations
Northwest Agricultural Research Foundation (NARF)	2019	Maintenance of the NWREC Perennial Berry Plots
Gowan	2019	Efficacy of Onager Optek on spider mites in red raspberry
Pending		
WRRC and WSCPR	2020	Improved management of lepidopteran pests in Washington State red raspberry (includes cutworms)
WBC and WSCPR	2020	Improved management of lepidopteran pests in Washington State blueberry
NARF and WSCPR	2020	Evaluation of a preplant incorporated insecticide/Ro-Neet tankmix to control root pests of spinach grown for seed
WRRC and USDA FAS TASC	2020	Amendment for the red raspberry decline study
BIOAg	2020	Sustainable production of sweet potato in Western Washington

2020 WASHINGTON RED RASPBERRY COMMISSION
RESEARCH PROPOSAL

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

Project Title: Plastic mulches for management of spotted wing drosophila

PI: Christelle Guédot
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Co-PI: Lisa W. DeVetter
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Co-PI: Hanna McIntosh
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City/State/Zip: Madison, WI 53706

Cooperators: None, research will be conducted at Washington State and University of Wisconsin research facilities.

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

Total Project Request: **Year 1**: $9,627

Other funding sources: Yes
Agency: Wisconsin Department of Agriculture, Trade, and Consumer Protection (DATCP)
Amount Awarded: $99,882
Agency: Wisconsin North Central Region SARE
Amount Awarded: $11,987
Notes: Both funding sources cover our assessment of the impact of mulches on SWD management, fruit quality, yield, plant establishment and growth, and soil health in Wisconsin. It does not overlap with the project proposed here.

Description:
Plastic mulches are commonly used in fruit and vegetable production for weed management, improving fruit quality and yield, and insect management. Research lead by Dr. DeVetter's group established the benefits of plastic mulches in spring-planted floricane red raspberry,

including improved tissue culture establishment, weed management, and first-year yield. Our group in Wisconsin has shown that mulches help manage spotted wing drosophila (SWD) in primocane raspberry. Research led by PhD student Hanna McIntosh in Drs. Guédot and Atucha's labs found that plastic mulches deter adult flies, reduce larval infestation of fruit, and quickly kill larvae that drop onto the surface of the mulch. However, it is unknown whether this management strategy will reduce the amount of unmarketable fruit growers have to discard at harvest, or if it will be effective in floricane raspberry. Objective 1 of this project will assess whether reduced fruit infestation due to metallic polyethylene, white biodegradable, and black biodegradable mulches is linked to a subsequent reduction in unmarketable fruit at harvest of 'Caroline' raspberry in Wisconsin. Objective 2 will leverage an existing project to test the efficacy metallic polyethylene and various black mulches for management of SWD adults and larvae in fruiting 'Meeker' raspberry in Washington.

Justification and Background:
Small fruit production worldwide is threatened by SWD. Larvae feed inside ripening, undamaged fruit, causing complete loss. Management relies primarily on chemical control, with some growers having to spray every 4-7 days (1) to prevent fruit loss and meet infestation levels specified by processors (2). Cultural practices like reduced harvesting intervals and field sanitation are helpful, but highly labor-intensive (3).
Plastic mulches are a promising cultural control since they modify the crop habitat to make it unfavorable or deadly to SWD. Our ongoing research in Wisconsin is testing metallic polyethylene, white biodegradable, and black biodegradable mulches as a management strategy for SWD, as well as their impact on fruit quality, yield, plant establishment and growth, and soil health. Preliminary data collected on a commercial primocane raspberry farm showed that all mulches provided three layers of protection for raspberry plants: 1) Fewer adult flies were found in the canopy above mulched plots compared to controls (Fig. 1a), suggesting that mulches deter adult flies; 2) Fruit infestation was lower in mulched plots (Fig. 1b); 3) All larvae died on black mulch in <1 hour and on white and metallic mulches in <3 hours. Because 82-100% of SWD larvae drop to the soil to pupate (4), high mortality of larvae could contribute to population

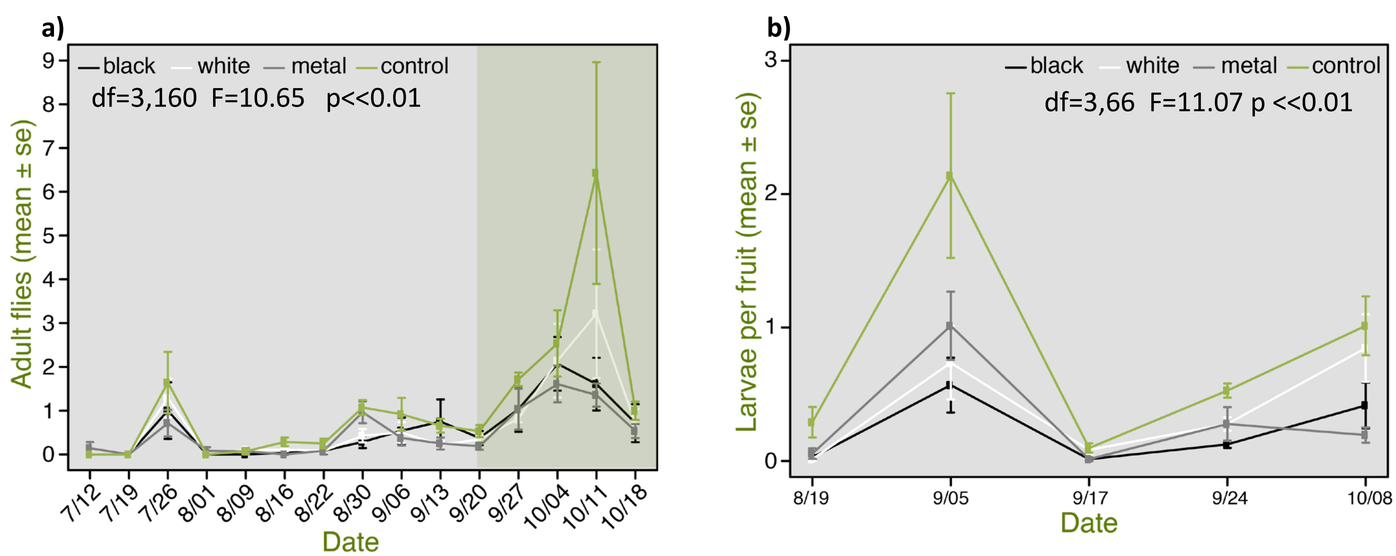

Figure 1: (a) Adult flies captured on clear sticky cards. Green box indicates when grower stopped harvesting at end of season, causing highest SWD populations. The effect of mulches was strongest when fly populations were highest, reducing adult SWD by 2-6 times. (b) Number of larvae recovered from fruit by salt floats. Mulches reduced larvae in fruit by 2-4 times at highest infestation levels.

suppression. Although these preliminary results are very promising, it is unknown whether the reduction in fruit infestation is linked to a subsequent reduction in unmarketable fruit at harvest. We should also expand this work to determine if mulches are effective in floricane raspberry. This proposed project will build on our previous work in Wisconsin, where we will assess whether metallic polyethylene, white biodegradable, and black biodegradable mulches effect the proportion of unmarketable fruit. Secondly, we will expand our research to determine the effects of metallic polyethylene and various black mulches on SWD in Washington. We chose black mulches because of their ability to quickly kill larvae on the mulch surface and their soil warming effects. We chose metallic mulches because of their ability to repel adult SWD and reflect light into the plant canopy. Completion of this project will help develop this promising strategy for SWD management, possibly reduce the number of insecticide applications needed to control the pest, and may decrease unmarketable fruit thereby reducing loss from SWD.

Relationship to WRRC Research Priorities:
Our project addresses management of spotted wing drosophila, which is a #1 priority.

Objectives:
Evaluate the efficacy of plastic mulches as a management tool for SWD in Wisconsin and Washington, as outlined in two objectives that will be completed in 2020:

1. We will build on our work in Wisconsin by assessing the impact of metallic polyethylene, white biodegradable, and black biodegradable mulches on fruit infestation and proportion of unmarketable fruit at the West Madison Ag. Research Station in Verona, Wisconsin.
2. We will assess whether metallic polyethylene, black polyethylene, black woven multi-season polyethylene weedmat, and new formulations of black biodegradable mulches impact adult fly populations, fruit infestation, and proportion of unmarketable fruit at the WSU NWREC in Mt. Vernon, Washington.

Procedures:
Objective 1: In May 2020, mulches will be established in a randomized complete design with four treatments (metallic polyethylene, white-on-black biodegradable, black biodegradable, and grower standard control) replicated five times in ‘Caroline’ raspberries established in 2019 at the West Madison Agricultural Research Station in Verona, WI. Mulch strips will be laid on both sides of emerging canes, with a 6-inch gap down the center for canes to emerge. Each plot will be 23’ long and mulch will be 4.9’ wide from side to side. When the first flies are detected using Scentry SWD traps with lures (approximately late June), we will begin taking measurements, which will continue to mid-October. Fruit infestation will be assessed weekly using salt floats. Approximately 36 ripe fruits (~100 g) will be randomly collected from each plot. Half of each sample will be combined with salt water and squished to count larvae. The other half of the fruit will be kept in the lab to count adult SWD emergence and calculate the proportion of emerged flies that are SWD. The calculated proportion will be used as a multiplier to determine actual larval infestation in the fruit. The proportion of unmarketable fruit will be assessed by weighing marketable fruit and unmarketable fruit at harvest.
Objective 2: In May 2019, mulches were established in a randomized complete block design, as described for the funded WRRC project “Multi-season plastic mulches for improved weed management and crop growth” (please see the other proposal for additional details). This existing project will be used for this proposed experiment. Black weedmat and polyethylene mulches are

still in treatment plots from 2019, but we will re-apply black biodegradable mulches in existing treatment plots and add the metallic mulch in half of our bare ground control plots. All treatments will be replicated four times for statistical robustness. When the first fly is detected (as described in Objective 1, around mid-June), we will begin taking measurements, which will continue until August. To assess adult populations, clear 6” x 6” sticky cards will be placed in the fruiting zone in every plot. Sticky cards will be replaced every 7 days, and the number of male and female SWD will be recorded. Fruit infestation and proportion of unmarketable fruit will be assessed as described in Objective 1.

Anticipated Benefits and Information Transfer:
We expect that plastic mulches are an effective tool that can positively contribute to SWD management. We anticipate mulches will reduce fly populations and decrease fruit infestation, thereby benefitting raspberry producers by decreasing the amount of unmarketable fruit and insecticide applications. Results from this project will be shared at field days in Washington and Wisconsin, at the Washington Small Fruit Conference (December 2020), and the Wisconsin Fresh Fruit and Vegetable Conference (January 2021). We will publish results on the WSU Small Fruit Horticulture Website, Wisconsin Fruit Website, *Whatcom Ag Monthly*, *Wisconsin Fruit Newsletter*, and in scientific publications.

References:
1) Van Timmeren, S., & Isaacs, R. (2013). Control of spotted wing drosophila, *Drosophila suzukii*, by specific insecticides and by conventional and organic crop protection programs. *Crop Protection, 54*, 126–133.
2) Bruck, D. J., Bolda, M., Tanigoshi, L., Klick, J., Kleiber, J., Defrancesco, J., … Spitler, H. (2011). Laboratory and field comparisons of insecticides to reduce infestation of *Drosophila suzukii* in berry crops. *Pest Management Science, 67*(11), 1375–1385.
3) Leach, H., Moses, J., Hanson, E., Fanning, P., & Isaacs, R. (2018). Rapid harvest schedules and fruit removal as non-chemical approaches for managing spotted wing Drosophila. *Journal of Pest Science*, *91*(1)*,* 219–226.
4) Woltz, J. M., & Lee, J. C. (2017). Pupation behavior and larval and pupal biocontrol of *Drosophila suzukii* in the field. Biological Control, 110(April), 62–69.

Budget	**2020**
Salaries	$0
Timeslip[1/]	$5,760
Operations (goods & services)[2/]	$1,000
Travel[3/]	$2,700
Equipment	$0
Benefits[4/]	$167
Total	$9,627

1/Timeslip in 2020 for field and lab data collection: $12/hr x 30 hr/week x 16 weeks = $5,760
2/Mulches, SWD trapping supplies, sticky cards, posts to hang sticky cards and traps
3/Travel from WI to Mt. Vernon in July 2020 for Hanna McIntosh to oversee protocols: $1,200. Travel from WI to WA Small Fruit Conference 2020, plus lodging, for Hanna to share results from WI and WA with WA growers, and get optimization feedback from growers: $1,500.
4/Benefits: Fringe benefits at 2.9% = $167

Washington Red Raspberry Commission
Termination Report for 2019 Projects

Title: Development of biologically-based RNAi insecticide to control spotted wing Drosophila

Personal: Man-Yeon Choi, USDA-ARS Horticultural Crops Research Laboratory, Corvallis, OR, Phone: 541-738-4026. E-mail: man-yeon.choi@usda.gov
Collaborator: Dr. Seung-Joon Ahn (Research associate), Oregon State University, Corvallis, OR

Accomplishment and Significant Findings (2017-19)
We selected, identified SWD 32 genes, and constructed double-stranded RNAs (dsRNAs) for the RNAi test, then screened 3 housekeeping and 3 receptor genes for potential RNAi targets. From the project, we established a bacterial-based system produced a large quantity of dsRNA for the cost-effective dsRNA production. In addition, a SWD specific nanoinjection system developed in the study can be applied for any fly pests. The RNAi impacts have been evaluated through three options, injection, feeding, and *Drosophila* cells. We found the activity of dsRNases in the SWD mid-gut.

Results:
Injection dsRNA into SWD: Thirty two RNAi candidates were screened through 4,000 nano-injections to 20 flies per treatment with 5 replications. We found effective phenotypic impacts, mainly mortality up to 60%, three SWD genes were selected and investigated their gene expression levels. All three RNAi target genes have been suppressed up to 70% by dsRNA introduction to SWD flies.

Oral administration (=feeding) of dsRNA: Flies fed dsRNA mixed diet or sprayed onto berries. The percentages of mortality in flies fed on the diet were not significantly different between the water control and dsRNA treatment for 7 days. Various dsRNA feeding tests with diet or blueberry also showed similar results on the fly survival rates. The female fecundity has been investigated with vitellogenin receptor dsRNA fed by flies, the egg reduction was not significant compare to the control. The outcome results indicate SWD dsRNA ingested in the flies could be degraded in the midgut or not pass through the midgut membrane (see below).

RNAi with *Drosophila* cells: Because RNAi feeding effect was limited, SWD dsRNA was directly introduced to *Drosophila* cells. Among nine SWD RNAi showed significantly inhibition of cell density. Their effect on cell growth inhibition was dose-dependent, and resulted in 20% reduction of cell viability. The genotypic effects were confirmed by suppression of gene expressions after dsRNA introduction.

Found dsRNA degradation enzymes in the mid-gut: Oral administration (*i.e.* feeding) of dsRNA would be more feasible; however, the target dsRNA must survive in the mid-gut and pass into the hemolymph where it can then act on the target gene. Minimal effect of RNAi by orally delivery could be attributed to extracellular degradation of the dsRNA in the gut lumen. In order to overcome any possible obstacle in the RNAi application to SWD, it is necessary to look into the dsRNA degrading activity in SWD digestive system. Alimentary tract of *Drosophila suzukii* is consisted with fore-gut, mid-gut, and hind-gut. Surprisingly, we found activity of dsRNA degradation in the mid-gut only, not in the other digestive organs. The putative dsRNA degrading activity was compared between mid-gut and crop of the SWD adult using their crude homogenates. The dsRNA has been gradually disappeared when equivalents of SWD mid-gut homogenate were increased and incubated with dsRNA. The result indicates the SWD mid-gut contains the RNaseIII type enzyme which functions to degrade dsRNA.

Conclusion and future study

In this study we selected and screened potential RNAi targets for SWD through nanoinjection into SWD, and confirmed an RNAi effect to inhibit cell growth of *Drosophila* cells. However, oral administration of the SWD dsRNA was limited due to a partial degradation of the dsRNA in the fly mid-gut. In addition, we identified two dsRNA degradation enzymes, RNase III type enzyme, which is specialized to degrade dsRNA in the fly mid-gut. We confirmed the homogenate and juice of the mid-gut degrading dsRNA, then decreasing the RNAi effect to SWD.

Although RNAi technology is a promising tool for insect pest management, there are major challenges: 1) identifying suitable target gene(s); 2) developing suitable RNAi delivery; and 3) providing cost-effective dsRNA production. We have established a bacterial-based system produced a large quantity of dsRNA for the cost-effective dsRNA production (Fig. 9), and developed non-toxic sugar as a phagostimulant to enhance RNAi delivery into SWD. Therefore, more study should be focused on how to protect dsRNA arrived in the mid-gut, and to increase the delivery efficacy for SWD RNAi application.

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. 2019. Sex-biased gene expression in antennae of *Drosophila suzukii*. Arch. Insect Biochem. Physiol. (under review).
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).
4. Choi, M.-Y., H. Lucas, R. Sagili, D. H. Cha, J. C. Lee. 2019. Effect of erythritol on *Drosophila suzukii* in the presence of naturally-occurring sugar sources, and on the survival of *Apis mellifera*. J. Econ. Entomol. 112: 981–985. 2019.
5. Choi, M-Y., R.K. Vander Meer. Phenotypic effects of PBAN RNAi using oral delivery of dsRNA to corn earworm (Lepidoptera: Noctuidae) and tobacco budworm larvae. J. Econ. Entomol. 112: 434–439. 2019.

2020 WASHINGTON RED-RASPBERRY COMMISSION RESEARCH PROPOSAL

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

Title: Delivery of dsRNA with nanoparticles to enhance RNAi effect on SWD

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

Principal Investigator: Man-Yeon Choi, Research Entomologist, USDA-ARS, 3420 NW Orchard Ave. Corvallis, OR 97330; **Email:** man-yeon.choi@usda.gov; **Phone:** 541-738-4026

Cooperator: Postdoctoral associate hired through OSU will join for this project.

Description: The research objective is to formulate dsRNA with nanoparticles to increase RNAi effect for control of SWD. In the previous study, we identified SWD specific RNase III type enzyme (= dsRNase) which functions to degrade dsRNA in the fly mid-gut. The long-term goal of the project is to develop biologically-based insecticides to stop SWD population development in berry fields. The RNAi-based insecticide in this project is going to be applied with non-transgenic applications such as oral administration (= feeding) and/or spray with attractants. Therefore, in order to increase the effect of RNAi, the dsRNA needs to be protected from the enzyme attacking that takes place in the mid-gut. This can be done with nanoparticles which are interfacial lipid layers to facilitate uptake of dsRNA molecules.

Justification and Background:

Spotted wing drosophila (SWD), *Drosophila suzukii*, is an economically damaging pest to a broad range of small fruit crops. The estimated economic impact is US$800 million annually in the U.S. alone, and increasing every year. Currently, most growers are controlling SWD with repeated organophosphate, pyrethroid and spinosyn insecticide application (Lee et al., 2011). Although chemical insecticides are effective, there are many negative impacts to the environment and human health, and also do not represent a sustainable pest management strategy. Therefore, there is a need to develop a pesticide with a biologically-based mode of action to control SWD populations in the field.

RNA interference (RNAi) for insect pest management presents a new direction to pest control (Huvenne et al., 2010). The application of RNAi techniques has progressed rapidly for a variety of insect pests, which is becoming a more promising next generation pesticide that has minimal impact on the environment and human health. Although RNAi technology is a promising tool, there are still technical challenges including suitable RNAi formulation.

Recently, PI team has identified potential RNAi targets for SWD through nano-injection and introduction of dsRNA to *Drosophila* cell lines, and results clearly showed negative impacts. Oral administration (*i.e.*, feeding) of dsRNA would be more feasible; however, the target dsRNA must survive in the mid-gut and pass into the hemolymph where it can then act on the target gene. The minimal RNAi effect observed from SWD adults fed dsRNA could be a result of the enzyme activity breaking down the dsRNA molecules in the fly mid-gut. Once in the mid-gut, dsRNA molecules need be protected and not degraded by dsRNA enzymes to pass through to the hemolymph and be effective. In order to overcome this hurdle, the formulation of dsRNA molecules is critical to increase RNAi efficacy.

Nanoparticles are particles between 1 and 100 nanometers in size with a surrounding interfacial layer. The interfacial layer typically consists of organic molecules coating inorganic nanoparticles. In nanotechnology, a particle is defined as a small object that behaves as a whole unit with respect to its transport and properties. Using this technology, nanoparticles have been used as dsRNA carriers or transfection reagents to deliver dsRNA orally to *Drosophila* species (Whyard et al. 2009; Zhang et al. 2010). In this project we adapt the technology to develop a dsRNA delivery method to enhance the RNAi effect on SWD.

Relationship to WRRC Research Priorities: Management options for control of spotted wing drosophila including, alternate products for control, and new products for SWD control strategy, which are related in WRRC's research priorities #1.

Research Objectives: <u>Our long-term goal</u> is to develop a new pest management strategy with biologically-based application to control SWD. To achieve the goal, the *specific objectives* for this project are the following:

1. Synthesize SWD dsRNA, and formulate the nanoparticles with dsRNA (0.5 yr)
2. Evaluate RNAi impacts on SWD through injection and feeding (0.5 yr)

Procedures:
PI has experience in insect RNAi and SWD, and has published research results in peer-reviewed papers (Ahn et al., 2019; Choi et al., 2012, 2019a,b) that demonstrate the selection of RNAi targets, construct of dsRNA, micro-injection and bioassay in various insects. Those research results have been published for RNAi patents (Vander Meer and Choi, 2015, 2018) to develop an RNAi control method, and are being developed for practical use. Therefore, PI is well-positioned to conduct all experimental procedures, and supervise technical assistants for this project.

1. Construct dsRNA for the target genes

We will use SWD1 gene which has been selected, tested and screened from our previous study. Using routine molecular biology techniques and software, specific primers and/or degenerate primer sets designed with 5'-T7 promoter appended will be applied to amplify partial lengths between 200- 400 nucleotides for the SWD1. SWD1 DNA fragments will serve as the template for dsRNA synthesis using a dsRNA synthesis kit. With PI's molecular biology knowledge and experience this approach is expected to be straightforward without possible pitfalls.

2. Prepare and formulate nanoparticles with dsRNA

The SWD dsRNA will be formulated with three different nanoparticles (Figure 1), cellfection, lipofectamine 2000, or branched amphiphilic peptide capsules (BAPC), in a mixture of buffered sucrose (20 % sucrose, 10 mM Tris, pH 7.5) and 0.05 mM spermidine. For all assays with the mixture with nanopartilces and dsRNA (1:1) will be used. The mixture will be incubated at room temperature for 5 min and then incorporated into the diet.

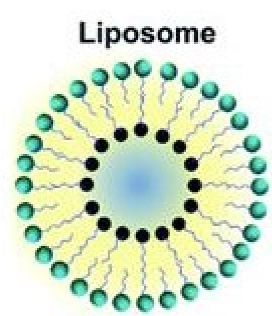

Figure 1. Model of lipid layer nanoparticles encapsulating dsRNA.

3. Evaluate RNAi delivery and impact(s) on SWD

3-1. Injection dsRNA into SWD: Formulated dsRNAs will be injected into SWD flies using a Nanoliter 2010™ injector fitted with custom-pulled borosilicate needles. Adult flies will be mounted on a custom-vacuum system developed specially for SWD. This system is particularly important to inject a nano-liter (50nL = 0.05µL) of solution into small insects such as SWD with minimal or no physical damage. PI lab has a lot of experience with micro-injecting dsRNA into flies. After injection of 20 flies per treatment, phenotypic changes will be monitored.

3-2. Feeding dsRNA to SWD: For adult feeding assays, formulated or untreated dsRNAs will be mixed with bread yeast or a sucrose solution. The diet mixed with the specific dsRNA will be provided to adult flies to feed on in a cage assay. After feeding, flies will be monitored for phenotypic changes and possible mortality for 7 days.

Anticipated Benefits and Information Transfer: At the completion of the research, the most important outcome is to identify SWD RNAi delivery methods, comparing applications of untreated and encapsulated dsRNAs. The research result will provide critical insight into whether the target dsRNA can be protected from the enzyme and penetrate the mid-gut membrane barrier, thus reaching the target cells. Therefore, outcomes are not only expected to address specific questions in SWD RNAi, but also to have fundamental impacts for the application of RNAi to control pest flies.

References:

1. 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
2. Choi, M.-Y., H. Lucas, R. Sagili, D. H. Cha, J. C. Lee. 2019a. Effect of erythritol on *Drosophila suzukii* in the presence of naturally-occurring sugar sources, and on the survival of *Apis mellifera*. J. Econ. Entomol. 112: 981–985.
3. Choi, M.-Y., R.K. Vander Meer, M. Coy, M.E. Scharf. 2012. Phenotypic impacts of PBAN RNA interference in an ant, *Solenopsis invicta*, and a moth, *Helicoverpa zea*. J Insect Physiol 58, 1159-1165.
4. Choi, M-Y., R.K. Vander Meer. 2019b. Phenotypic effects of PBAN RNAi using oral delivery of dsRNA to corn earworm (Lepidoptera: Noctuidae) and tobacco budworm larvae. J. Econ. Entomol. 112: 434–439.
5. Huvenne, H., G. Smagghe. 2010. Mechanisms of dsRNA uptake in insects and potential of RNAi for pest control: a review. J Insect Physiol 56, 227-235.
6. Lee, J.C., D.J. Bruck, A.J. Dreves, C. Ioriatti, H. Vogt, P. Baufeld. 2011. In Focus: Spotted wing drosophila, *Drosophila suzukii*, across perspectives. Pest management science 67, 1349-1351.
7. Vander Meer, R.K., M.-Y. Choi. 2018. *U.S. Patent 10,093,925 B2*. Lepidopteran Moth Control Using Double-Stranded RNA Constructs.
8. Vander Meer, R.K., M.-Y. Choi. 2015. *U.S. Patent 9,000,145 B2*. Control of insect pests through RNAi of Pheromone Biosynthesis Activating Neuropeptide Receptor.
9. Whyard S, A.D. Singh, S. Wong. 2009. Ingested double-stranded RNAs can act as species specific insecticides. Insect Biochem Mol Biol 39:824–832.
10. Zhang X, J. Zhang, K.Y. Zhu. 2010. Chitosan/double-stranded RNA nanoparticle mediated RNA interference to silence chitin synthase genes through larval feeding in the African malaria mosquito (*Anopheles gambiae*). Insect Mol Bio 19:683–693.

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Budget Justification

This project will be submitted to the Oregon Blueberry & Blackberry commissions, Washington Blueberry Commission. The goal is to obtain enough funding to hire a post-doc fellow for this project. USDA-ARS base funds in Dr. Choi's programs will be used to fund additional technical support and supplies for the project.

	2020
Salaries[1/]	$21,200
Time-Slip	$0
Supplies & Services	$10,000
Travel[2/]	$500
Meetings	$0
Other	$0
Equipment[3/]	$0
Benefits[4/]	$8,300
Total	**$40,000**

Budget Justification

[1/]Postdoctoral associate (0.4FTE) - The salary for the full time Postdoctoral Associate is supported by the grant fund.

[2/]Support domestic travel to attend a conference, commission, or grower meetings each year. The objective is to present the results of the proposed research to diverse interested groups.

[4/]Benefit (40%) - Fringe benefits are actual cost (~$1,722 per month).

Total Budget for Project 2020 $40,000

Funding Breakdown

WRRC, WBC, OBC, ORBC ($10,000 each)

Washington Red-raspberry Commission Budget Request $10,000

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:				
Choi	OR Association of Nursery	$18,000	06/01/2019-05/31/2020	5	Identify biological targets including RNAi to develop thrips management for nursery crops
Choi/Martin	OR Seed Council	$20,000	01/01/2018-12/31/2019	10	Screening of target genes to develop an RNAi-based biopesticide to control gray garden slug (*Deroceras reticulatum)*
McDonnell/Denver/Choi/Martin	OR Dep. Agriculture	$174,853	10/01/2018-03/31/2021	10	Development of new biological control strategies for pest slugs
	Pending:				
Choi	WRRC, WBC, OBC, ORBC	$40,000	01/01/2020-12/31/2020	10	Delivery of dsRNA with nanoparticles to enhance RNAi effect on SWD
Lee/Choi	WA Tree Fruit Research	$35,800	01/01/2020-12/31/2020	5	Non-caloric sugar-based control strategy for spotted wing drosophila
Choi	OR Association of Nursery	$20,000	01/01/2020-12/31/2020	5	Development of biologically based thrips management for nursery crops

WEEDS

2020 WASHINGTON RED RASPBERRY COMMISSION
RESEARCH PROPOSAL

New Project Proposal **Proposed Duration:** (2 years)

Project Title: Preventing Wild Buckwheat Seed Production in Raspberries

PI: Steven Seefeldt
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Co-PI: Chris Benedict
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Address 2: Suite 201
City/State/Zip: Bellingham, WA 98225

Cooperators:

Year Initiated 2020 Current Year 2020 Terminating Year 2021

Total Project Request: $18,827 Year 1 $9,132 Year 2 $9,695 Year 3

Other funding sources: None

Description: The study will evaluate herbicides for management of wild buckwheat and determine if a degree day model could be utilized to prevent wild buckwheat seed production in red raspberry crops.

Justification and Background: (400 words maximum)

- Wild buckwheat is problematic in red raspberry production by competing with plants for resources and hindering mechanical harvesting resulting in reduced yields.
- 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) it is expected that there will be a rapid decline in wild buckwheat populations over the course of a control program. 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).

Relationship to WRRC Research Priority(s): This study is a #2 priority

Objectives:

- Determine if wild buckwheat control based on a growing degree day model will eliminate seed production
- Determine if wild buckwheat control measures cause injury to raspberries

Procedures: (400 words maximum)

- Anticipated length of project is 2 years
- Year 1 will be herbicide applications and measures of plant response. Year 2 will be a replication of year 1 treatments and measures.

Two infestations in three raspberry fields will be identified. In one of the areas standard grower practices will be applied by the grower (STD). In the other area wild buckwheat plants will be treated with spot applications of a glyphosate product just before plants begin to produce viable seed (GDD). Timing of applications will be determined using the growing degree day model developed as part of a WSDA Specialty Crop Block Grant. In the both STD and GDD areas, the number of buckwheat plants per linear meter of row and their sizes (height and width) will be measured each time we go to the field to spot treat the GDD area. Red raspberry plants will be inspected for signs of herbicide injury (yellowing of leaves, inhibited growth) when we measure wild buckwheat plants. At this stage of the study we will not be measuring raspberry yields, however, if there are herbicidal symptoms on the crop, then we will follow up with a study on what that means for reductions in raspberry yields. Results from the WSDA study indicate that wild buckwheat can go from first leaf to viable seed in 3 to 4 weeks depending on rainfall and temperature, therefore all areas will be visited once or twice a month. Using a drone after harvest, the sizes of the wild buckwheat patch will be measured using a multi-spectral sensor (MicaSense, Seattle WA).

In the second year these same areas will be treated and measured in the same manner as the first year. This second measure will give an indication of wild buckwheat population increases and decreases as well as patch size increases and decreases as a consequence of the treatments.

Anticipated Benefits and Information Transfer: (100 words maximum)

- This project will improve raspberry yields and it will provide a control method that could remove wild buckwheat seed from the soil in less than 6 years.
- Results will be presented at the annual WA Small Fruit Conference.

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

	2020	**2021**
Salaries[1/]	$4,818	$5,011
Time-Slip	$1,800	$1,800
Operations (goods & services)	$100	$
Travel[2/]	$44	$435
Meetings	$	$
Other	$	$
Equipment[3/]	$	$
Benefits[4/]	$2,370	$2,449
Total	**$9,132**	**$9,695**
Grand total		**$18,827**

Budget Justification

[1/]Specify type of position and FTE. Up to 10% FTE

	2020	2021
Faculty	10 days	10 days
Technician	28 days	28 days
Part time	12 days	12 days

[2/]Provide brief justification for travel requested. Travel is used to pay for mileage as the study is conducted off station in farms in Skagit and Whatcom Counties. Some travel will be used to present research results at the WA Small Fruit Conference.

[3/]Justify equipment funding requests. There are no equipment requests.

[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. Benefits for faculty = 41.32%, technician = 46.31% and for Part time 22.5%.

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 Chad Kruger	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	1/1/2018-12/31/2019	6	Integrating compost and biochar for improved soil health, crop yield, and air quality
Steven Seefeldt Chad Kruger	Western Region IR-4	$10,000	9/1/2018-8/31/2020	6	Environmental Horticulture
	Pending				
Steven Seefeldt Chris Benedict	WA Blueberry Commission	$13,778	1/1/2020-12/31/2022	6	Will Chlorsulfuron Safely Manage Horsetail in Blueberries
Steven Seefeldt Chris Benedict	WA Raspberry Commission	$13,778	1/1/2020-12/31/2022	6	Will Chlorsulfuron Safely Manage Horsetail in Raspberries
Steven Seefeldt Chris Benedict	WA Raspberry Commission	$18,827	1/1/2020-12/31/2021	6	Preventing Wild Buckwheat Seed Production in Raspberries

2020 WASHINGTON RED RASPBERRY COMMISSION
RESEARCH PROPOSAL

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

Project Title: Will Chlorsulfuron Safely Manage Horsetail in Raspberries

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 2020 Current Year 2020 Terminating Year 2022

Total Project Request: $13,778 Year 1 $1,823 Year 2 $9,928 Year 3 $2,027

Other funding sources: None

Description: The objective of this study is to determine if there is a rate of chlorsulfuron that will control horsetail without causing injury to established raspberries. If there is a dose of chlorsulfuron that can control horsetail without harming raspberries, growers should be able to increase raspberry yields through reducing competition for resources and avoid issues with mechanical harvesting.

Justification and Background: (400 words maximum)

- Horsetail is common in many red raspberry fields in Whatcom and Skagit Counties.
- Yield is impacted as horsetail physically pushes back catcher plates resulting in increased dropped fruit.
- This project does not relate to any other projects in British Columbia, Idaho or 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 found chlorsulfuron (both Glean and Telar) having 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 #2 priority

Objectives:

- Evaluate red raspberry tolerance to chlorsulfuron rates that manage horsetail.

Procedures: (400 words maximum)

- Anticipated length of project is 3 years
- Year 1 will be herbicide applications and first measure of plant response. Year 2 will be three more measures of plant response. Year 3 will be a final measure of horsetail control (details below).

This project will require three years because herbicide application will take place in the autumn after raspberry harvest and measurements will take place the following growing season.

In the autumn of 2020 and 2021, six application rates of chlorsulfuron will be applied to both sides of three raspberry plants using a CO_2 backpack sprayer with a shielded 8002 even flat fan nozzle (Spraying System Co, Wheaton, IL). It is important to use the shielded nozzle to minimize drift which will harm the raspberry plants. The rates will be 0.16, 0.08, 0.04, 0.02, 0.01 and 0 oz ai/A. This set of treatments will require 18 plants (6 doses x 3 plants) and the set of treatments needs to be replicated three times for a total of 54 plants per field. Chlorsulfuron is not registered for use in raspberries, so these plants will not be harvestable. In addition, at the higher rates of herbicide, there may be some injury to the raspberry plants. This study needs to be conducted at three farms in northwest WA. If there are positive results the entire study needs to be repeated starting in 2021 to fine tune the herbicide rate and impacts on raspberries.

Plant response to the treatments will be measured two weeks after treatment, in the early spring, in mid-summer, at harvest, and the following spring (Table 1).

Table 1: Plant response to herbicide treatment measurements

Time	Raspberry	Horsetail
2 weeks after treatment	Growing point yellowing	Yellowing of stems
Early spring	Growing point yellowing Reduction in new leaves	Differences in ground cover
Mid-summer	Reduction in new plant growth (measure growth from annual collar) Changes in branching	Differences in ground cover

Just before Harvest	Estimate visually if there are reductions in blueberry numbers, sizes and maturity	Differences in ground cover
Following spring		Differences in ground cover

Anticipated Benefits and Information Transfer: (100 words maximum)

- If successful, this project will improve red raspberry yields.
- Results will be presented at the annual WA Small Fruit Conference.

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

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

	2020	**2021**	**2022**
Salaries[1/]	$1,196	$5,151	$1,382
Time-Slip	$	$1,800	$
Operations (goods & services)	$100	$	$
Travel[2/]	$44	$435	$44
Meetings	$	$	$
Other	$	$	$
Equipment[3/]	$	$	$
Benefits[4/]	$483	$2,542	$601
Total	**$1,823**	**$9,928**	**$2,027**
Grand total			**$13,778**

Budget Justification

[1/]Specify type of position and FTE. All FTE up to 10%

	2020	2021	2022
Faculty	4 days	15 days	4 days
Technician	3 days	15 days	4 days
Part time		15 days	

[2/]Provide brief justification for travel requested. Travel is used to pay for mileage as the study is conducted off station in farms in Skagit and Whatcom Counties. Some travel will be used to present research results at the WA Small Fruit Conference.

[3/]Justify equipment funding requests. There are no equipment requests.

[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. Benefits for faculty = 41.32%, technician = 46.31% and for Part time 22.5%.

Current & Pending Support

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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
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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	1/1/2018-12/31/2019	6	Integrating compost and biochar for improved soil health, crop yield, and air quality
Steven Seefeldt Chad Kruger	Western Region IR-4	$10,000	9/1/2018-8/31/2020	6	Environmental Horticulture
	Pending				
Steven Seefeldt Chris Benedict	WA Blueberry Commission	$13,778	1/1/2020-12/31/2022	6	Will Chlorsulfuron Safely Manage Horsetail in Blueberries
Steven Seefeldt Chris Benedict	WA Raspberry Commission	$13,778	1/1/2020-12/31/2022	6	Will Chlorsulfuron Safely Manage Horsetail in Raspberries
Steven Seefeldt Chris Benedict	WA Raspberry Commission	$18,827	1/1/2020-12/31/2021	6	Preventing Wild Buckwheat Seed Production in Raspberries

PHYSIOLOGY

Washington Red Raspberry Commission
Final Report for 2019

Project No: 1

Title: Impacts of Mycorrhizal Fungal Colonization on Raspberry Plant Growth

Personnel: R. Bunn and L.W. DeVetter

Reporting Period: This report presents preliminary results from 2019. Additional results will be available in 2020. Experimental work is complete, but analysis is on-going.

Accomplishments: Could arbuscular mycorrhizal fungi (AMF) benefit tissue culture 'Meeker' raspberry plants by providing resistance to pest and disease or access to nutrients in organic fertilizers? To answer this question, we conducted two greenhouse experiments in 2019. The first experiment (Exp 1) was conducted from April to September at Western Washington University. Exp 1 was a fully crossed design of AMF and pest/disease treatments (4 AMF treatments x 4 pest/disease treatments x 10 replicates = 160 plants total). AMF treatments included a control and three sources of AMF, rhizosphere soil from: 7-year old raspberry field (fumigated with Telone C-35 22 months prior), wild thimbleberry patch, and a constructed community. Pest and disease treatments included a control, *Phytophthora rubi* (10% by volume), 1000 root lesion nematodes (*Pratylenchus penetrans;*RLN), or both pests at the same application rate. Plants were grown for 24 weeks with a 12 hr day (~200 μmol m^{-2} s^{-1} PAR), mean temperature of 22ºC, and a fertilization rate of 0.17 g N/plant. The second greenhouse experiment (Exp 2) was conducted from June to September at the Washington State University's Mt Vernon Extension Center. Exp 2 was a fully crossed design of bio-inoculants that include AMF and fertilizer source treatments (5 bio-inoculant treatments x 3 fertilizer treatments x 8 replicates = 120 plants). The bio-inoculant treatments included a non-inoculated control, field inoculum used in Exp 1, and three commercially available products [Bio-Organics Endomycorrhizal Inoculant (Bio-Organics LLC, New Hope, PA); MycoApply® Soluble MAXX (Mycorrhizal Applications, Grants Pass, OR), and MYKOS® (Xtreme Gardening, Gilroy, CA)]. Fertilizer treatments included a control, WISErganic (3-2-2; WISErg Corporation, Redmond, WA), and urea. Plants were grown for 16 weeks with a 12 hr day (~175μmol m^{-2} s^{-1} PAR), mean temperature of 16ºC, and fertilizer application rate of 0.34 g N/plant (WISErganic and urea treatments). An additional fertilizer treatment, composted dairy manure, was dropped because its N concentrations were too low to achieve the fertilizer application rate. During the experiments we collected data biweekly on shoot height, node numbers, and relative leaf N concentration with a SPAD-502 chlorophyll meter. At harvest, we collected data on shoot/root biomass and leaf mass area. In Exp 1, RLN densities were measured in roots and soil (+RLN treatments only). On-going data collection includes shoot nutrient concentrations, AMF colonization of roots (3 replicates each have been completed for Exp 1&2), and AMF spore densities in roots and soil (Exp 1 only).

Results: In Exp 1, AMF colonization was high across all plants receiving AMF inoculum, including raspberry field soil, and we found ~90% of root intersections contained AMF structures (hyphae, vesicles and arbuscules). Thus, AMF propagules seem to be readily available in at least one managed raspberry field. However, in Exp 2 the same field inoculum resulted in colonization lower than the commercially available bio-inoculants. This may be due to shorter growing period, lower light, and/or higher nutrient availability in Exp 2 which may have caused overall lower colonization (Table 1). In Exp 2, colonization also differed among bio-inoculants with higher levels in raspberries planted with MYKOS and Bio-Organics than MycoApply. These results should be interpreted with caution as they are based on a subset of the data that will eventually be collected.

Plants receiving mycorrhizal treatments had slightly higher SPAD/N levels in leaves in Exp 1 (Table 2), but not Exp 2. Instead, SPAD/N levels in Exp 2 were greatest among urea-fertilized plants followed by WISErganic and then the control. Biomass and node counts were either unaffected or reduced in plants that received inoculum in both Exp 1 (Table 2) & 2. Pest and disease treatments did not reduce plant biomass in

Exp 1, but incoming data on nutrient content of shoots may provide evidence of a pest/disease effect. Without evidence that plants are stressed by the pest/disease treatments, we have no way to answer our original question; do AMF ameliorate effects of *P.rubi* and RLN on raspberries? Notwithstanding, our data reveal an interaction between AMF, *P.rubi*, and RLN. We observed RLN densities in roots were lower and less variable when *P.rubi* was also present (Figure 1). Fertilizer, but not AMF, treatments affected plant biomass in Exp 2. Plants grown with urea were larger than plants treated with the organic-derived fertilizer source, which were larger than plants receiving the low-fertilizer control.

Conclusions: Our results-to-date suggest that AMF colonization of raspberries can be high but depends on inocula and environmental conditions. Commercially available bio-inoculants can, but don't always, result in colonization. Even when low-level colonization from these products occurs, there may not be an effect on plant access to different forms of N. Furthermore, Exp 1 indicated ample AMF propagules can be available in managed raspberry fields, thus mycorrhizae may already form in raspberry fields even without pre-inoculation. Thus, we do not recommend the bio-inoculants used in this study. When AMF colonization is high and N is limiting, as in Exp 1, plants may benefit from increased N uptake compared to un-inoculated plants. However, managed fields are rarely limited by N, and therefore this benefit may not be important to growers. Our current data set does not provide information about whether mycorrhizae can ameliorate the effects of *P.rubi* or RLN. Nevertheless, based on the high degree of AMF colonization observed in Exp 1 and the ability of AMF to reduce pest/disease effects in other crops, we feel this question is worthy of further investigation. In our next step, we will be repeating a subset of Exp 1 (*P.rubi* and known AMF community) with the cool and wet environmental conditions known to promote root rot disease in plants.

Given these preliminary data, bio-inoculants from this study are not recommended because their effectiveness is variable. Furthermore, AMF colonization of 'Meeker' raspberry plants from propagules in raspberry fields can be very high, even within two years of fumigation. Thus, field soils may be a good source of inoculum if pre-inoculation of raspberry plugs proves useful. Finally, whether raspberry plants in managed fields benefit from AMF colonization remains unclear.

Publications/Outputs:

- Presentations at the Small Fruit Conference in Lynden, WA.
    - Whitney and Bunn. 2019. Mycorrhizal fungal colonization of red raspberry, and influence on root-rot and root-lesion nematodes
    - Qianwen and DeVetter. 2019. Do commercial mycorrhizae inoculants improve raspberry growth?
    - Presentations will be available at WSU Small Fruit Horticulture: https://smallfruits.wsu.edu
- Two publications in preparation for *Plant and Soil* and *HortTechnology*.
- Results will also be chapters in the theses of Erika Whitney and Qianwen Lu.

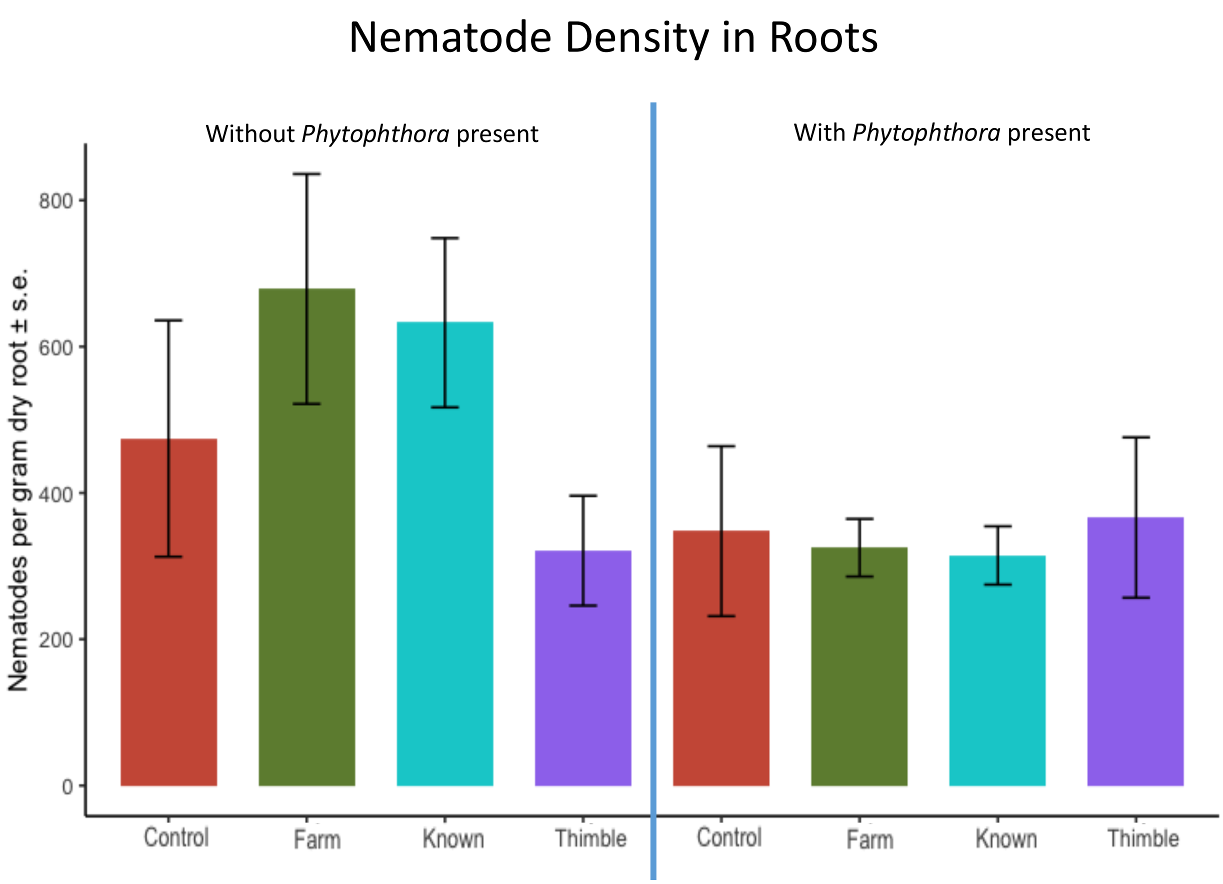
Table 1. Arbuscular mycorrhizal fungal (AMF) colonization of 'Meeker' raspberry roots grown with different bio-inoculant and fertilizer treatments in Experiment 2. Vesicles and AMF-like hyphae were observed, but not arbuscules. Means ± standard errors from 3 replicates are presented and different letters indicate significantly different means within each fertilizer treatment ($p < 0.05$). No fungal structures were found in the non-inoculated controls (data not presented).

Bio-inoculants	AMF colonization rate (%) with WISErganic	AMF colonization rate (%) with urea
Bio-Organics	17 ± 3 a	32 ± 4 a
MycoApply®	10 ± 1 b	4 ± 1 b
MYKOS®	22 ± 2 a	26 ± 2 a
Raspberry field community	2 ± 1 c	0 ± 0 c

Table 2. Shoot biomass, node counts, and SPAD-chlorophyll measures from 'Meeker' raspberry grown with different arbuscular mycorrhizal fungal incoula in Experiment 1. Data displayed are means ± standard errors from 40 replicates. Different letters indicate significantly different means ($p < 0.05$).

Mycorrhizal Treatment	Shoot mass (g/plant)	Node counts	SPAD-Chlorophyll
Control	11.75 ± 0.54 a	41.7 ± 0.8 a	31.3 ± 0.3 b
Raspberry Field Soil	11.30 ± 0.57 ab	40.5 ± 0.8 ab	32.7 ± 0.4 a
Constructed Community	11.37 ± 0.56 a	40.5 ± 0.7 a	32.7 ± 0.3 a
Thimbleberry Soil	10.03 ± 0.43 b	37.7 ± 0.6 b	33.4 ± 0.3 a

Figure 1. Density of nematodes in roots receiving root lesion nematode treatments in Experiment 1 either along with or without *Phytophthora rubi* treatment. Error bars represent ± standard errors from the mean of 10 replicates. Different letters indicate significantly different means ($p < 0.05$).



Attached please find our report for Project 1: Impacts of Mycorrhizal Fungal Colonization on Raspberry Plant Growth, which was funded by the WRRC in 2019. As you will note when you read the report, we completed two greenhouse studies in 2019. We present our results and conclusions to date, but we are still collecting data and doing our analyses, so please bear that in mind as you review the report. Because these projects are both parts of graduate student theses, we will have more complete summaries in the form of thesis chapters which could be shared with WRRC in 2020. We will also be working to publish the results of these studies. When those manuscripts are available, we can share them as well.

Please let me know if you have any questions or concerns.

We appreciate WRRC's support, which has provided this exciting opportunity to begin studying raspberries and mycorrhizal fungi.

Best wishes,
Rebecca

Washington Red Raspberry Commission – Terminal Report

Project number: 3455-6640

Title: Comparison of Alternate- and Every-Year Production in Summer-Bearing Red Raspberry

Personnel: Lisa Wasko DeVetter (PI), Suzette Galinato, and Chris Benedict. Jonathan Maberry is a farmer collaborator/cooperator for both experiments.

Reporting Period: 2015-2019

Accomplishments:

- Alternate-year (AY) and every-year (EY) treatments were maintained in Mr. Jon Maberry's field in Lynden, WA.
- Modified bed experiment was established in Mr. Jon Maberry's field in Lynden, WA, in 2018.
- All data collection occurred as planned, although we are collecting additional cultivar data from 'Meeker' and 'WakeField' in addition to 'Whatcom' and 'WakeHaven' for the modified bed experiment.
- A focus group and survey data led to the creation and publication of a red raspberry enterprise budget (listed in publications).
- Economic data for the AY-experiment were collected and analyzed.
- Results from the AY-experiment were presented at the 2019 Small Fruit Conference and Michigan Great Lake's Expo.
- A newsletter article summarizing the AY-experiment was to be published in July 2019, but that has been postponed to 2020 given the *Whatcom Ag Monthly* was not active in 2019 due to co-PI Benedict's sabbatical leave.

Results:

1) AY/EY Experiment: Project data were collected according to plan. Figure 1 shows treatment effects on yield and primocane growth. Overall, yield was lower in the AY treatment during non-fruiting years, which was expected given treatment rows were managed to produce a crop every-other year. No statistical effects were found for primocane height, node number, and internode length. However, primocane height tended to be lower in AY-treated plots in 2017 and 2019.

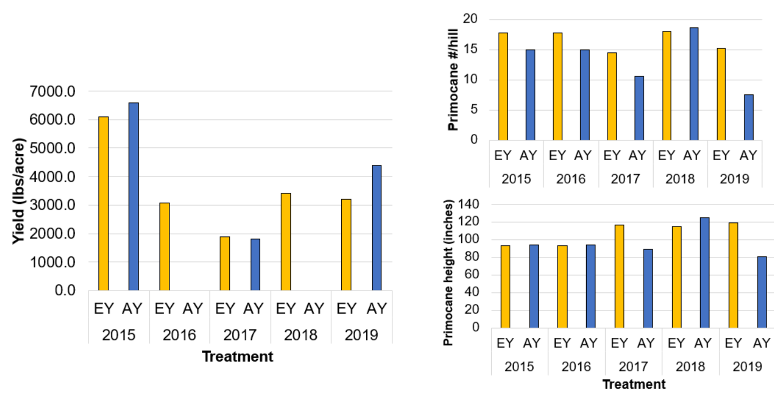


Figure 1. Yield, primocane number/hill, and primocane height of 'Meeker' red raspberry grown in alternate-year (AY) and every-year (EY; control) production systems, 2015-2019.

Primocane number per hill was also lower in AY-treated plots in 2017 and 2019. Tissue nutrient analyses for some micronutrients different in some but not all years and there were no consistent patterns nor trends (data not presented). Economic analyses revealed AY production is not economically viable based on the assumptions of our model with production practices, crop yield, price received [$0.76/lb (average of IQF and blend)], and total production costs provided by our trial, grower cooperator, and Henry Bierlink. Even though AY systems had lower operating costs (48% of costs in the EY system was labor, while it was only 42% of the costs in AY), the loss in yield was too great to offset these savings. Based on our analyses, the price of raspberries must be $0.73/lb in the EY system in order to recover the total cost of production and $0.87/lb in the AY system. Our sensitivity analysis showed that varying price while holding all else the same, AY profit = EY profit when the price of raspberries in AY is ~$0.91/lb. Therefore, market price has to be higher and/or yields increased to make AY more profitable than the grower standard of EY. Higher planting densities and different training and primocane suppression techniques could promote higher yields, but remain untested. One important consideration that we are now modeling is extended planting longevity– if the AY planting were to have a longer lifespan than EY and be slower to get raspberry bush dwarf virus, resulting in a higher proportion of fruit that goes to the individually quick frozen market, this may make AY more economically viable. We are currently working on additional analysis with scenarios that take into account greater longevity of AY versus EY.

2) Modified Bed Experiment. Data were collected according to plan and this was the first year yield could be collected from the planting. Yield, primocane height, and primocane number per hill are presented below in Figure 2. Overall, yield showed a response due to cultivar and tended to be greater among plants grown with 10-ft centers (3-ft raised beds; control) versus 12-ft centers (6-ft raised beds). Primocane height and number did not differ by bed size, but height tended to be greater among plants grown on 12-ft centers. However, acquired UAV data that quantified total plant biomass found no statistical effects due to our treatments. While we are not submitting a continuation proposal for this project in 2020, we will continue to monitor this trial in case treatment effects become more visible in the second harvest year. If there are treatment effects in the second harvest year, we may submit another proposal for more in-depth study.

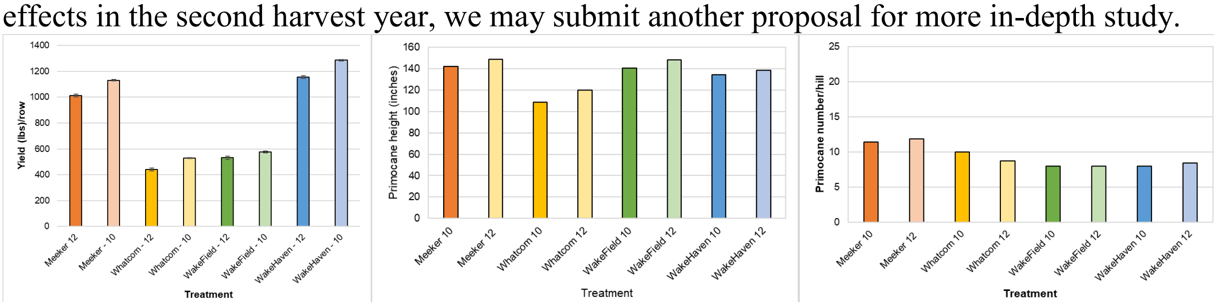


Figure 2. Yield, primocane height, and primocane number per hill of 'Meeker', 'Whatcom', 'Wake^{TM}Field', and 'Wake^{TM}Haven' red raspberry grown on 10- and 12-ft centers (3- and 6-ft wide raised beds, respectively) in Whatcom County, WA, 2019. Data were collected from 10 plants per row. Only means are presented, as the design in the field did not permit statistical analysis.

Publications:

- Galinato, S. and L.W. DeVetter. 2016. 2015 Cost Estimates of Establishing and Producing Red Raspberries in Washington State. Washington State University Extension Bulletin. TB21. Available at: http://pubs.cahnrs.wsu.edu/publications/pubs/tb21/.
- Website (project website to be updated in 2020): https://smallfruits.wsu.edu/projects-and-activities/comparison-of-alternate-and-every-year-production-in-summer-bearing-red-raspberry/
- A publication summarizing the AY study is to be submitted by Galinato and DeVetter in 2020

Washington Red Raspberry Commission – **Terminal Report**

Project No: 3455-3223

Title: Application of Polyethylene Mulch in Summer-Planted Tissue Culture Red Raspberry: Impacts on Weed Control, Parasitic Nematodes, and Crop Growth and Yield

Personnel: L.W. DeVetter, H. Zhang, C. Miles, and I. Zasada.

Reporting Period: This is a terminal report of 2019 proposal.

Accomplishments:

The overall goal of this project is to develop knowledge and practical strategies to manage weeds while promoting tissue culture raspberry establishment, plant growth, and fruit yield through application of plastic mulches. In addition, a secondary goal of this project is to better understand population dynamics of root lesion nematode (*Pratylenchus penetrans*; RLN) in summer-planted raspberry when established with polyethylene (PE) mulch in comparison to bare ground (BG).

Our main accomplishments for 2019 include: 1) Collecting all data as planned [except RLN samples in spring 2019; this was an intentional group decision made based on recommendations from co-PI Zasada (a nematologist); fall sampling is considered more indicative of population densities]; 2) Extension of project information at international, national, regional, state, and local levels; and 3) Submission of a scientific journal article in fall 2019 (article submitted to *HortScience*; currently the paper is in review and can be made available to growers upon request). An economic assessment including a cost-benefit analysis of using plastic mulches in both spring- and summer-planted red raspberry is in preparation. This economic assessment will be made available to growers when complete.

This project is one of few studies exploring the use of plastic mulches in perennial fruit crop production and the first study exploring the use of plastic mulches in a summer-planted floricane raspberry production system. There has been a rapid adoption of plastic mulches in red raspberry fields in Whatcom County, which is also an accomplishment if growers are gaining the benefits observed in our current and previous studies.

Results:

- PE mulch remained in the field for 20 months after planting and was removed by the grower cooperator in March 2019.
- Soil temperature and moisture were not recorded after PE mulch removal because both the PE and bare ground (BG) control plots were in the same condition (i.e., unmulched). When PE mulch was present (from Aug. 2017-March 2019), soil temperature under PE mulch was ~2.5 °F higher than the BG control.
- Primocane height measured in Sept. 2018 was 8 inches greater in PE mulched plots relative to the BG control. This difference was statistically significant.
- Despite differences in primocane height, no yield differences were observed between the PE and BG control plots in 2019 (first harvest for this trial; yield was collected from 15 harvests; *P-value* = 0.37).

- Plants grown with PE mulch were observed to break bud earlier than the BG control, which may have made them more sensitive to cold injury in February 2019. However, dissections revealed no visible differences in bud and vascular tissue injury in 2019.
- PE mulch might delay the harvest season by several days compared to the BG control. This effect may be due to winter injury, as black PE mulches usually advance (not delay) harvest.
- Fruit from plants grown with PE mulch had a higher SSC than the BG control during the mid-season sampling point (July 16) (P-value = 0.03). SSC values were the same as the BG control at all other sampling points.
- Average berry size, pH, and total titratable acidity were not affected by mulch treatments.
- Although the grower cooperator hand-weeded BG control plots in Dec. 2017 and May 2018 and applied herbicides in May 2018, weed populations (measured as weed number and dry shoot biomass) were significantly reduced in the PE mulch plots relative to the BG control in 2017 and 2018. After PE mulch removal in Mar. 2019, weed populations between the two treatments were similar, indicating PE mulch provided good weed control.
- Despite on-farm primocane burning practices that occurred twice in the BG control plots (Apr. and May 2019), primocane emergence measured in July 2019 was significantly lower in the PE mulch treatment (61 primocanes/30 ft) than the BG control (107 primocanes/30 ft). However, primocane height and number were the same between both treatments when measured again in Sept. 2019 (P-value = 0.80 and 0.52 for primocane height and number, respectively).
- RLN densities were very low in this field, which is a reflection of the efficacy of bed fumigation. Monthly samples of soil and roots were collected from a different field mulched with PE in late summer 2018. We collected samples from this field as a back-up in case population densities were low in the other trial. This second field site had a history of very high RLN population densities. However, we retrieved few RLN from this site, as well. This second site was also bed fumigated and we attribute the lack of RLN in our studies due to the efficacy of bed fumigation, not necessarily due to mulching.

Publications/Outputs:

***Scientific Journal*:**

- Zhang, H., C. Miles, S. Ghimire, C. Benedict, I. Zasada, H. Liu, and L.W. DeVetter. 2019. Plastic mulches improved plant growth and suppressed weeds in floricane raspberry established in late summer. HortScience. *Submitted in review.*

Presentations:

- Zhang, H (presenter), S. Ghimire, L.W. DeVetter, and C. Miles. 2019. Plastic mulches: Is it worth it? Washington Small Fruit Conference. Lynden, WA.
- Zhang, H (presenter), S. Ghimire, L.W. DeVetter, and C. Miles. 2019. Biodegradable plastic mulches are effective and sustainable. 2019 Lower Mainland Horticulture Improvement Association. Abbotsford, British Columbia, Canada. Invited
- Zhang, H. (presenter), L.W. DeVetter, C. Miles, S. Ghimire, C. Benedict, and I. Zasada. 2019. Plastic mulches promote weed management and plant growth for floricane raspberry planted in late summer in northwest Washington. Poster presentation. American Society for Horticultural Science Annual Conference. Las Vegas, NV.
- Zhang, H. (presenter), L.W. DeVetter, C. Miles, S. Ghimire, C. Benedict, and I. Zasada. 2019. Plastic mulches increased yields and suppressed weeds in floricane raspberry.

United State Department of Agriculture Agricultural Research Service Nematological Laboratory, Corvallis, OR.

- Zhang, H. (presenter), L.W. DeVetter, C. Miles, S. Ghimire, C. Benedict, and I. Zasada. 2019. Plastic mulches increased yields and suppressed weeds in floricane raspberry. Oregon State University Caneberry Field Day. Aurora, OR.
- DeVetter, L.W. (presenter), H. Zhang, C. Miles, S. Ghimire, C. Benedict, and I. Zasada. 2019. Application of biodegradable plastic mulches in red raspberry. 2019 Washington Berry Workshop. Mount Vernon, WA.
- Zhang, H. (presenter), L.W. DeVetter, C. Miles, S. Ghimire, C. Benedict, and I. Zasada. 2019. Application of biodegradable plastic mulches on tissue culture red raspberry. WSU President Visit at WSU NWREC. Mount Vernon, WA.

Washington Red Raspberry Commission – Progress Report

Project Number: 3455-3222 **Proposed Duration:** 2 years

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

Personnel: Lisa Wasko DeVetter (PI), Huan Zhang, Carol Miles, and Chris Benedict

Reporting Period: 2019

Accomplishments:

- The experiment was established and project data were collected according to plan.

Results:

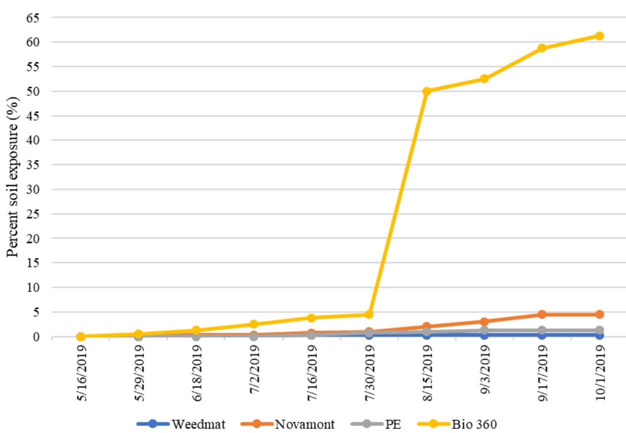


Figure 1. Percent soil exposure of biodegradable and non-degradable plastic mulches in a permanent 1 ft^2 area per plot. Weedmat is a woven polyethylene (PE) and is non-degradable along with PE. Novamont is an experimental multi-season biodegradable film and Bio360 is marketed as a biodegradable film. Data are from 2019.

- Complete soil moisture and temperature data for 2019 are pending, but mulched plots on average were warmer than non-mulched plots and retained more soil moisture. Data can be provided upon request in Jan. 2020.
- Percent soil exposure (PSE) estimated surface degradation and demonstrated our biodegradable plastic mulch treatment (Bio360 at 0.6 mil) started to increase in surface degradation between July 30 and Aug. 15, 2019 (Fig. 1). PSE for all remaining mulch treatments ranged from 0-4.5% in 2019, indicating the experimental multi-season BDM provided by Novamont performs more similarly to PE than Bio360.
- Both weed number and shoot biomass were reduced in mulched plots compared to the non-mulched control. Key weed genera observed in this study include pigweed (*Amaranthus* spp.) and buckwheat (*Polygonum* spp.). Horsetail (*Equisetum* spp.) was also observed. Horsetail was observed puncturing the biodegradable and standard PE films, demonstrating our mulch treatments do not suppress horsetail. However, incidence of horsetail was lower in the "weedmat" plot and this will continue to be monitored.
- Primocane height was tallest across mulched plots, averaging 86 inches in Sept. 2019. Primocanes from the bare ground control were shorter, averaging 68 inches in Sept. 2019.
- Primocane number showed a similar trend as height and averaged 8 primocanes per hill across mulched plots, while plants grown without mulch averaged 4 primocanes per hill in Sept. 2019. Increased weed pressure and lower soil moisture and temperature likely contributed to reduced primocane growth in non-mulched plots compared to our mulched plots.
- No signs of vole activity have been observed.

Publications - None to date

2020 WASHINGTON RED RASPBERRY COMMISSION
RESEARCH PROPOSAL

Project Number: 3455-3222 **Proposed Duration:** 2 years

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

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Co – PIs:
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- 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

Cooperators: None at this point, but we will identify one if funded and have several in mind.

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

Total Project Request: $24,178 **Year 1**: $12,625 **Year 2**: $14,563

Other funding sources: No
Agency: NA
Amount Requested: NA
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. Also, the field where this planting is established is where we propose doing our collaborative work with Christelle Guédot from the University of Wisconsin-Madison (please see separate application submitted in 2020).

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 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 43% 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 will explore the application of thicker, non-degradable 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 red raspberry. Research conducted by this team and funded partially by the WRRC 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). The weed control provided by mulching reduced the need to apply post-plant herbicides and perform hand-weeding during the planting year, which saves costs and reduces labor needs for weed management. Furthermore, the increase in plant growth was manifested into a 43% 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 the benefits we observed 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 spring-planted floricane raspberry planted as TC transplants. However, multi-year mulches 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 to discern their viability in northwestern Washington.

This project builds upon our 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 establishment of raspberry planted as TC transplants, weed management, and plant productivity over two years. We will also evaluate incidence of vole activity. 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) and weed management (#2 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 to 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; and 5) Evaluate fruit yield and quality of raspberry.

We will assess weed incidence, mulch surface degradation, plant growth, and vole incidence in 2019 and 2020. Yield and fruit quality will be evaluated in 2020, when the planting produces its first crop.

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) PE mulch (single-season; positive control); and 4) bare ground (herbicide plus hand weeding using standard grower practices; negative control).

The following was completed in 2019 and will be repeated in 2020.

1. May 2019/2020 - Install soil temperature and moisture probes, record temperature and moisture conditions every 15 minutes from May to Dec. 2019. Repeat in 2020.
2. May to Dec. 2019/2020 - 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. 2019/2020 - 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 will be repeated in 2020.
4. May to Oct. 2019 - Measure primocane number and height from 10 randomly selected representative plants per plot. This was done once every two months in 2019 and will only be done once in Sept. 2020 to estimate primocane emergence and vigor.
5. Sept. 2020 - Estimate plant biomass using an unmanned aerial vehicle (UAV).
6. 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. Repeat in 2020.
7. July 2020 - Machine harvestable yield, average berry size, fruit total soluble solids, and pH will be measured in 2020.

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 lower disposal costs. Additionally, we anticipate benefits from multi-year mulches will last longer than single-season mulches. Project information will be presented at field days and the Washington Small Fruit Conference in 2020.

Additionally, we will post project results on the WSU Small Fruit Horticulture website (http://smallfruits.wsu.edu/articles-and-publications-on-bdms-in-raspberry/). Results will also be shared through the *Whatcom Ag Monthly* and scientific publications.

References:

1. 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.
2. 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.
3. 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.
4. 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. *In review*.

Budget:

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

1/ Scientific assistant (Sean Watkinson) at 1 month, 100% FTE (salary at $ 4,112/month) and Research Associate (Ed Scheenstra) at 1 month, 80% FTE (salary at $4,180) in 2020.
2/Timeslip in 2020 for field (i.e., harvest) and lab data collection: $13.50/hr x 20 hr/week x 6 weeks = $1,620.
3/Consumables (field work supplies) at $450; land-use fees at WSU NWREC at $585; field work equipment/rental at $1,200.
4/No travel requested.
5/Benefits for Watkinson at 44.3% and Scheenstra at 38.2%; benefits for timeslip at 9.4%.

*Approved by Jean Canonica on Nov. 27, 2019

PATHOLOGY
VIROLOGY

Management of Fungicide Resistant Botrytis in Red Raspberry

Alan Schreiber, Tom Walters, Steve Song, Tobin Peever

Background. Resistance has been documented to four of five active ingredients historically used for control of botrytis. Based on Dr. Peever's work, it is clear that there is widespread resistance to active ingredients in Elevate, Pristine, iprodione and Switch and the level of resistance appears to have increased in the short time after he has started monitoring resistance throughout western Washington. This project screened currently used products, other products that are registered but not commonly used, and products not registered for raspberry for control of botrytis. 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. This project includes a standard efficacy trial look at efficacy of single products, and a program trial look at the effect of combination/rotation of multiple products at different timings.

Materials and Methods (shared by efficacy and program trials)

The staff at the Agriculture Development Group, Inc. started a research trial near Everson, WA in May 2019 to evaluate the effect of 28 selected treatments (efficacy trial), and in a separate trial, 18 selected programs (program trial) for the control of raspberry gray mold disease caused by *Botrytis cinerea*. The experimental design for this trial was a Randomized Complete Block with 4 replications and plot sizes of 10 ft x 25 ft. Applications for this trial were made with an over the row sprayer (Photo 1) calibrated to apply treatment sprays at 84 gallons per acre to cover both sides of raspberry canes. No maintenance fungicides were sprayed during this study to prevent the possibility of interfering with the existing trial's objectives.

Six applications were made for efficacy trial on May-26, Jun-4, Jun-14, Jun-24, Jul-6, and Jul-19, as well as for program trial on May-26, Jun-4, Jun-17, Jun-24, Jul-8, and Jul-18. The phytotoxicity of each treatment was evaluated at each application after the first application, and at 7 and 14 days after the final application. We observed no phytotoxicity from any treatments during the study.

The gray mold disease caused by *Botrytis cinerea* was evaluated in field by counting the number of infected fruits in 90 seconds on July 18. The level of this disease was relatively low due to unusually dry and warm conditions during the research season, combined with the relatively sparse canopy of the older 'Meeker' plants in the study. As a result, to better assess the treatment effect, 30 raspberries from each plot were harvested on July 18 from the efficacy trial and on July 23 from the program trial. The collected fruits were then transferred to food service containers and stored for transport in coolers with cold packs. The following day, samples were transferred to moistened paper towels on 1/2" hardware cloth and were incubated in opaque sealed plastic containers at 60-65 F (Photo 2). The number of gray mold disease infected berries was counted on July 19, 20, 22, and 24 for efficacy trial and on July 26, 27, 29, and 31 for program trial, respectively represented infection incidence at 2, 3, 5, and 7 days after incubation (DAI) for both trials.

Late in the trial, the disease, yellow rust of raspberry (*Phragmidium rubi-idaei*), showed up in the trial (Photo 3). The disease was then evaluated on July-25, as percent of rust on each leaf. Twenty leaves were evaluated for each plot. Then disease incidence was calculated by using the number of diseased leaves divided by 20; the disease severity was calculated by the sum of the percent of rust for all 20 leaves divided by the number of diseased leaves.

Results and Discussion

1. *Efficacy Trial*

Although in-field rating on the botrytis infection showed no significant differences among treatments and untreated check, treatments such as Captan, Elevate, Fontelis, Kenja, and Propulse showed some potential of direct suppression of botrytis infestation with 30% to 60% relative lower count than untreated.

Incubation of the fruits showed rapid infestation of botrytis, with infection incidence reached >30% for all treatments by 2 DAI (Table 1). There was a significant treatment effect by 3 DAI (Table 1; Figure 1), while most treatments resulted in similar infestation incidence as untreated (77%), Fontelis at 20 fl oz/a, Kenja at both rates (15.5 and 13.5 fl oz/a), Propulse at 13.6 fl oz/a, and Miravis at highest rate 150 g ai/ha significantly controlled the incidence between 53 to 66%. All treatment lost their residual control effect by 5 DAI with >98% infection incidence.

Area under the disease progress curve (AUDPC) (Table 1; Figure 2) is a measurement of disease intensity over time. It is used in plant pathology to indicate and compare levels of resistance to diseases among varieties or treatments. It represents cumulative incidence data, and showed similar trend. Fontelis and highest rate of Miravis had the lowest overall infection incidence AUDPC of 409 and 429, resulted in 14% and 10% significant reduction compared to untreated. Followed by both rates of Kenja and Propulse at AUDPC of 443, 439, and 434 which were relatively 7% to 9% less than untreated.

For yellow rust, most treatments generally showed lower % incidence and severity than the Untreated Check (Table 1; Figure 3 and 4). However, only Luna Tranquility, Oxidate, Proline, OSO (lower rate at 6.5 fl oz/a), Fontelis, Propulse, and lower rates of Miravis at 75 and 100 g ai/ha resulted in significantly lower incidence than untreated check, with 46 to 92% relative reduction. Further, only Omega, Meteor, Proline, and OSO low rate at 6.5 fl oz/a, Fontelis, Kenja both rates, GWN-10474 at 21 and 35 oz/a, Propulse, and all 3 rates of Miravis significantly reduce severity, with relative 53 to 100% control compared to untreated. Conclusively, Proline, Fontelis, and Propulse showed consistent and excellent control of rust, with >75% incidence reduction and >88% control on severity, compared to untreated.

In summary, our data suggested the treatments with the best botrytis control efficacy are Fontelis at 20 fl oz/a, Kenja at both rates (15.5 and 13.5 fl oz/a), Propulse at 13.6 fl oz/a, and Miravis at highest rate 150 g ai/ha, where Proline, Fontelis, and Propulse showed the best rust control. It appears that Fontelis and Propulse was the only 2 treatments had a universal control effect on both botrytis and rust.

Table 1. ANOVA mean separation table for comparison of 28 treatments for control of rust, or gray mold on raspberry at 2, 3, 5, and 7 days after incubation.

Pest Name					Botrytis	Botrytis	Botrytis	Botrytis	Botrytis	Botrytis	Rust	Rust
Rating Type					incidence	incidence	incidence	incidence	AUDPC	count/plot	incidence	severity
Rating Unit					2 day %	3 day %	5 day %	7 day %		# infected fruits in 90 sec	%	%
Rate Date					July-19-2019	July-20-2019	July-22-2019	July-24-2019		July-18-2019	July-25-2019	July-25-2019
Trt No.	Treatment Name	Rate	Rate Unit	Appl Code	1*	2*	3*	8*	5*	6*	7*	8*
1	Untreated Check				43a	77a-d	99a	99a	476a-e	10a	76abc	17ab
2	PhD	6.2	oz/a	ABCDEF	39a	78a-d	99a	99a	471a-e	14a	50a-i	14abc
3	Omega	1.25	pt/a	ABCDEF	32a	71a-e	93a	98a	439c-f	13a	51a-i	4e-i
4	Luna Tranquility	18	fl oz/a	ABCDEF	38a	64de	98a	98a	445b-f	9a	31f-k	10b-g
5	Scala	18	fl oz/a	ABCDEF	48a	68b-e	97a	100a	466a-f	9a	80a	19a
6	Switch	14	oz/a	ABCDEF	44a	80a-d	99a	100a	485a-e	9a	66a-e	12a-e
7	Captan	2	lb/a	ABCDEF	39a	70a-e	98a	100a	459b-f	7a	71a-d	11a-f
8	Elevate	1.5	lb/a	ABCDEF	49a	80a-d	99a	100a	490a-d	6a	48a-i	11a-f
9	Pristine	23	oz/a	ABCDEF	46a	79a-d	97a	99a	479a-e	10a	71a-d	10b-g
10	Meteor	2	pt/a	ABCDEF	53a	79a-d	99a	99a	496abc	11a	46a-i	5e-i
11	Oxidate	32	fl oz/100 gal	ABCDEF	60a	88ab	100a	100a	521a	11a	41d-j	9b-h
12	Proline	5.7	fl oz/a	ABCDEF	39a	70a-e	98a	100a	457b-f	10a	8jk	2ghi
13	OSO	6.5	fl oz/a	ABCDEF	42a	89a	99a	99a	494abc	10a	24g-k	4e-i
14	OSO	13	fl oz/a	ABCDEF	37a	80a-d	98a	100a	470a-e	14a	65a-f	9b-g
15	Fontelis	20	fl oz/a	ABCDEF	28a	53e	96a	98a	409f	7a	19ijk	0i
16	Kenja	15.5	fl oz/a	ABCDEF	36a	66de	97a	98a	443b-f	6a	45b-i	7c-i
17	Kenja	13.5	fl oz/a	ABCDEF	37a	64de	94a	99a	439c-f	8a	71a-d	8c-i
18	Miravas Duo	13.7	fl oz/a	ABCDEF	32a	68cde	95a	97a	436def	10a	49a-i	11a-f
	NIS	6	fl oz/100 gal	ABCDEF								
19	Experimental	21	oz/a	ABCDEF	46a	79a-d	99a	99a	485a-e	8a	54a-h	6c-i
	NIS	6	fl oz/100 gal	ABCDEF								
20	Experimental	28	oz/a	ABCDEF	47a	87abc	99a	99a	498ab	10a	70a-e	10b-g
	NIS	6	fl oz/100 gal	ABCDEF								
21	Experimental	35	oz/a	ABCDEF	45a	81a-d	99a	99a	486a-e	9a	55a-g	8c-i
	NIS	6	fl oz/100 gal	ABCDEF								
22	Experimental	42	oz/a	ABCDEF	56a	89a	100a	100a	518a	17a	58a-g	13a-d
	NIS	6	fl oz/100 gal	ABCDEF								
23	Ecoswing	2	pt/a	ABCDEF	46a	78a-d	100a	100a	486a-e	11a	61a-f	9b-h
24	Serenade Optimum	20	oz/a	ABCDEF	43a	81a-d	96a	97a	473a-e	13a	78ab	9b-i
25	Propulse	13.6	fl oz/a	ABCDEF	30a	63de	98a	100a	434def	4a	6k	1hi
26	Miravis	75	g ai/ha	ABCDEF	38a	74a-d	99a	99a	466a-f	11a	20h-k	3f-i
	SB-56	6	fl oz/100 gal	ABCDEF								
27	Miravis	100	g ai/ha	ABCDEF	40a	76a-d	97a	100a	467a-e	11a	36e-k	5d-i
	SB-56	6	fl oz/100 gal	ABCDEF								
28	Miravis	150	g ai/ha	ABCDEF	32a	63de	94a	99a	429ef	9a	43c-i	6c-i
	SB-56	6	fl oz/100 gal	ABCDEF								
LSD P=.05					18.3	20.0	4.8	2.6	57.6	7.1	34.4	8.4
Standard Deviation					13.0	14.2	3.4	1.8	41.0	5.0	24.5	6.0
CV					31.36	19.02	3.51	1.85	8.74	52.01	49.18	72.13
Replicate F					4.023	1.279	1.409	0.659	3.003	11.334	0.090	1.052
Replicate Prob(F)					0.0101	0.2872	0.2460	0.5799	0.0352	0.0001	0.9653	0.3742
Treatment F					1.417	1.634	1.234	1.139	1.753	1.155	2.926	2.240
Treatment Prob(F)					0.1176	0.0478	0.2331	0.3193	0.0283	0.3034	0.0001	0.0029

Figure 1. Comparison of 28 treatments for control of botrytis blight in raspberry-incidence after 3 days' of incubation.

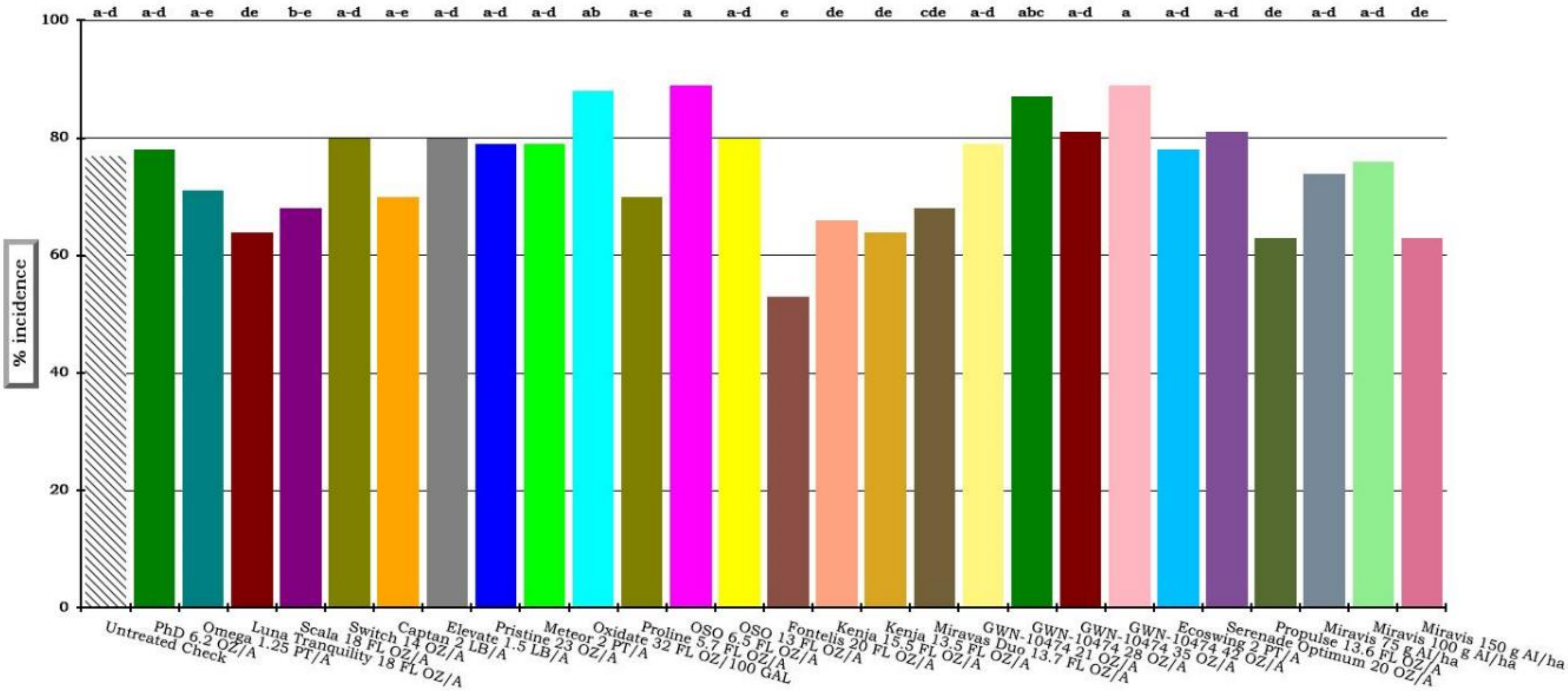


Figure 2. Comparison of 28 treatments for control of botrytis blight in raspberry-cumulative incidence represented as AUDPC.

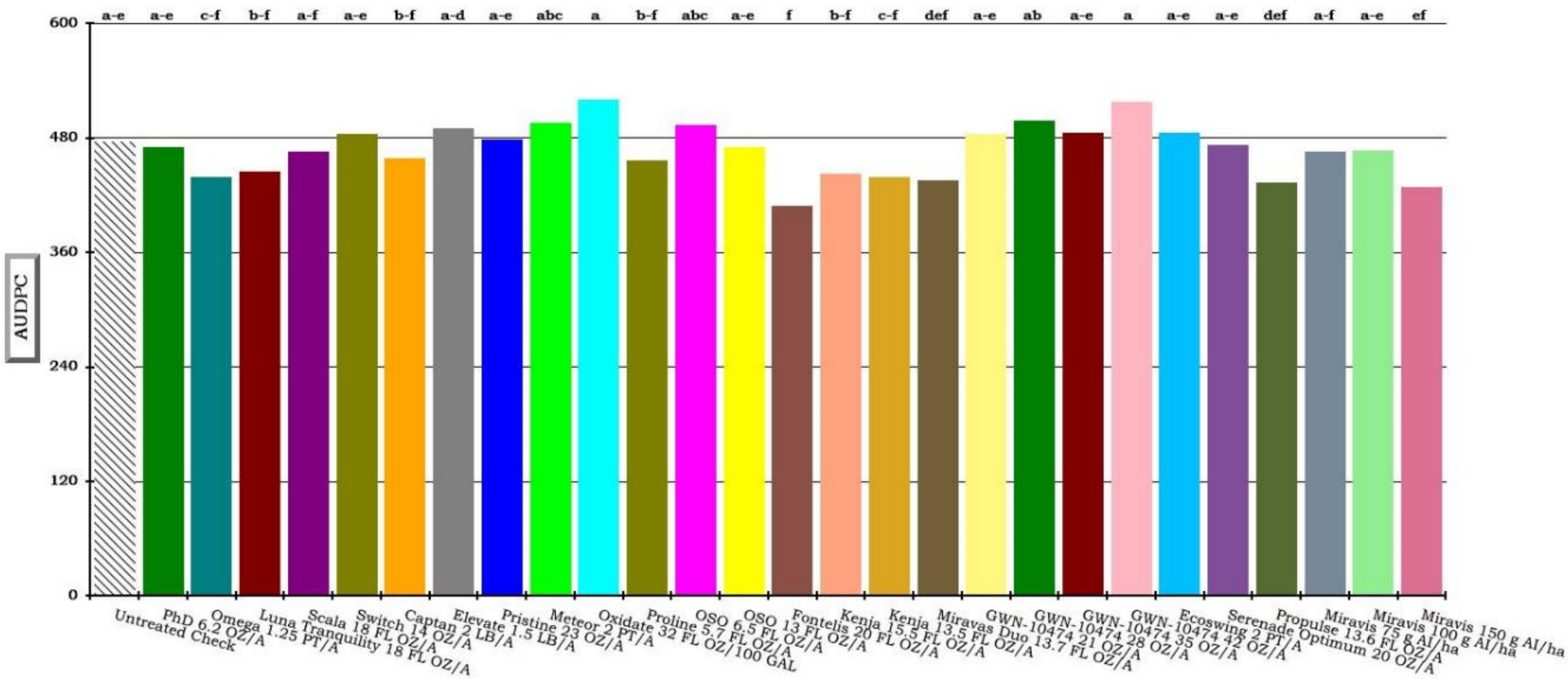


Figure 3. Comparison of 28 treatments for control of yellow rust in raspberry-incidence data.

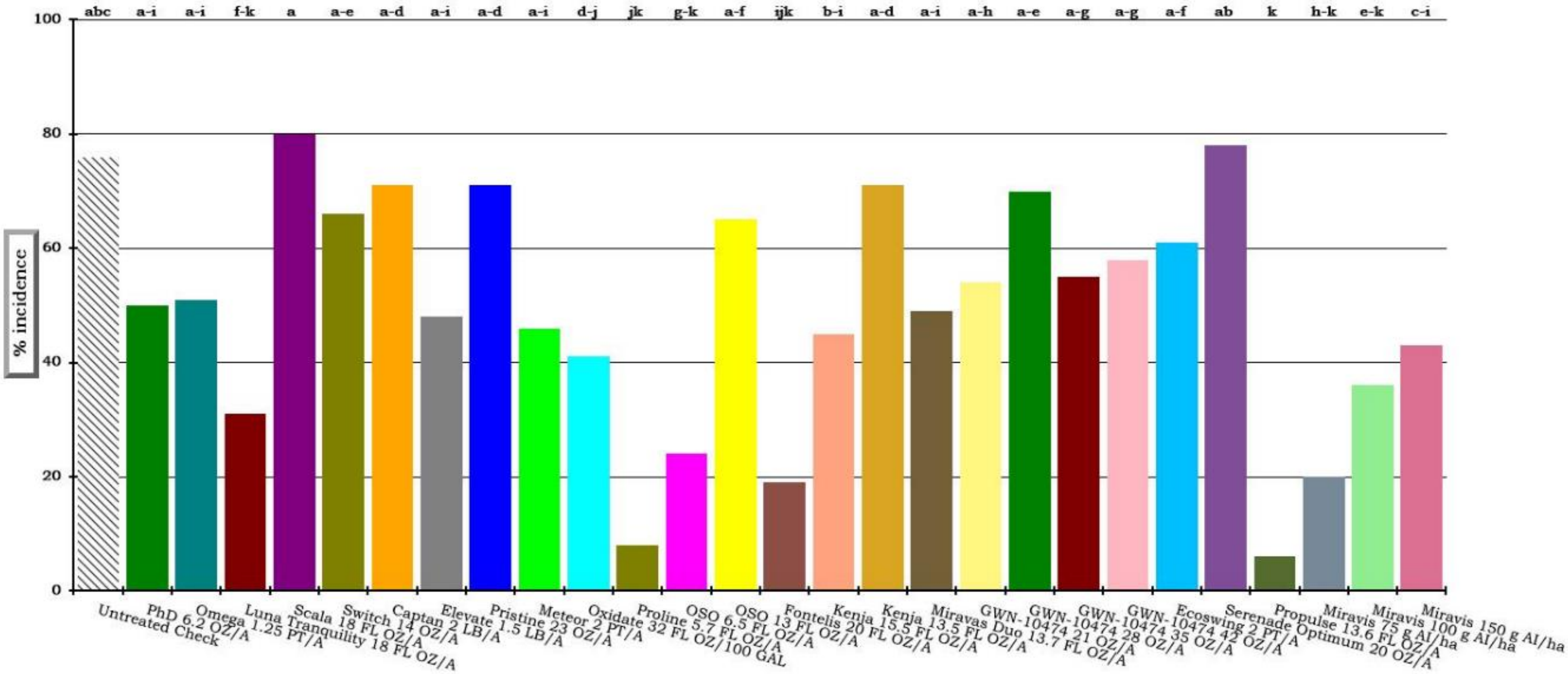
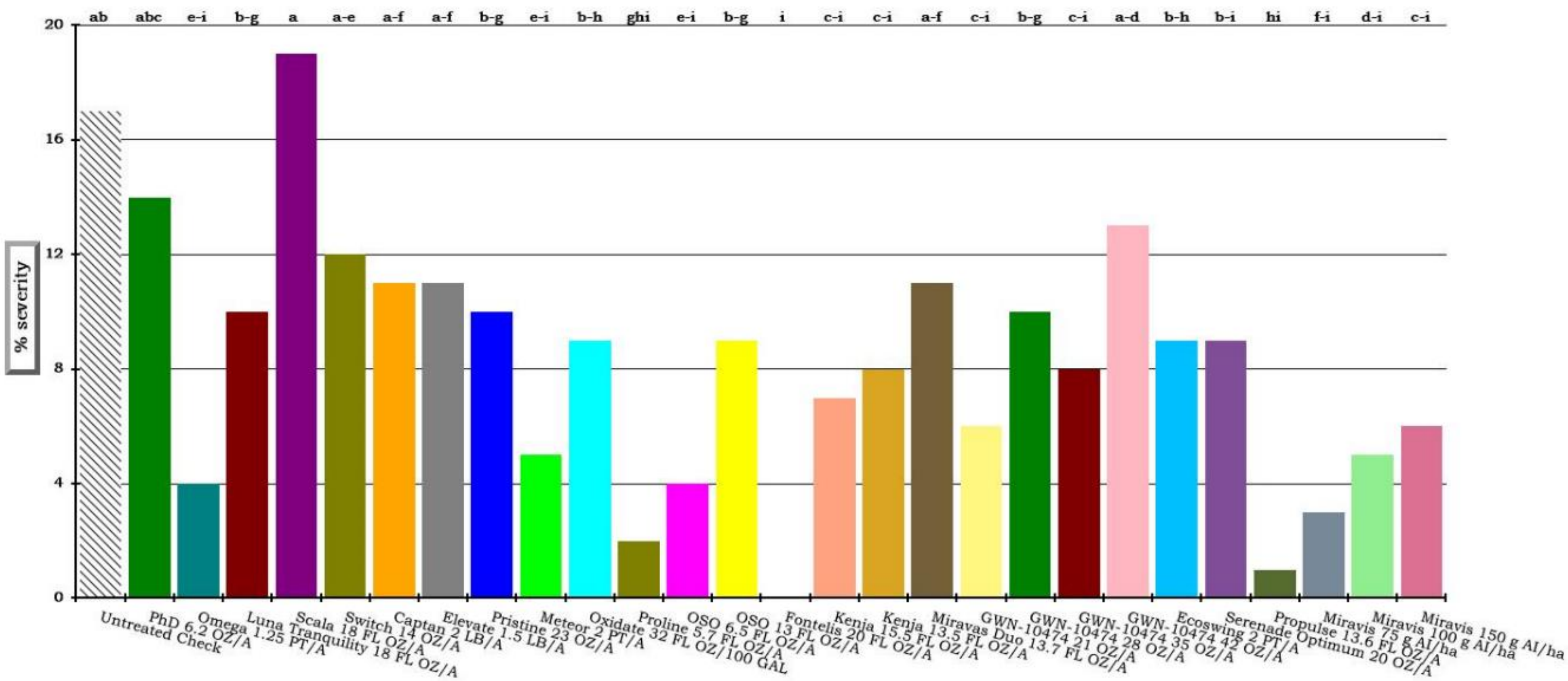


Figure 4. Comparison of 28 treatments for control of yellow rust in raspberry- severity data.



2. ***Program Trial***

In-field rating on the botrytis infection of the program trial showed significant differences among treatments (Table 2; Figure 5). Except for the Experimental 1 and Experimental 2 alone programs (13, 14, and 15), all the other programs reduced infection incidence compared to untreated check. Especially, program 2, 3, 7, 9, 10, and 11 resulted in 1.3 to 1.8 infected fruit count in 90 seconds, which is statistically lower (55% to 67%) infection incidence than untreated (3.9 count/90 seconds). The rest programs showed some potential with control efficacy ranged from 13% to 46%, compared to untreated.

Similar to the efficacy trial, incubation caused rapid development of *Botrytis*. While most programs resulted in lower disease than untreated check (57%) infection incidence by 2 DAI, programs 6, 12, 13, 14, 15, and 18 actually caused even higher than untreated infection incidence (Table 2; Figure 6). Further, at 2 DAI, programs 9 with rotation of Kenja, Captan, PhD, Meteor, and Switch was the only program that had statistically significant lower incidence (24%) than untreated check (57%), resulted in a 58% control efficacy relative to untreated. Program 11 also showed good potential with 38% infection incidence.

By 3 DAI (Table 2; Figure 7), most programs already lost their treatment effect and resulted in the same level of infection incidence as untreated. Again, program 9 was the only program that showed some control potential, although statistically non-significant, with 54% infection incidence which a 32% control efficacy compared to untreated check (79% incidence). All treatments reached 95 to 100% infection by 5 DAI.

The cumulative incidence AUDPC data (Table 2; Figure 8) showed similar trend as what we observed at 2 DAI. Program 12, 13, 15, and 18 resulted in even higher AUDPC (512 to 558) than untreated check (506). Program 9 was the only program that significantly reduced the overall infection with an AUDPC value of 409, which is 19% control efficacy compared to untreated (506). Programs 5, 7, and 11 showed some potential with AUDPC values of 449, 464, and 465, suggesting 8 to 11% control efficacy.

For the yellow rust, only program 11 showed promising control, with 44% incidence and 3% severity, indicating 53% incidence control and 88% severity control compared to untreated which had 93% incidence and 26% severity(Table 1; Figure 9 and 10). Programs 2, 6, 7, 10, and 13 also exhibited some potential of rust suppression. They did not stop the rust from infect the leaves with the same or even higher level of incidence (83% to 94%) than untreated (93%). However, although not statistically significant, they may have reduced disease severity, with 15 to 17% severity in infected leaves, which is around 38% control compared to the 26% severity of untreated.

In summary, our data suggested the program with the best botrytis control efficacy is program 9 with rotation of Kenja, Captan, PhD, Meteor, and Switch, followed by program 11 (rotation: PhD + Fontelis + PhD + Fontelis + Switch + Fontelis). Programs 5 and 7 showed some potential control yet further validation is needed. Program 11 also controlled yellow rust, while programs 2, 6, 7, 10, and 13 may have modestly suppressed rust severity.

These results indicate that there is a massive amount of botrytis inoculum present in this raspberry field demonstrating that the lack of apparent disease symptoms is due to the lack of environmental conditions conducive for disease development. This means that all of the ingredients for a severe disease outbreak are present as soon as favorable weather conditions occurring during the growing season. The significance of this cannot be overstated.

Table 2. ANOVA mean separation table for comparison of 18 programs for control of rust, or gray mold on raspberry at 2, 3, 5, and 7 days after incubation.

Pest Name					Yellow Rust	Yellow Rust	Botrytis sp.	Botrytis sp.	Botrytis sp.	Botrytis sp.	Botrytis sp.	Botrytis sp.
Rating Date					Jul-25-2019	Jul-25-2019	Jul-18-2019					
Rating Type					incidence	severity	count	2D incubate	3D incubate	5D incubate	7D incubate	AUDPC
Rating Unit					%	%/leaf	#/90 sec	%	%	%	%	
Days After First/Last Applic.					60 7	60 7	53 10					
Trt No.	Treatment Name	Rate	Rate Unit	Appl Code	1*	2*	3*	4*	5*	6*	7*	
1	Untreated Check				93a	26a	4ab	57b-e	79a	100a	100a	506abc
2	Captan	2	lb/a	A	89a	16a	1d	47c-f	72a	100a	100a	478bc
	Switch	14	oz/a	A								
	Captan	2	lb/a	B								
	Pristine	23	oz/a	B								
	Captan	2.5	lb/a	C								
	Meteor	32	fl oz/a	C								
	Captan	2	lb/a	D								
	Switch	14	oz/a	D								
	Captan	2	lb/a	E								
	PhD	6.2	oz/a	E								
	Captan	2	lb/a	F								
	Switch	14	oz/a	F								
	NIS	6	fl oz/100 gal	ABCDEF								
3	Captan	2.5	lb/a	A	91a	28a	2cd	44c-f	79a	100a	100a	485bc
	Meteor	32	fl oz/a	A								
	Captan	2.5	lb/a	B								
	Pristine	23	oz/a	B								
	Captan	2.5	lb/a	C								
	Switch	14	oz/a	C								
	Captan	2.5	lb/a	D								
	Switch	14	oz/a	D								
	Captan	2.5	lb/a	E								
	PhD	6.2	oz/a	E								
	Switch	14	oz/a	F								
	NIS	6	fl oz/100 gal	ABCDEF								
4	Captan	2.5	lb/a	A	93a	22a	2bcd	54b-e	80a	95a	95a	486bc
	Captan	2	lb/a	B								
	PhD	6.2	oz/a	B								
	Captan	2.5	lb/a	C								
	Switch	14	oz/a	C								
	Captan	2.5	lb/a	E								
	Switch	14	oz/a	E								
	NIS	6	fl oz/100 gal	ABCD								
5	Captan	2.5	lb/a	A	83a	27a	3bcd	43def	66a	95a	97a	449cd
	Switch	14	oz/a	A								
	Captan	2.5	lb/a	B								
	Captan	2.5	lb/a	C								
	Captan	2.5	lb/a	E								
	Switch	14	oz/a	E								
	NIS	6	fl oz/100 gal	ABCD								
6	Captan	1.5	lb/a	A	86a	16a	3a-d	59a-e	79a	96a	98a	497abc
	Captan	1.5	lb/a	B								
	Captan	1.5	lb/a	C								
	Captan	1.5	lb/a	E								
	NIS	6	fl oz/100 gal	ABCD								
7	Captan	1.25	lb/a	A	89a	17a	2cd	41def	67a	100a	100a	464cd
	Switch	14	oz/a	A								
	Captan	1.25	lb/a	B								
	Pristine	23	oz/a	B								
	Captan	2.5	lb/a	C								
	Kenja	15.5	fl oz/a	C								
	Captan	1.25	lb/a	D								

	Switch	14oz/a	D								
	PhD	6.2oz/a	E								
	Kenja	15.5fl oz/a	E								
	PhD	6.2oz/a	F								
	Switch	14oz/a	F								
	NIS	6fl oz/100 gal	ABCDEF								
8	Captan	2lb/a	A	94a	25a	3abc	52b-e	73a	99a	99a	484bc
	Meteor	32fl oz/a	A								
	Captan	2lb/a	B								
	Pristine	20oz/a	B								
	Captan	2.5lb/a	C								
	Switch	11.2oz/a	C								
	Captan	2lb/a	D								
	Switch	11.2oz/a	D								
	Captan	2lb/a	E								
	PhD	6.2oz/a	E								
	Captan	2lb/a	F								
	Switch	11.2oz/a	F								
	NIS	6fl oz/100 gal	ABCDEF								
9	Kenja	15.5fl oz/a	ACD	90a	24a	2cd	24f	54a	97a	98a	409d
	Captan	2lb/a	ABCDEF								
	PhD	6.2oz/a	B								
	Meteor	32fl oz/a	E								
	Switch	14oz/a	F								
	NIS	6fl oz/100 gal	ABCDEF								
10	Elevate	1.5lb/a	A	83a	15a	1d	53b-e	80a	100a	100a	500abc
	Meteor	32fl oz/a	B								
	Elevate	1.5lb/a	C								
	Pristine	20oz/a	D								
	Elevate	1.5lb/a	E								
	Switch	14oz/a	F								
	NIS	6fl oz/100 gal	ABCDEF								
11	PhD	6.2oz/a	A	44b	3a	1d	38ef	74a	99a	99a	465cd
	Fontelis	20fl oz/a	B								
	PhD	6.2oz/a	C								
	Fontelis	20fl oz/a	D								
	Switch	14oz/a	E								
	Fontelis	20fl oz/a	F								
	NIS	6fl oz/100 gal	ABCDEF								
12	Luna Tranquility	16fl oz/a	BDE	80a	15a	2bcd	81a	91a	100a	100a	558a
	Meteor	2qt/a	A								
	PhD	16oz/a	CF								
	NIS	6fl oz/100 gal	ABCDEF								
13	Experimental 1	28fl oz/a	ABCDEF	94a	16a	5a	60a-e	82a	100a	100a	513abc
14	Experimental 1	42fl oz/a	ABCDEF	95a	25a	4ab	61a-d	75a	98a	99a	497abc
15	Experimental 2	55fl oz/a	ABCDEF	85a	18a	4ab	67abc	89a	100a	100a	533ab
	Kinetic	0.125% v/v	ABCDEF								
16	Experimental 1	28fl oz/a	ACE	88a	19a	3a-d	56b-e	70a	100a	100a	489bc
	Pristine	23oz wt/a	BDF								
17	Experimental 2	55fl oz/a	ACE	95a	18a	3a-d	48cde	74a	98a	99a	478bc
	Kinetic	0.125% v/v	ACE								
	Pristine	23oz wt/a	BDF								
18	Experimental 2	5lb/a	ABCDEF	90a	20a	3a-d	74ab	84a	98a	99a	533ab
LSD P=.05				16.3	12.6	1.9	23.1	19.9	5.2	4.5	64.1
Standard Deviation				11.5	8.8	1.4	16.2	14.0	3.6	3.2	45.1
CV				13.23	45.6	51.83	30.53	18.46	3.69	3.19	9.21
Replicate F				2.570	1.923	1.656	2.147	5.024	0.392	0.204	3.117
Replicate Prob(F)				0.0643	0.1375	0.1881	0.1057	0.0040	0.7592	0.8929	0.0340
Treatment F				4.094	1.822	2.322	2.720	1.541	0.984	0.786	2.203
Treatment Prob(F)				0.0001	0.0508	0.0106	0.0030	0.1179	0.4892	0.6994	0.0155

Figure 5. Comparison of 18 fungicidal programs for control of botrytis blight in raspberry-in field rating for # of infected fruit found in 90 seconds.

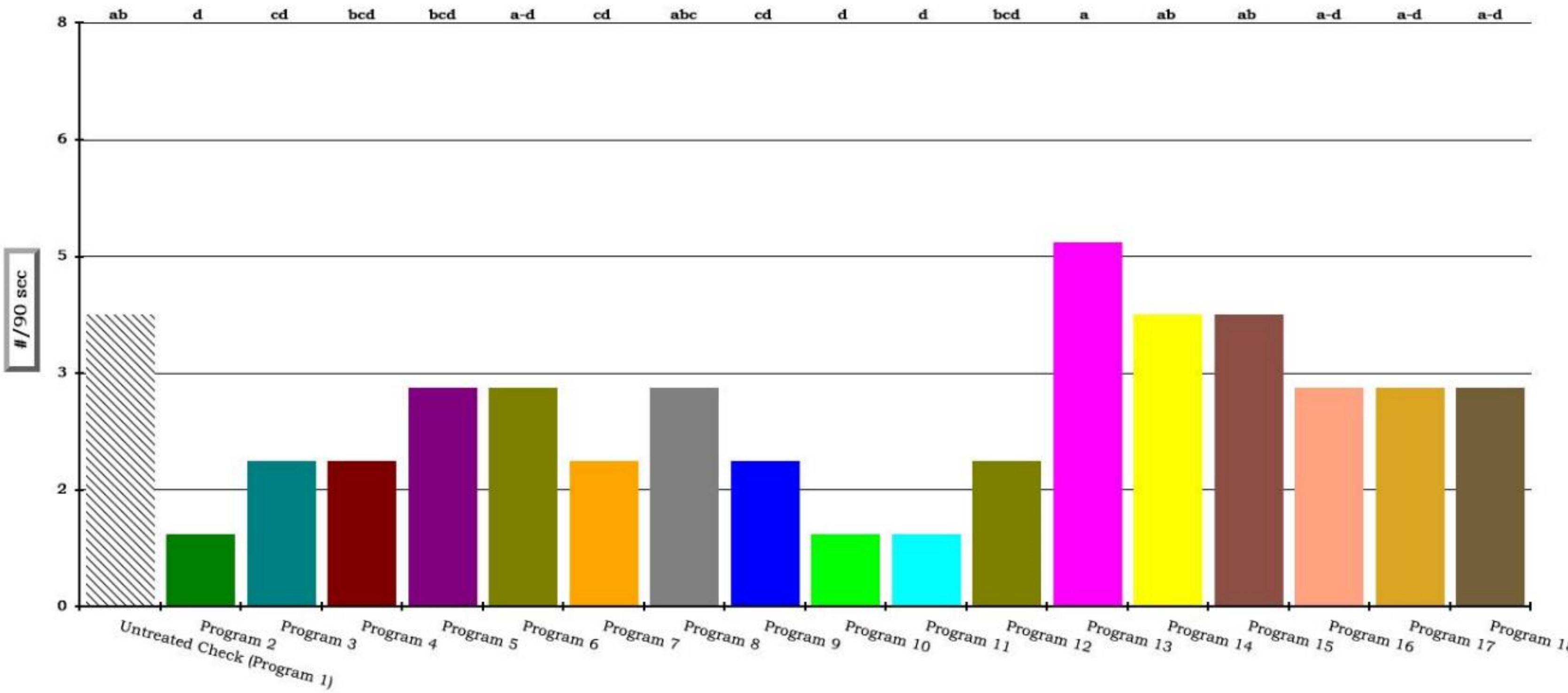


Figure 6. Comparison of 18 fungicidal programs for control of botrytis blight in raspberry-incidence after 2 days' of incubation.

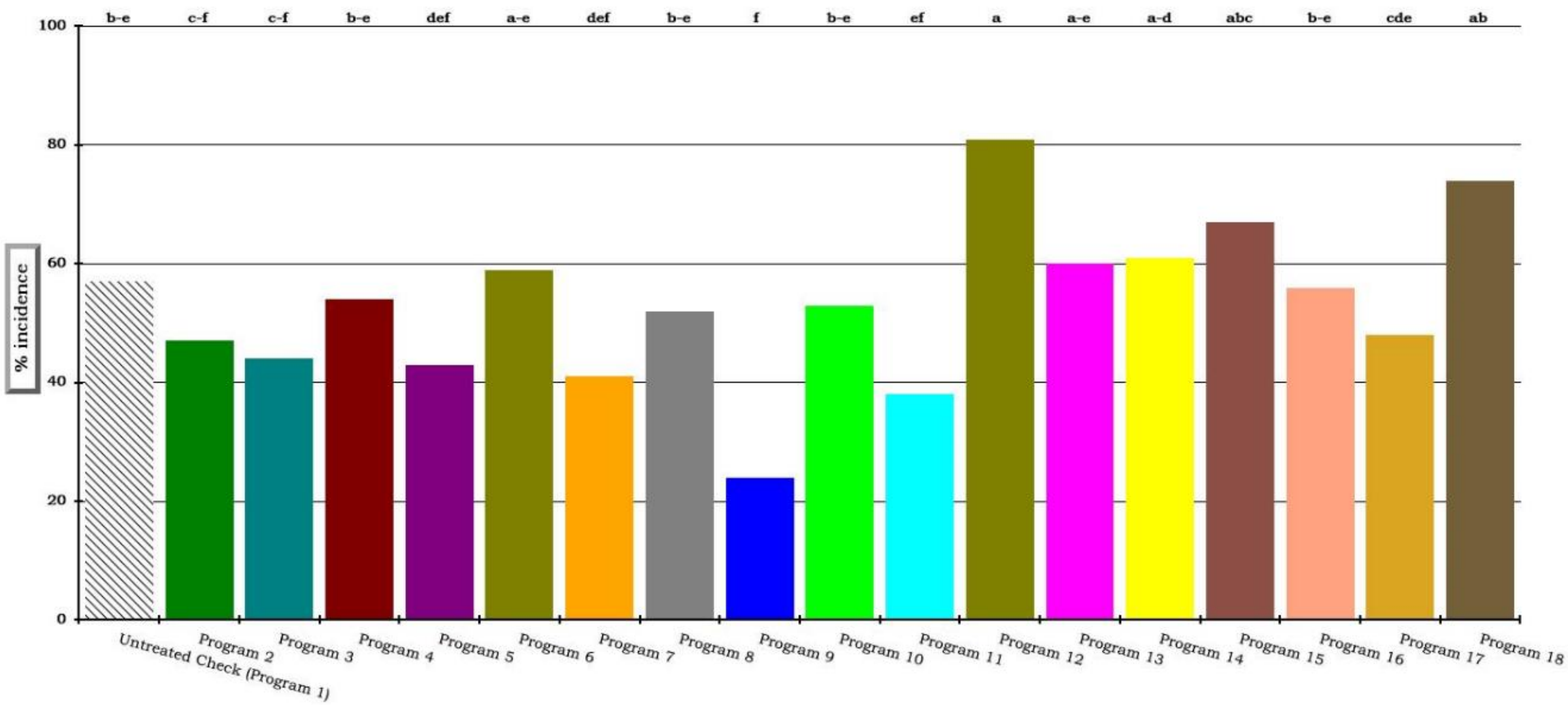


Figure 7. Comparison of 18 fungicidal programs for control of botrytis blight in raspberry-incidence after 3 days' of incubation.

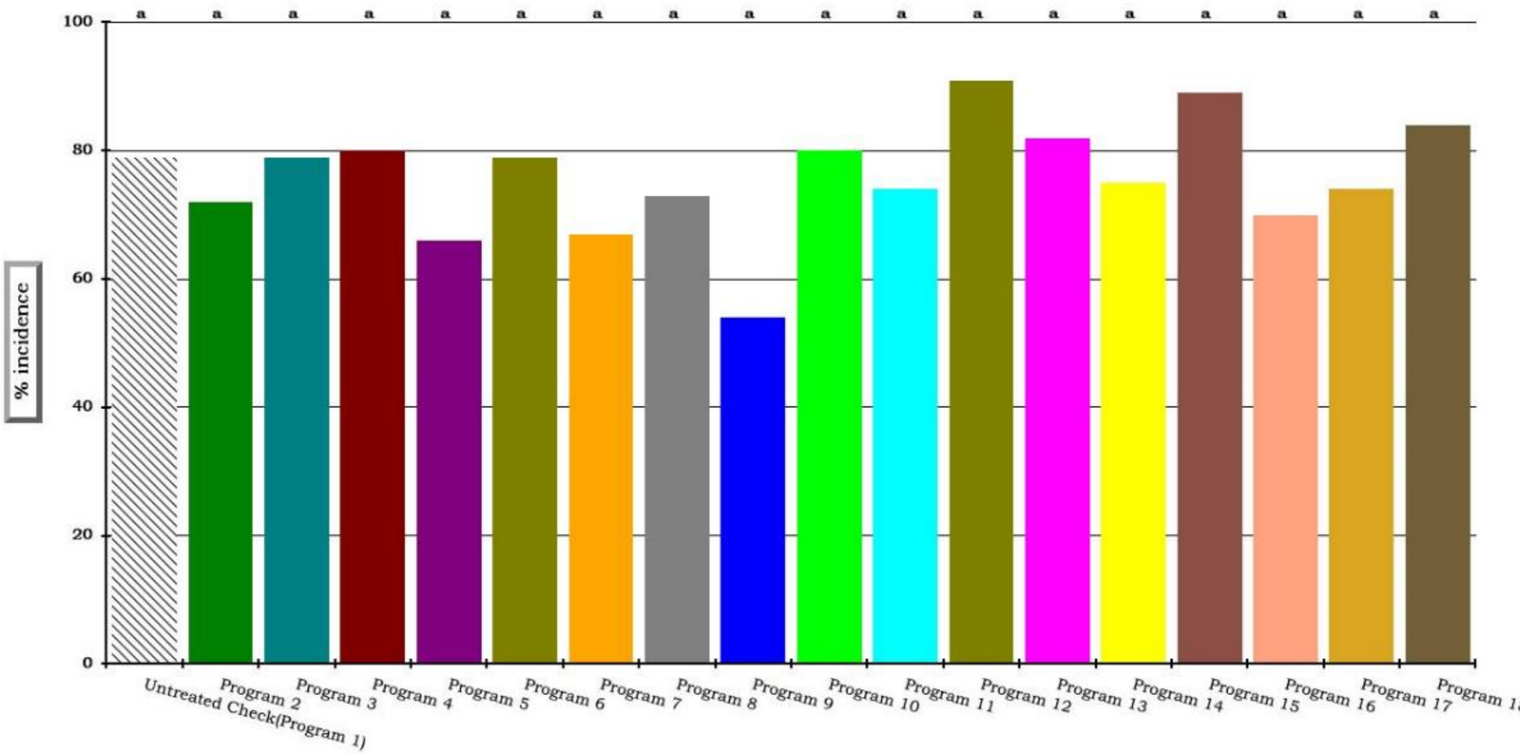


Figure 8. Comparison of 18 fungicidal programs for control of botrytis blight in raspberry-cumulative incidence represented as AUDPC.

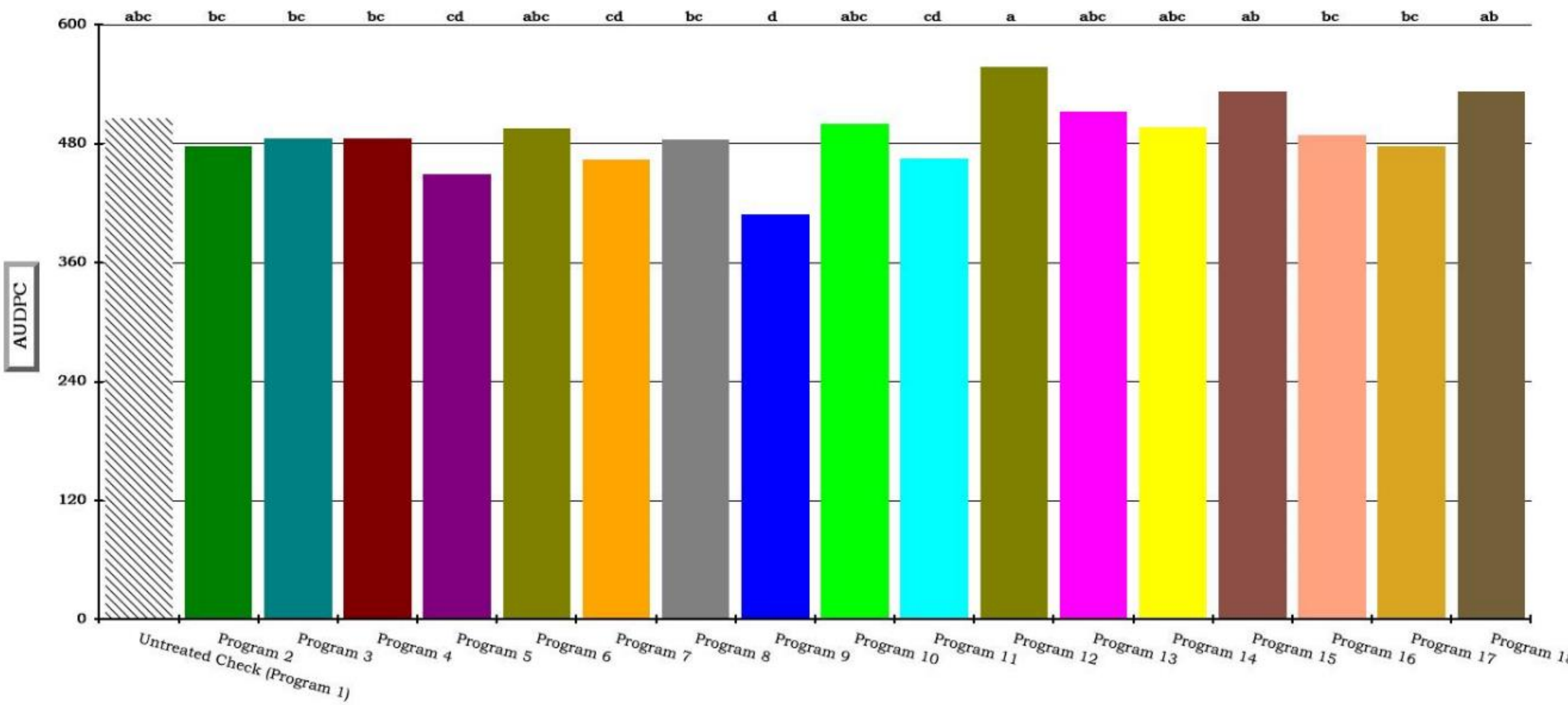


Figure 9. Comparison of 18 fungicidal programs for control of yellow rust in raspberry-incidence data.

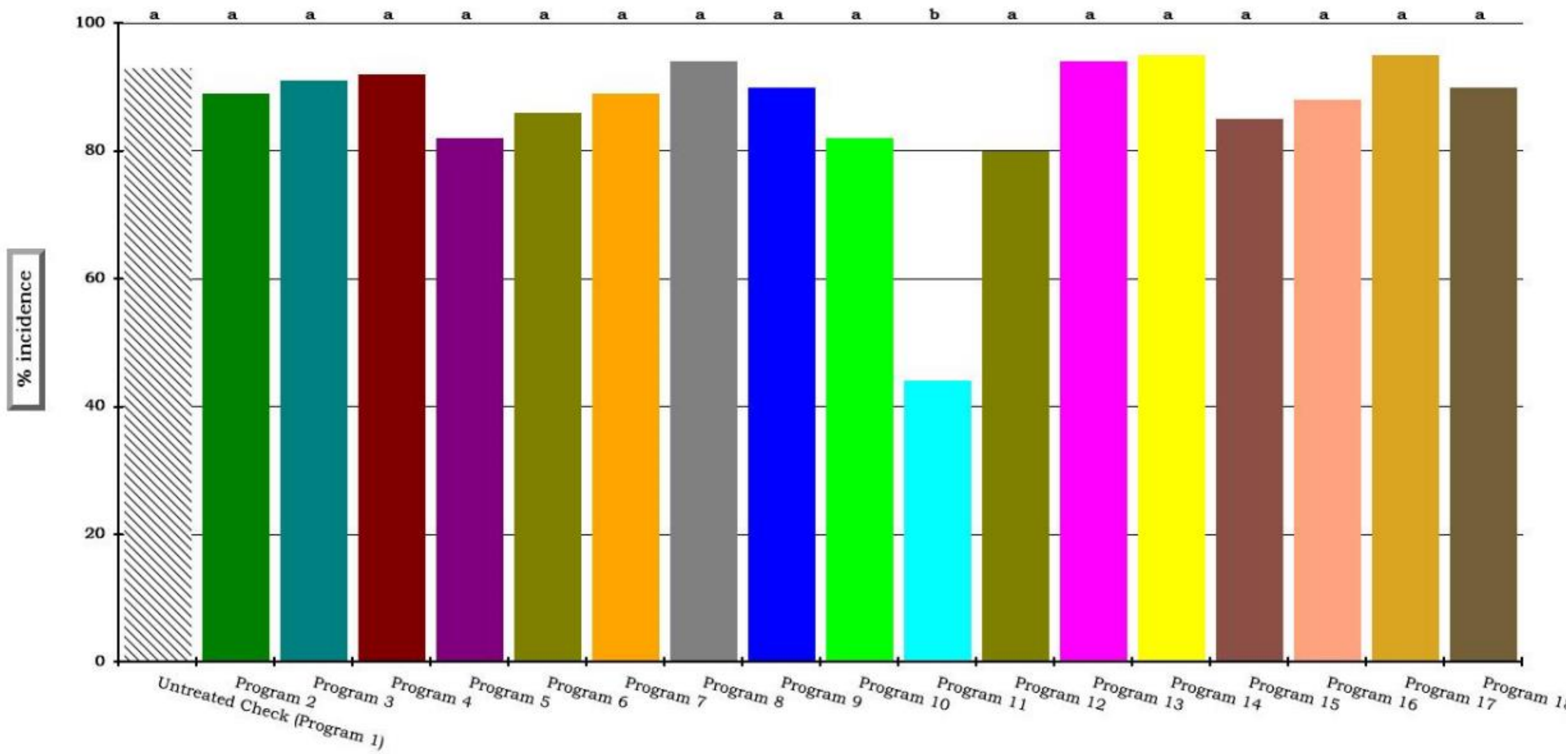


Figure 10. Comparison of 18 fungicidal programs for control of yellow rust in raspberry-severity data.

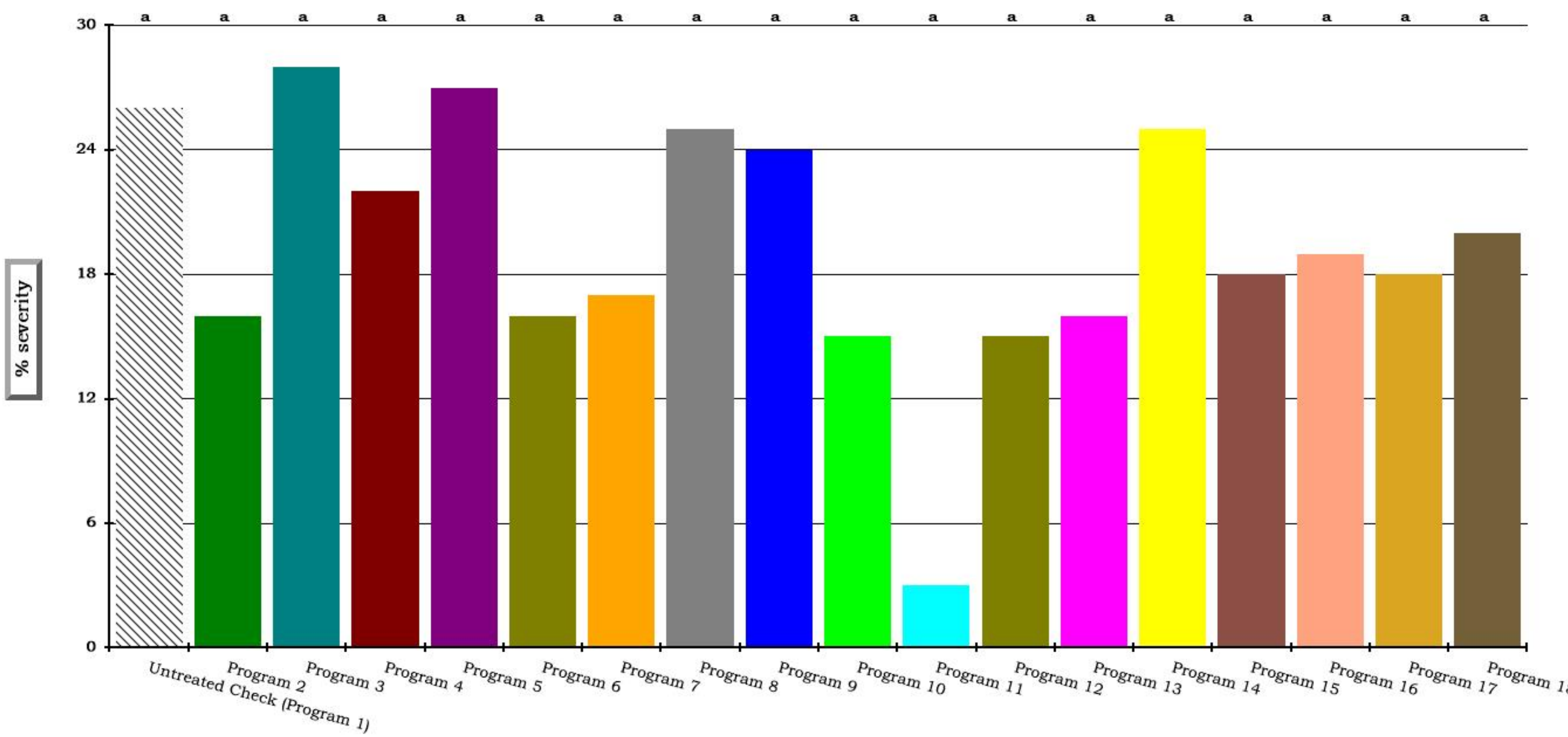


Photo 1. Application using over the row sprayer on raspberry.

Photo 2. Representative photos of raspberry in incubator.

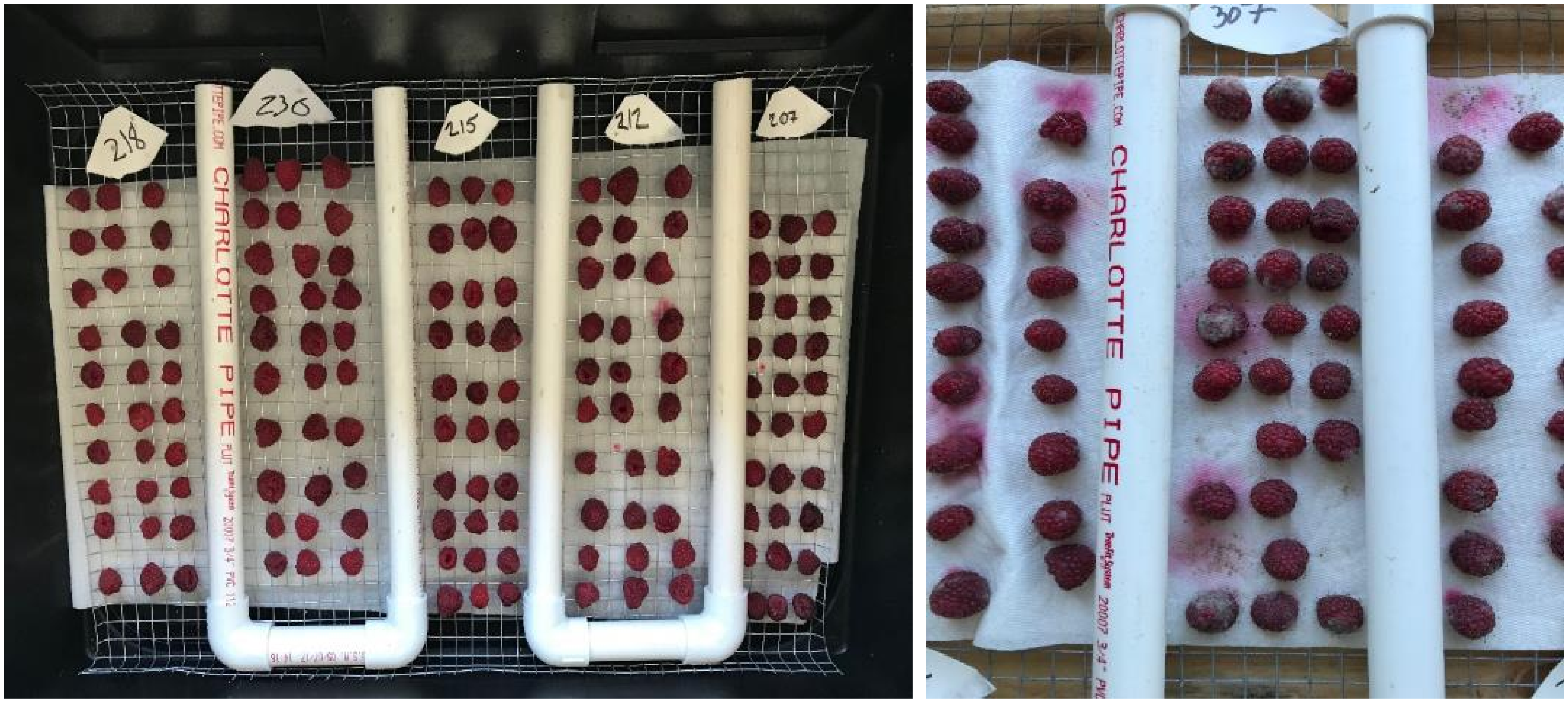


Photo 3. Yellow rust symptom on raspberry leaf.

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)
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Address: 2621 Ringold Road, Eltopia, WA 99330

Cooperators: Dr. Tom Walters-Walters Ag Research, Olga Kozhar, WSU

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

Total Project Request: Year 1 $12,000 Year 2 $13,000 Year 3 $14,000

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. 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 resistance. This project proposes to screen currently used products, other products that are registered but not commonly used, and products not registered for raspberry for control of botrytis. This project will be a standard efficacy trial that is modeled after the 2019 trial, 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 three trials: an efficacy program trial screening several fungicides, a program trial that evaluates all major raspberry botrytis programs, and a third trial on blackberry where disease pressure is higher than that on raspberry. 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.

Justification and Background: This project will generate conclusions on which fungicidal products are effective for controlling botrytis and which products are not. WSU's Olga Kozhar will work cooperatively with this project. I am submitting this proposal at the request of the WRRC to ensure that the necessary information is generated for the raspberry industry of

Washington. 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 you find it, think you have it, or are at risk of having it, then you 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 that is especially concerning is that all new and pending registrations are for active ingredients that are 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 2020 that are similar to the trials done in 2018 and 2019. 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 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 2020, one that would screen for new products and a second trial that would evaluate season long programs that are currently being used by growers. The reason we are targeting blackberry is because it appears to have a higher likelihood of developing botrytis. 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. Peever 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 2020 trial. 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. All travel costs are related to traveling to the site and/or meeting with industry representatives.

Results from 2019.

Efficacy Trial. Our data suggested the treatments with the best botrytis control efficacy are Fontelis at 20 fl oz/a, Kenja at both rates (15.5 and 13.5 fl oz/a), Propulse at 13.6 fl oz/a, and Miravis at highest rate 150 g ai/ha, where Proline, Fontelis, and Propulse showed the best rust control. It appears that Fontelis and Propulse was the only 2 treatments had a universal control effect on both botrytis and rust.

Program Trial. Our data suggested the program with the best botrytis control efficacy is program 9 with rotation of Kenja, Captan, PhD, Meteor, and Switch, followed by program 11 (rotation: PhD + Fontelis + PhD + Fontelis + Switch + Fontelis). Programs 5 and 7 showed some potential control yet further validation is needed. Program 11 also controlled yellow rust, while programs 2, 6, 7, 10, and 13 may have modestly suppressed rust severity.

The results indicate that there is a massive amount of botrytis inoculum present in this raspberry field demonstrating that the lack of apparent disease symptoms is due to the lack of environmental conditions conducive for disease development. This means that all of the ingredients for a severe disease outbreak are present as soon as favorable weather conditions occurring during the growing season. The significance of this cannot be overstated.

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, Tom Walters, Walters Ag Research

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

Materials and Methods

A raspberry cane blight trial was conducted in July, 2019 by Agricultural Development Group, Inc. at Everson, WA to evaluate the effect of different fungicides on raspberry cane blight. The experimental design was a RCB with 4 replications with the plot size of 10 ft x 40 ft. Applications for this trial were made by an over the row sprayer to apply treatment spray at 25 gallons/acre. 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 raspberry variety is WakeHaven. The applications were made on July 3, July 9, July 17, and July 25. The raspberry plots were harvested from June 24 to August 14. The harvester damaged canes were pruned out and put in moist chambers to check for growth of the cane blight fungus. The canes were pruned out of the field on Aug 21 and 22. Moist chambers were set up on Aug 23. The evaluation of the canes in the moist chambers started on August 26 and continued through September 4 as symptoms developed. The cane blight incidence was calculated by the number of cane blight damaged cane/total number of pruned canes X100. The cane blight trial evaluations were done by collecting all of the harvester damaged canes and placing them in moist chambers for symptoms (mycelial growth and/or fruiting bodies along with tissue discoloration) to develop, this took place over 2.5 weeks. Only harvester damaged canes were rated because those are the infections that lead to yield loss the following year.

Results and Discussion

The results showed no statistically differences were noticed across all treatments and the untreated check. Treatment 2, 3, 5, 6, 7, 8, 9, and 10 showed 1%, 4%, 1%, 6%, 10%, 3%, 11%, and 11% numerically less cane blight incidence compared to the untreated check.

The results indicated that Quilt Xcel+Switch+Pristine, Luna Tranquility, and Velum Prime may have the potential for suppressing cane blight in raspberry. Preliminary petri dish sensitivity tests done in early 2019 showed that these fungicides were very effective against cane blight with the exception of Quilt Xcel because it was not included in the tests. Four applications may not work for a long season variety like WakeHaven, since most of the lesions looked like recent infected after the harvest was over. So for next year, we probably need to look at the infections sooner after application or/and have more applications to cover the whole season.

Minimally damaged canes generally won't develop lesions large enough to reduce yield. Ideally, we would have liked to wait until fall to do ratings because it is easier to determine if a cane is infected by the presence of fruiting bodies. Since the field was to be taken out, we had to prune the canes for evaluation prematurely. Dr. Jones believes the % incidence was likely similar in all plots because of the long harvest season of Wake Haven, the plots continued with harvest about 2.5 weeks after the last spray. Many of the canes looked to have younger lesions that may have developed after the last treatment. From this trial we learned that fungicides are not likely to inhibit inoculum production from last year's canes, but they may have an effect on reducing new cane infections. For next year, we could treat plots through the harvest season, maybe try for a WakeField field that has a shorter harvest season than Wake Haven. Alternatively, we could do something similar to this past season and collect the canes after the last spray treatment and before the next harvest. Other ideas for expanding areas of research for next year include the following. One, trying Luna Tranquility as a drench in the spring, since it is systemic it could inhibit growing lesion enough to stop yield loss. Two, trying a biological fungicide, since the cane blight fungus takes a couple days to germinate and grow, if we could find something to outcompete it the lesion may not develop. We don't usually see mixed infections on the damaged part of the cane.

One other possible treatment could be added – hand pruning of primocanes by a trained eye (Dr. Jones). She would prune out sources of inoculum before the harvest season, in practice this would be done when the canes are trellised during the winter. From her epidemiological observations, she believes that spores are spread by the mechanical harvester but spore dispersal distance is generally short. Her theory is that spores are picked up and spread by the harvester plates primarily within a few plants from the original inoculum source with a much lower frequency of longer distance dispersal. This could be why it takes several years for infestations to really get going. She believes pruning alone would have a significant effect on cane blight control, pruning plus and effective fungicide would be even better.

ANOVA means table

Trt No.	Treatment Name	Rate	Rate Unit	Appl Code	1
Crop Type, Code					C -
Rating Type					Cane blight
Rating Unit					% incidence
Number of Subsamples					1
Number of Decimals					0
1	Untreated check				88a
2	Tanos 50 DF	10	oz/a	ABCD	87a
	SB-56	6	fl oz/100 gal	ABCD	
3	Switch 62.5 WG	14	oz/a	ABCD	84a
	SB-56	6	fl oz/100 gal	ABCD	
4	Pristine	23	oz/a	ABCD	88a
	SB-56	6	fl oz/100 gal	ABCD	
5	Quilt Xcel	21	fl oz/a	ABCD	87a
	SB-56	6	fl oz/100 gal	ABCD	
6	Tanos	10	oz/a	A	82a
	Switch	14	oz/a	B	
	Tanos	10	oz/a	C	
	Pristine	23	oz/a	D	
	SB-56	6	fl oz/100 gal	ABCD	
7	Quilt Xcel	21	fl oz/a	A	78a
	Switch	14	oz/a	B	
	Quilt Xcel	21	fl oz/a	C	
	Pristine	23	oz/a	D	
	SB-56	6	fl oz/100 gal	ABCD	
8	Tanos	10	oz/a	A	85a
	Copper-Count-N	1	qt/a	A	
	Switch	14	oz/a	B	
	Copper-Count-N	1	qt/a	B	
	Pristine	23	oz/a	C	
	Copper-Count-N	1	qt/a	C	
	SB-56	6	fl oz/100 gal	ABCD	
9	Luna Tranquility	16.42	fl oz/a	ABCD	77a
	SB-56	6	fl oz/100 gal	ABCD	
10	Velum Prime	6.5	fl oz/a	ABCD	77a
	SB-56	6	fl oz/100 gal	ABCD	
LSD P=.05					10.2
Standard Deviation					7.1
CV					8.47
Levene's F					0.203
Levene's Prob(F)					0.992
Skewness					-0.326
Kurtosis					-0.6483
Replicate F					5.269
Replicate Prob(F)					0.0054
Treatment F					1.621
Treatment Prob(F)					0.1592

Graph 1. Effect of fungicides on raspberry cane blight incidence.

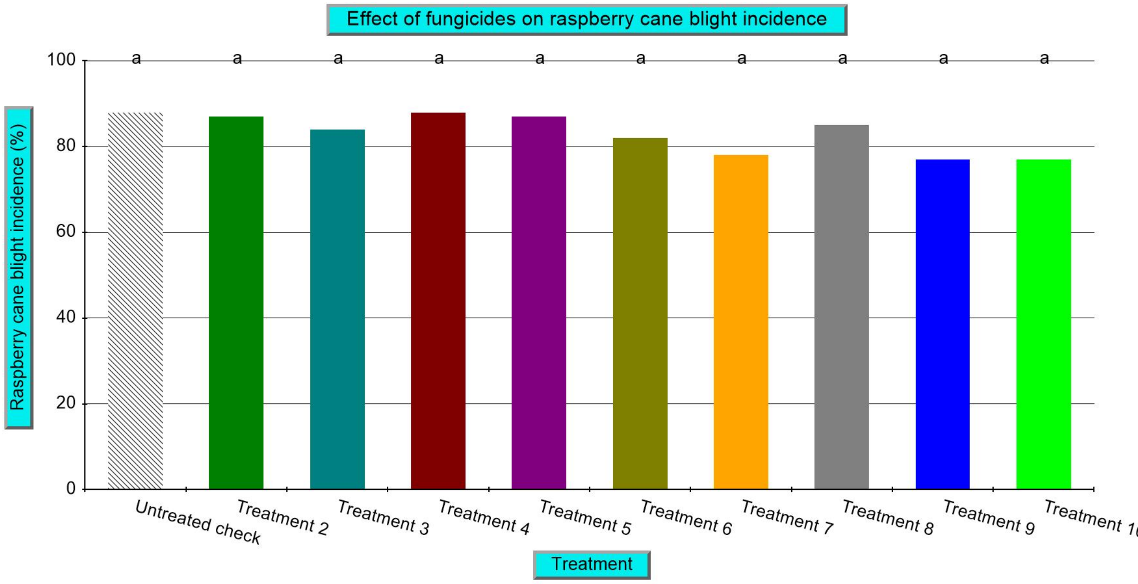
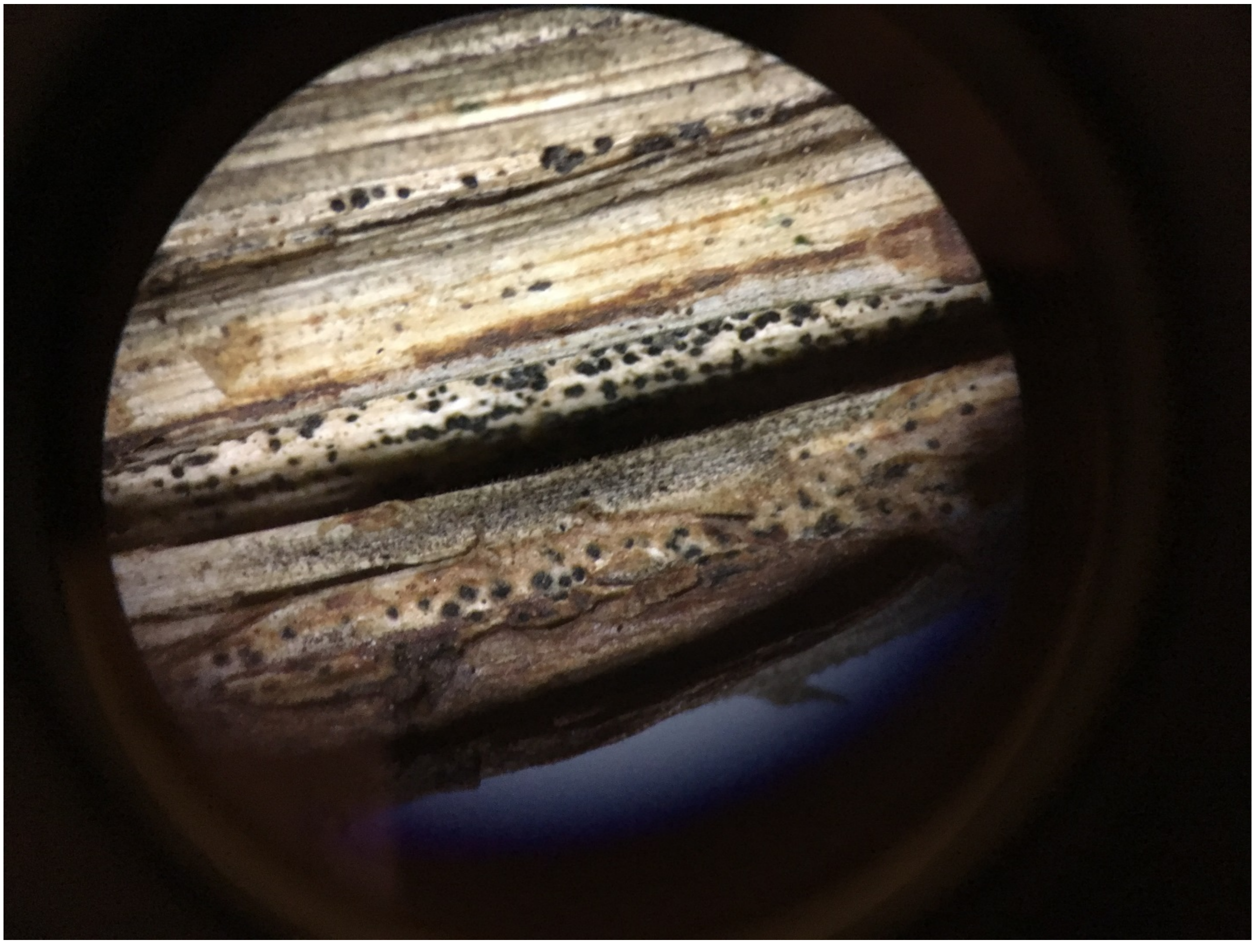


Photo 1. Application using over the row sprayer.

Photo 2. Cane blight lesions in the field.

Photo 3. Close-up photo for raspberry cane blight lesions.

Photo 4. 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
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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 the 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 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 are addressing this issue. Currently, the two products recommended for control of cane blight are Tanos (famoxadone (Group 11) and 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.

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 would be set up on a susceptible variety (most likely WakeField) in a location that has a history of cane blight. The trial would be set up as a randomized complete block design with four replications. Plot size would be approximately 10 feet by 30 feet. Some treatments will be a straight program of a single product to determine the level of efficacy provide by the product and some treatments will be a program approach that might resemble what a grower might use. The products in the trial and the program treatments have not been finalized. Tanos, Quilt Xcel, Pristine and Switch will likely be included based on preliminary industry feedback. Luna Tranquility and copper products are also likely candidates. It might be interesting to use a straight Group 11 product such as azoxystrobin to determine if the package mixes are providing enhanced control or if the relatively cheaper straight Group 11 product will provide a similar level of control. The Washington berry industry has a 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. This group will assist with setting up the list of treatments. Some potential treatments might be 1) Untreated check, 2) Tanos, 3) Switch, 4) Pristine, 5) Quilt Xcel, 6) Tanos, Switch, Tanos Pristine, 7) Quilt Xcel, Switch ,Quilt Xcel, Pristine, 8) Tanos+copper rotated with Switch+copper rotated with Pristine+copper, 9) Luna Tranquility (foliar), 10) Luna Tranquility (drench), and 11) Miravas Duo.

At this time, we plan to make four to six applications. The applications would be timed to start just prior to harvest and continue through harvest as this disease is thought to be tied to the mechanical harvest of raspberry. An over the row sprayer would be used to make the applications. The selection of fungicides and applications 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, that will appear. Application of products such as Pristine, Switch and Luna Tranquility for cane blight also has implications for *Botrytis* resistance management strategies. Historically, a Group 3 fungicide, Orbit (propaconazole), was thought to have a deleterious impact on raspberries and is not used by the industry. All treatments will be rated for phytotoxicity with specific attention given to Quilt Xcel since Quilt Xcel contains propaconazole.. However, the above plan is likely to be modified based on additional raspberry industry feedback. The berry industry hosts an annual meeting in February to discuss and plan berry disease research priorities and experimental design. This project, if funded, will be placed on the agenda of that meeting.

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.

New Project Proposal to Washington Red Raspberry Commission

Proposed Number: New **Proposed Duration**: 1 year

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

PI: Lisa Jones, PhD
Organization: Northwest Plant Company
Title: Scientist
Phone: (360)-966-6462 (cell)
Email: lisa.jones@nwplant.com
Address: 8021 Woodland Rd, Ferndale, WA 98248

Cooperators:

CHS Northwest Agronomy, 2041 Agronomy Way, Lynden, WA 98264, (360) 354-2418

Raspberry Growers, to be determined.

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

Total Project Request: $6,950

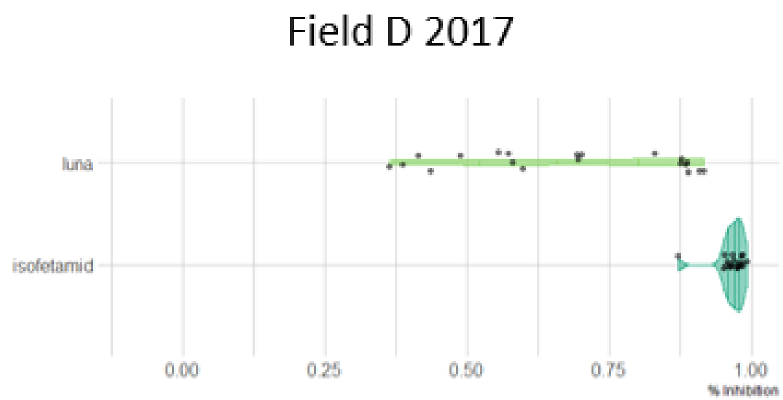
Other Funding Sources: None at this time

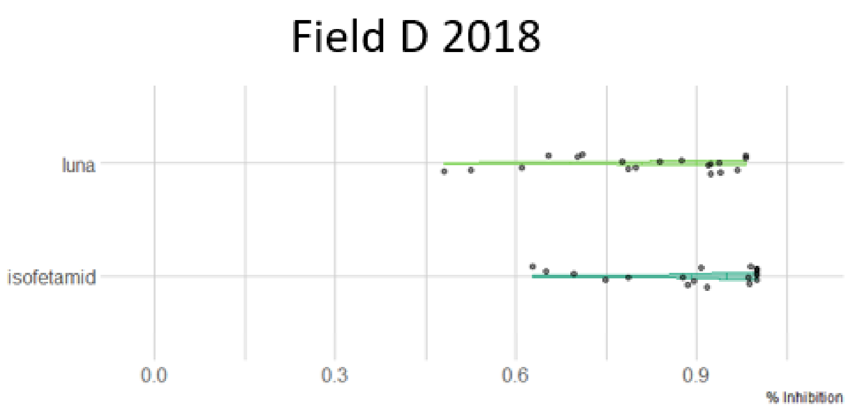
Description:

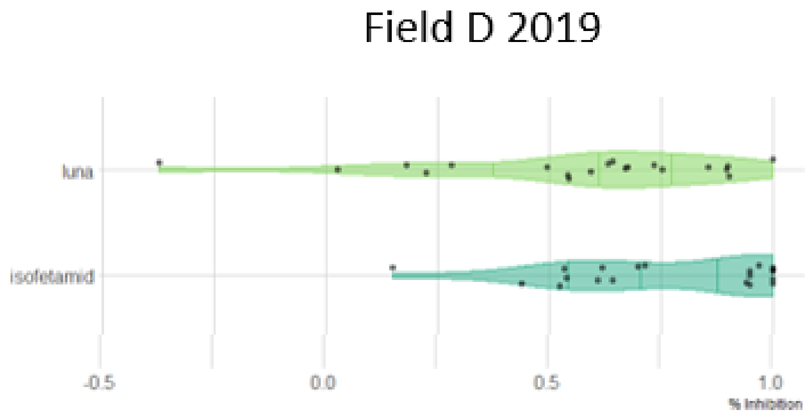
Fungicide resistance is widely reported for *Botrytis*. Kenja (isofetamid, FRAC7) and Luna Tranquility (fluopyram, pyrimethanil, FRAC7,9) are relatively new products for control of *Botrytis* on raspberries. Efficacy of new fungicides generally starts out high and it is almost expected that fungi will 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 as Peever et al. (WSU, personnel communications) demonstrated the specific mutation in the sdhB gene plays a large role is whether there is cross resistance among FRAC7 fungicides. Pyrimethanil is not a new active ingredient for the berry industry and resistance has been widely reported. The inclusion in Luna Tranquility may have effects on other FRAC9 fungicide use because there is strong cross resistance among the group. 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.

Justification and Background:

Northwest Plant Company has been monitoring fungicide efficacy of four raspberry fields in Whatcom County during the past three seasons. Below are data showing % inhibition of fungal isolate growth in the presence of a fungicide over consecutive years in the same field. The data represents declining efficacy over time of Kenja (isofetamid) and Luna Tranquility (fluopyram, pyrimethanil). This field never received a direct application of Kenja and only one application per season of Luna Tranquility. It is likely that this field was in very close proximity to fields that both products were used in greater frequency. The data from the other three fields show similar trends. An assessment of isolates from fields with greater use of Kenja and Luna Tranquility would provide a better picture of the potential of fungicide resistance in raspberry *Botrytis* populations.







Relationship to WRRC Research Priority: This project directly addresses the WRRC RFP #1 priority category “Fruit rot including pre-harvest, post-harvest, and/or shelf life”.

Objective 1. Understand the 2020 status of *Botrytis* fungicide resistance to Kenja and Luna Tranquility in Washington raspberries after several seasons of use.

Objective 2. Determine the genetic variation in the SdbH protein associated with FRAC 7 resistant isolates.

Procedures:

A minimum of 12 raspberry fields, preferably with as many different growers as possible, will be sampled in early 2020. Collection of isolates during the winter will allow for information to be distributed to growers before the 2020 harvest season so that growers can make more informed decisions. The field sites will be concentrated on those with a history of Kenja and / or Luna Tranquility use. Two sites without a history of Kenja or Luna Tranquility use will be included for comparison. EC_{50}, the effective concentration that reduces mycelial growth by 50%, will also be determined for a subset of isolates and fungicide sensitivity assays will be run for each individual active ingredient (isofetamid, fluopyram, and pyrimethanil). This information will be necessary to properly understand the current efficacy status and to monitor fungicide resistance in the future. During the summer and fall of 2020 a selection of moderately to highly resistant isolates will be assessed for mutations in the SdhB protein that may confer resistance to FRAC 7 fungicides. This work will be done similarly to protocols found in Peres et al., 2019. Dr. Virginia Stockwell, USDS-ARS plant pathologist in Corvallis, OR, will be consulted to standardize fungicide resistance protocols in the region so that results are easily comparable within the Pacific Northwest Berry industry.

Anticipated Benefits and Information Transfer:

The current status of fungicide resistance for the active ingredients in Kenja and Luna Tranquility will be determined and distributed to raspberry growers before routine flower sprays in the spring time begin. The data generated from this project would help raspberry growers understand the pace at which fungicide resistance can develop and emphasize the importance of fungicide rotation to keep our products efficacious. This information would be provided to growers directly, through CHS, through WRRC reports, and at the WSU Small Fruit Conference at grower meetings.

Budget:

	2019	
	WRRC	**In-Kind**
Salaries	$3,200	$1,560
Operations	$3,750	$1,600
Transportation	$0	$350
Total	**$6,950**	**$3,510**

The funds for salaries will be used for 1 month of combined technical support for this project (Amber Kelley, TJ VanderYacht, and Brooke Berendsen). The funds for operations will be used for lab consumables, reagents and DNA sequencing through Psomagen (Rockville, MD). In-kind support from Northwest Plant Company will cover transportation and lab facility use in addition to Lisa Jones' time spent to manage, analyze, and report the results from this project.

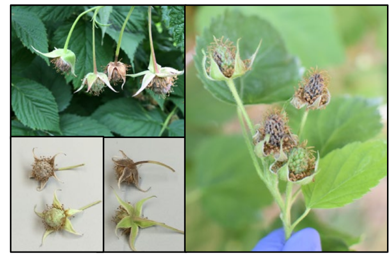
References:

Peres et al., 2019. Baseline sensitivity of *Botrytis cinerea* isolates from strawberry to isofetamid compared to other SDHIs. Plant Disease, In Press.

Washington Red Raspberry Commission
Progress Report for 2019 Projects

Title: Refining the microbiome of developing red raspberry fruit tissues.
Personnel: Virginia Stockwell, Brenda T. Shaffer, and Gayle McGhee USDA ARS Horticulture Crops Research Unit, Corvallis, OR
Period: 2019
Accomplishments and Results:

<u>1) Dry berry disease of *Rubus* in northern Washington.</u>



Raspberry Blackberry

- We successfully obtained the only known culture of *Rhizoctonia rubi* described by McKeen as the fungal pathogen that causes dry berry in British Columbia, CA. The culture was deposited in an international culture collection in The Netherlands by Dr. McKeen in 1958.
- We used molecular tests and confirmed that *Rhizoctonia rubi* and dry berry isolates from Lynden red raspberries and Columbia star blackberries are the same fungus.
- Additional molecular tests showed that the dry berry fungus is not a *Rhizoctonia*, but rather belongs to the genus *Monilinia*. Phylogenetic analysis placed it in the *Monilinia alpina* Group, and *Monilinia urnula*, which causes mummy berry of lingonberry, is the most closely-related species.
- With this data, we secured grant funding for 2 two-year projects to sequence genomes of the several isolates of the dry berry pathogen, develop molecular tools to detect the pathogen, and study the epidemiology of dry berry of raspberry.

<u>2) Microbiome Project.</u>

We visited and repeatedly sampled four red raspberry fields of cooperative growers in the Lynden area five times during the 2019 growing season. The sampling trips were done every two weeks, beginning at early bud break (5/2/19) and continued to ripe fruit (7/2/19). Ten replicate samples from each block were 1) quick frozen and stored at -80ºC until processing for molecular characterization of the microbiome and another 10 were 2) processed and spread on two media for enumeration and recovery of fungi, yeasts, and bacteria. An additional sample of 50 ripe fruit were collected from each block to assess the incidence of storage rot. In the 2019 season, we processed 900 tissue samples and stored >1,900 clean isolates of fungi, yeasts, and bacteria, including >200 isolates of *Botrytis*.

- Incidence of *Botrytis* storage rot ranged from 48% to 69% among the fields.
- *Botrytis* was isolated from each raspberry field and at each sampling time, beginning at bud break.
- We collected isolates of the non-fermentative yeast called *Aureobasidium pullulans*, which is the same species as the yeast in the gray mold biocontrol product called 'Botector.' The yeasts in 'Botector' are incompatible with fungicides used for gray mold control. We found that several of the *Aureobasidium* yeast isolates from Lynden red raspberry fields were tolerant of several FRAC groups of fungicides. We will evaluate the capacity of the fungicide tolerant yeasts to suppress *Botrytis*. If successful, they may be tested in an integrated (biocontrol + fungicides) disease control field trial.

Publications: None

2020 Washington Red Raspberry Commission Research Proposal

Continuation Project Proposal **Proposed Duration:** 2 years total

Project Title: Microbiome of developing red raspberry fruit tissues: Year 2.

PI: Virginia Stockwell
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Title: Research Plant Pathologist
Phone: 541-738-4078
Email: virginia.stockwell@usda.gov
Address: 3420 NW Orchard Avenue
City/State/Zip: Corvallis, OR 97330

Year Initiated **<u>2019</u>** **Current Year** **<u>2020</u>** **Terminating Year** **<u>2020</u>**
Total Project Request: Previous year 1 $ 8,350 **<u>Current (Year 2) $ 11,152</u>**

Other funding sources: This is a continuation of a 2019 proposal to 1) collect samples and microorganisms from red raspberry from bud emergence to ripe fruit for a microbiome study and 2) Characterize and compare the 'blossom blight' pathogen from raspberry to the dry-berry pathogen from other *Rubus* spp.

For the second objective from the 2019 proposal, I was awarded two grants (one from NCSFR and another from USDA) totaling ~$180,000 over two years for research on dry berry disease of red raspberry in Washington. Consequently, this continuation proposal is a request for funds to partially support the research described in Objective 1.

Description:
This research is a continuation of a previously-funded project to identify microorganisms (bacteria, yeast, and fungi) present on raspberry from bud-break to harvest. We sampled four fields repeatedly in 2019, from bud break (5/2/19) through ripe fruit (7/2/19), and processed 900 tissue samples. The samples were spread on culture media to isolate fungi, yeasts, and bacteria. We stored over 1900 bacteria, yeast, and fungi (including 200+ *Botrytis* isolates) from these samples by two technicians in my lab. This second year proposal involves using a nonculture-based molecular method to identify and quantify the organisms in each tissue. We will isolate total DNA and sequence the DNA to detect, identify, and quantify the microorganisms in each tissue—this is called a microbiome study.

The specific outcomes of the research will be an assessment of when *Botrytis* is colonizing fruiting tissues of raspberry and the population dynamics and interactions of microorganisms from pre-bloom to fruit maturity (3, 6). This data can provide information for questions such as: which microorganisms are present on flowers and raspberry fruit, when do various organisms colonize tissues, do the organisms persist through fruit development, and does the microbiome vary between years or is it fairly stable?

Justification and Background:
The impact of *Botrytis* on raspberry production in years when climatic conditions support the

infection of flowers and developing fruit is significant and well documented (2, 7). Our previous microbiome project in 2016 had two major outcomes that could impact disease management: 1) demonstrated the increased sensitivity of the microbiome method to detect *Botrytis* throughout the season compared to culture-based methods and 2) showed that *Botrytis* was present in fields at the early sample point of floral bud break. It was not known if the early detection of *Botrytis* was due to the unusual climatic conditions in 2016 (an early and relatively dry season) or if *Botrytis* often is active in fields at bud break. Repeating the microbiome study in 2019 adds robustness and rigor to the findings. By culturing samples, we found that *Botrytis* was active in fields at bud break also in 2019. Separate from this proposal, we are currently working on methods to reduce overwintering inoculum *Botrytis*, which hopefully will reduce disease pressure later in the season.

To my knowledge, this is the only microbiome project looking at the diversity of pathogens and potentially beneficial microorganisms on red raspberry flowers and fruits over time. This research complements the surveys and characterization of diseases of small fruits by Dr. Sabaratnam's group in Abbotsford BC.

This proposed project is unique from the other research groups by examining the behavior of *Botrytis* using sensitive molecular detection methods and also looking at the behavior of *Botrytis* in context to the co-inhabitants of the fruiting tissue. Using the microbiome approach, we also may detect other emerging pathogens, when they are first present on tissues. This information, in turn, may be used to develop weather-based disease risk models.

Relationship to WRRC Research Priority(s):
The proposed research addresses Priority group #1 "Fruit rot, including pre harvest, post harvest, and/or shelf life"

Objective:
1) Define the microbiome of raspberry fruit from bud break to harvest.

Procedures:
This is the second year of a two-year project on the microbiome of red raspberry. In the first year of the project (2019), we sampled raspberry tissues for the microbiome project. Microorganisms were cultured from a complete set of the tissues and stored. This year, we will process another complete set of the tissues that have been stored at -80°C. For these tissues, in 2020, we will use molecular methods to characterize the microbiome.

1) Define the microbiome of raspberry fruit from bud break to harvest. Tissues were sampled in the 2019 growing season from four commercial raspberry fields (two Meeker and two Wakefield) in the Lynden area. These fields also were sampled in 2016. Floral/fruit samples were collected every other week at four points of development: 1) as floral buds emerge, 2) bloom, 3) green fruit, and 4) ripe fruit. Each field had five replicate blocks of labeled plants for sampling. Twenty samples were collected from each replicate block at each sample time. At harvest, an additional 50 fruits were collected from each block and incubated in moist chambers at room temperature to determine gray mold incidence.

Molecular characterization of microorganisms (microbiome). Samples collected in the field were placed and transported on ice, and then immediately frozen at -80°C upon arrival in Corvallis. The samples will be freeze-dried and then total DNA will be extracted from a subsample of each of the tissues. We will construct the microbiome libraries and sequence them at the Oregon State University Core Lab using Illumina-based technology (1, 5). Sequence analysis will detect and identify the genera of fungi, yeasts, and bacteria present and their relative abundance on individual tissues. The nature of work involved in the project requires a two-year time period due to the large number of samples obtained, processed, the collection and storage of nearly 2000 isolates, and the generation of the molecular data.

Anticipated Benefits and Information Transfer:
This project use sensitive methods to detect when specific microorganisms colonize raspberry buds, flowers, and fruit. This provides information about *Botrytis*, and also other pathogens that may be present, and 'who else' is residing in the tissues. We did this in 2016, but buds emerged early and harvest was done in June that year. Repeating the experiment in 2019 provides information on the effect of weather on the microbiome and pathogen emergence. Project results will be shared through presentations at grower and commission meetings and scientific publications.

References:

1. Borman, A.M., Linton, C.J., Miles, S-J., and Johnson, E.M. 2008. Molecular identification of pathogenic fungi. J Antimicrob. Chemot. 61: i7-i12.
2. Dashwood, E. P., and Fox, R. A. 1988. Infection of flowers and fruits of red raspberry by *Botrytis cinerea.* Plant Pathol. 37:423-430.
3. Johnson, K. B. and Stockwell, V. O. 1998. Management of fire blight: A case study in microbial ecology. Annual Review of Phytopathology 36: 227-248.
4. McKeen, W.E. 1959. *Rhizoctonia rubi* sp. nov. associated with the dry-berry disease of the loganberry. Canadian Journal of Plant Science 39: 82-85
5. Steven, B., Huntley, R.B. and Zeng, Q. 2018. The influence of flower anatomy and apple cultivar on the apple flower phytobiome. Phytobiomes 2:171-179.
6. Stockwell, V. O. and Stack, J. P. 2007. Using *Pseudomonas* spp. for integrated biological control. Phytopathology 97: 244-249.
7. Williamson, B., McNicol, R. J., and Dolan, A. 1987. The effect of inoculating flowers and developing fruits with *Botrytis cinerea* on post-harvest gray mold on red raspberry. Ann. Appl. Biol. 111:285-294.

Budget:

	2019 (last year)	2020 (this request)
Salaries[1/]	$ 3,960	$ 1,891
Operations (goods & services) [2/]	$ 3,500	$ 9,000
Travel[3/]	$ 500	$ 110
Meetings	$ 0	$ 0
Other	$ 0	$ 0
Equipment	$ 0	$ 0
Benefits[4/]	$ 390	$ 151
Total	**$ 8,350**	**$ 11,152**

Budget Justification

[1/] McGhee, 1 month salary. McGhee is a part-time technician with experience with microbiomes and molecular characterization of microorganisms.

[2/] Partial support of materials and supplies for molecular reagents, and sequencing costs.

[3/] Stockwell, 1 trip from Corvallis to Lynden; Hotel @ $110/night.

[4/]Benefits are for the part-time technician.

Virginia Stockwell

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:				
Stockwell and Yan	OSU AG Research Foundation	$12,000	2018-2020	5%	RNAseq-guided identification of genes for production of a novel antimicrobial by the biocontrol agent *Pseudomonas fluorescens* A506
Stockwell and Yang	OR Blueberry Commission	$14,406 ($7216 to Stockwell)	4/1/2019 to 3/30/2020	20%	Investigation of Crown Gall Disease in Blueberries
Stockwell	WRRC	$8,350	2/14/2019 2/15/2020	25%	Refining the microbiome of developing red raspberry fruit tissues.
Stockwell	NCSFR	$40,814	10/1/2019 to 9/30/2020	25%	Identification of the fungal pathogen causing dry-berry and development of tools for rapid identification.
Stockwell	USDA Postdoctoral Program	$140,000	5/1/2020-4/30/2022	15%	Shedding light on a stealth killer of blackberries and raspberries
	Pending:				
Stockwell	WRRC	$ 8,350	2/14/2019 2/15/2020	25%	Microbiome of developing red raspberry fruit tissues: year 2 (this proposal)
Stockwell and Yang	OR Blueberry Commission	$14,244 ($7,216 to Stockwell)	4/1/2020 to 3/30/2021	20%	Field Development of Aerial Gall Disease in Blueberries

SOILS

Washington Red Raspberry Commission
Progress Report Format for 2019 Projects

Project No: 3419-3144

Title: Reducing alleyway tillage to decrease costs and improve soil health

Personnel:
Principal Investigator: Deirdre Griffin LaHue, Assistant Professor of Soil Quality and Sustainable Soil Management
E-mail: dgriffin@wsu.edu **Phone:** (202) 415-3614
Mailing address: Washington State University (WSU) Northwestern Washington Research and Extension Center (NWREC)16650 SR 536, Mount Vernon, WA 98273

Co-Principal Investigators:
Chris Benedict, Gabriel LaHue, Lisa Wasko DeVetter

Other personnel: Toby Una (M.S. Student), Betsy Schacht (Scientific Assistant)

Reporting Period: 2019, Terminating project

Accomplishments:

The impacts of an alternative alleyway tillage management strategy on soil physical health and labor costs were evaluated in a 'Meeker' red raspberry (*Rubus idaeus*) field in Lynden, WA. An Imants Rotary Spader 40 Sx series (hereafter referred to as "spader") was investigated as a possible alternative to numerous passes with a rototiller and chisel plow that are commonly used to incorporate cover crop biomass in spring and relieve compaction after harvest. The spader is described as being able to incorporate biomass in a single pass and to limit formation of a plow pan. The grower collaborators were interested in whether use of the spader could reduce labor needed to manage red raspberry alleyways and create less disturbance to the soil, and this was the purpose of our study.

In Fall 2018, an 8-row trial was set up in a randomized complete block design, with four rows of a "grower practice" treatment and four rows of spader. For the fall tillage routine, the grower practice consisted of a single pass of a subsoiler, rototiller, chisel plow, and cultivator, while the spader practice consisted of a single pass with the spader. For the spring tillage routine, the grower practice consisted of a single pass of a cane chopper, chisel plow, rototiller, followed by another pass with the chisel plow, while the spader practice consisted of a single pass each with a cane chopper and spader.

Soil samples and measurements of penetration resistance (compaction) were collected before and after spring and fall tillage events. Field saturated hydraulic conductivity (similar to infiltration) was also measured before and after tillage in Fall 2019. Labor cost calculations were completed based on the number of equipment passes, the time required to complete each pass, and a labor cost rate of $17 based on a published WSU Enterprise Budget (Galinato and DeVetter, 2016).

The time required to recover the cost of purchasing the spader was also estimated.

This project provides quantitative evidence regarding the suitability of the spader, an implement being used in some annual cropping systems, for use in red raspberry systems. It has generated better information about the degree and depth profile of alleyway compaction after raspberry harvests, how well tillage operations alleviated compaction in this trial, and the impact that compaction had on water movement in alleyway soils.

Results:

We found that the spader reduced compaction from 6”-14” compared to the grower’s standard practice. This pattern emerged after the first spader pass in Fall 2018 (Figure 1A) and remained through the winter (Figure 1B) and harvests until post-tillage in Fall 2019 (Figure 1C). Though this reduction in compaction may be beneficial for water movement and soil aeration, there is anecdotal evidence that the spader created void spaces that caused issues with subsequent sprayer traffic. Therefore, another pass with a cultivator or other implement may be required to settle the soil.

These differences in compaction did not translate to measured differences in water movement. The field saturated hydraulic conductivity in Fall 2019 was impacted by tillage occurrence (before vs. after tillage), but there was no statistically significant difference between grower practice vs. spader, though conductivity was numerically higher with the spader than in the grower practice treatment after tillage (Figure 2).

Several biological soil health measurements are still ongoing, but active carbon (a measure of microbially available carbon) was measured before and after tillage in Spring 2019 when cover crops were incorporated. Post-tillage active carbon was slightly higher with the spader than the grower practice treatment at the 6”-12” depth (Figure 3), which may indicate that the spader promotes better biological soil health. However, additional soil health analyses being performed (microbial community analysis and microbial biomass) will help to further elucidate this effect.

Labor cost savings from using one pass of the spader to replace several passes of a chisel plow, rototiller, and subsoiler (in fall) were calculated to be approximately $11/acre per event (i.e. $22/acre per year in 2 events). However, to do a full cost analysis, fuel cost savings will need to be factored in. Considering labor alone, these cost savings could offset the higher price of the spader in 1-2 years in high acreage (500+ acres) operations.

Publications:

This information was presented at the Washington Small Fruit Conference in Lynden, WA on December 5, 2019, and will also be published in a peer-reviewed journal, such as Hort Technology.

References:

Galinato, S., L. DeVetter. 2015 Cost Estimates of Establishing and Producing Red Raspberries in Washington State. (2016) WSU Extension Publication TB21

Appendix.

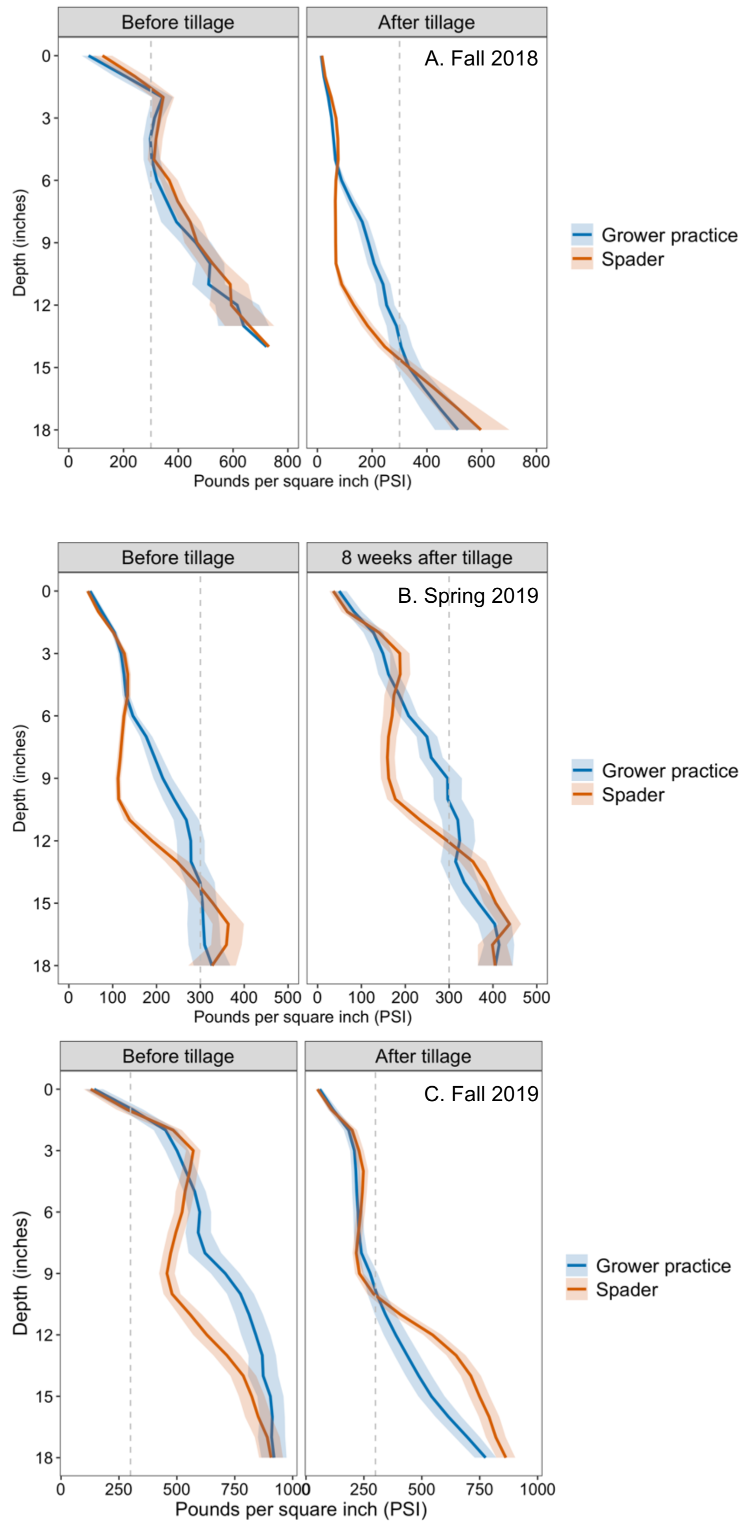

Figure 1. Soil penetration resistance patterns with depth (inches) before and after tillage in A) Fall 2018, B) Spring 2019, and C) Fall 2019. Shaded areas represent the 95% confidence interval, and non-overlapping shaded regions are considered significantly different. The grey dotted line at 300 PSI represents a threshold for compaction.

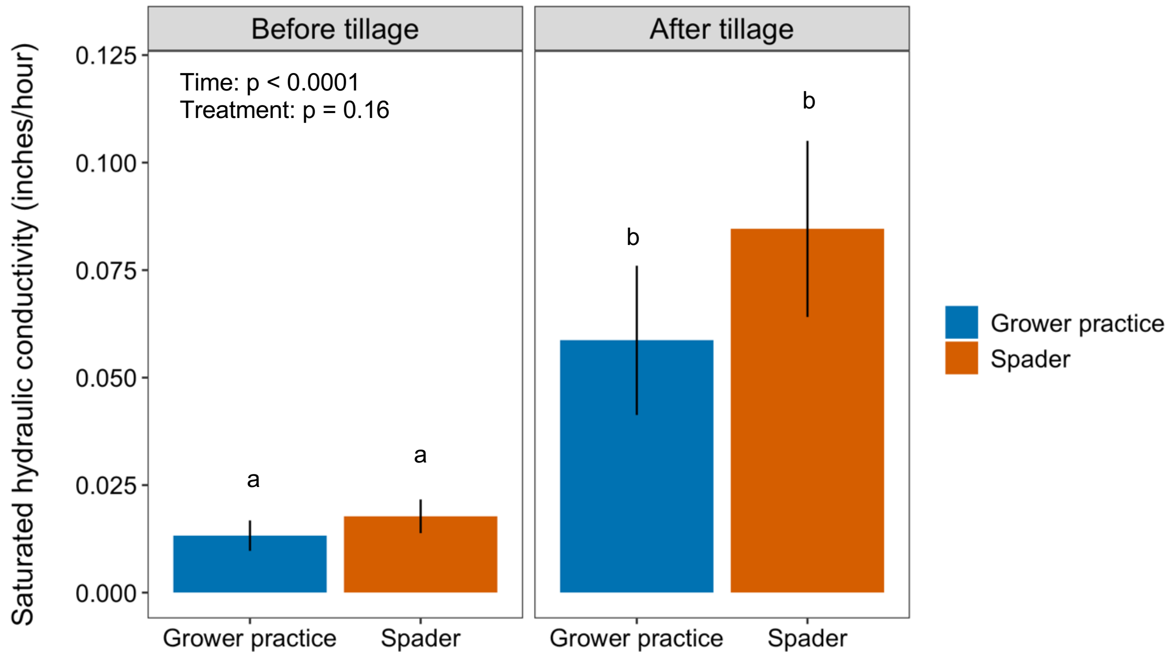

Figure 2. Field saturated hydraulic conductivity measured in Fall 2019. Bars show the mean of 4 replicates and error bars represent standard error.

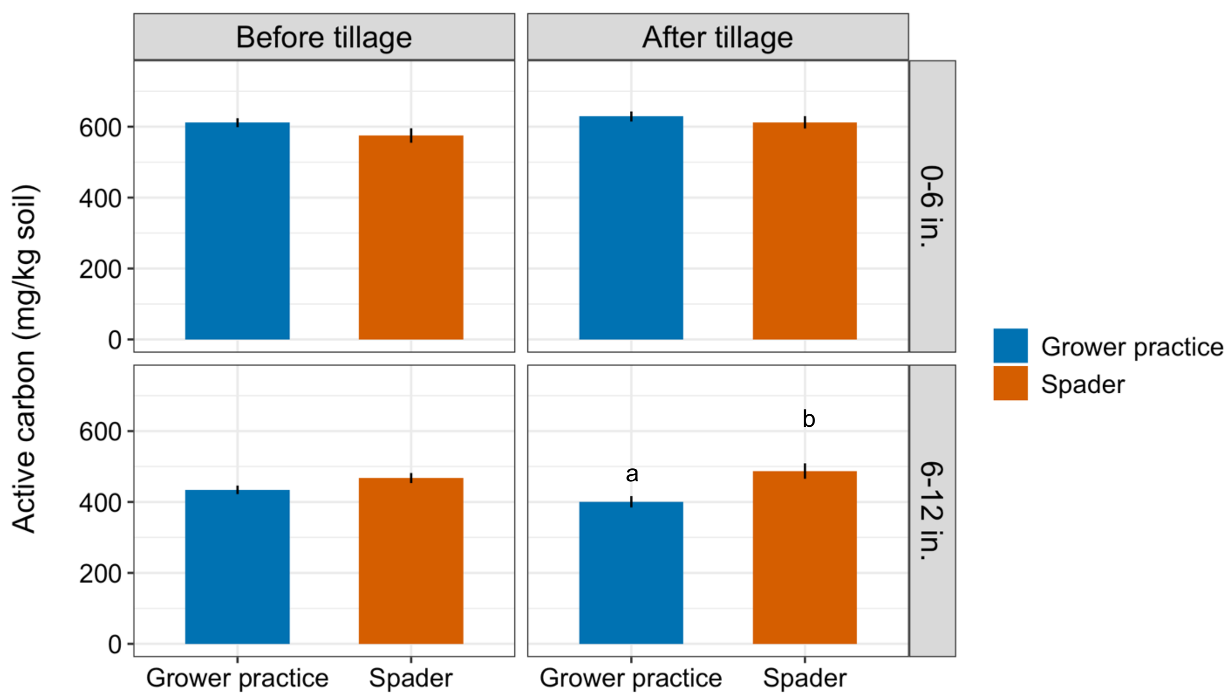

Figure 3. Active carbon (permanganate-oxidizable carbon) in soil before and after tillage in Spring 2019. Bars show the mean of 4 replicates and error bars represent standard error.

Washington Red Raspberry Commission Research Proposal

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

Title: Measuring and mitigating soil compaction in red raspberry fields for improved soil conditions

Principal Investigator:
Deirdre Griffin LaHue, Assistant Professor of Soil Quality and Sustainable Soil Management
E-mail: d.griffin@wsu.edu **Phone:** (360) 848-6127
Mailing address: Washington State University (WSU) Northwestern Washington Research and Extension Center (NWREC) 16650 State Route 536, Mount Vernon, WA 98273

Co-Principal Investigators:
Chris Benedict, Agriculture Agent, Whatcom County Extension
E-mail: chrisbenedict@wsu.edu **Phone:** (360) 778-5809
Mailing address: 1000 N. Forest Street, Suite 201, Bellingham, WA 98225

Haly Neely, Assistant Professor of Spatial Soil and Water Management
Email: h.neely@wsu.edu, **Phone:** 509-335-0947
Mailing address: Johnson Hall, PO Box 646420, Pullman, WA 99164-6420 USA

Gabriel LaHue, Assistant Professor of Soil Science
E-mail: gabriel.lahue@wsu.edu **Phone:** (360) 848-6146
Mailing address: WSU NWREC, 16650 SR 536, Mount Vernon, WA 98273

Year Initiated__2020____ Current Year_2020____ Terminating Year __2020_____

Total Project Request: Year 1 $14,664

Other funding sources: None

Justification and Background:

Soil compaction can be a major challenge in agricultural systems, affecting water infiltration and drainage, water holding capacity, soil aeration, and root growth. Compaction occurs when soil pores, which ideally make up 40-50% of the soil volume, are compressed, limiting air, water, and biological movement and increasing the hardness of the soil. Wet soils are particularly susceptible to compaction; however, in high rainfall areas like western Washington, this is difficult to avoid. With reduced water drainage in compacted soils, it can be even more difficult to access fields for operations in early spring and early fall. Though the raised beds in perennial systems like raspberry do not receive traffic after establishment, alleyways between rows are subject to intensive traffic and may be an area where compaction is an issue. In particular, the high number of harvests involved in raspberry may contribute to compaction issues.

Raspberry growers in Whatcom County have expressed interest in better understanding soil compaction in alleyways, including 1) how soil compaction affects drainage and soil saturation in raspberry production fields; 2) how soil properties (e.g. soil texture or organic matter) impact the severity of compaction; and 3) how current alleyway management practices, including equipment use and ground cover, improve or worsen soil compaction. Additionally, documented compaction thresholds in annual production systems may not transfer to perennial systems in this region. In order to improve management of soil compaction, we must first understand and measure the problem and what factors affect it.

We plan to collect this information through a compaction survey of raspberry fields of Whatcom County. To our knowledge, this data has not been collected before; however, a recent compaction survey of non-berry land in Whatcom county, including corn, pasture, and hay fields, was conducted by Dr. Heather MacKay and her student in order to assess potential for groundwater recharge. We have been in touch with Dr. MacKay and discussed potential for synergistic activities to maximize the information gained from our respective research projects.

Relationship to WRRC Research Priority(s):

This research project addresses the research priority of "Labor saving practices", as this project is a step toward optimizing time-intensive alleyway tillage operations. There may be a linkage to soil borne disease management as compacted soils are more likely to have standing water which can may lead to increases in disease such as Phytophthora root rot. This initial phase of this project will not, however, quantify the presence of this disease but we anticipate in future iterations the inclusion of such assessments. Numerous growers in western Washington have expressed specific interest and support for this project, through feedback during the WA Red Raspberry Commission Research Review and in individual conversations. Growers have asked questions about how much compaction may be an issue in red raspberry fields and whether the current methods they are using to manage alleyway compaction are indeed helping to relieve compaction in the long-term.

Objectives:

The objectives of this assessment are:

1) Measure soil compaction within raised beds and alleyways of raspberry fields in Whatcom County,
2) Evaluate how soil compaction may be related to soil type (e.g. soil texture, soil organic matter content), alleyway ground cover, and equipment use (e.g. type, number of passes),
3) Determine how soil compaction is impacting water movement (e.g. infiltration) in alleyways, and
4) Collect preliminary data on the effectiveness of current management practices used to mitigate compaction.

Procedures:

At least 10 raspberry fields will be selected, chosen in collaboration with growers to be as representative as possible of the breadth of raspberry alleyway management practices and soil types. Variability of soil properties within selected fields will be determined first by scanning with a Geonics EM38-MK2 instrument. The EM38 responds to differences in soil properties such as soil texture and moisture content. These measurements are non-destructive and will be used to inform sampling locations so that measurements are strategic in representing the field. This will be done in spring 2020.

Figure 1. The Geonics EM38-MK2 (left) and an example of a utility vehicle pulling the EM38 in a sled for non-invasive soil mapping (right).

A nested sampling design will be used within each field to collect penetration resistance measurements (Objective 1), soil core samples for soil texture, moisture content, and organic matter analysis (Objective 2), and measurements of field saturated hydraulic conductivity to estimate the ability of water to move through the soil (Objective 3). Within a single field, we will take penetrometer measurements at approximately 20 locations, soil cores at 10 locations, and saturated hydraulic conductivity measurements at 4 locations (Figure 2). At each penetrometer location, measurements will be taken horizontally across the alley to assess where compaction is most significant. A trailer- or ATV-mounted penetrometer will be used to measure soil penetration resistance, giving a force per unit area (e.g. PSI) at depth increments of 1 inch (see Figure 3 for a similar model). The use of a hydraulic penetrometer removes any human influences that introduce variability and make sampling at depth more difficult. Our target measurement depth is 36 inches, though this may be adjusted based on soil depth and compaction level. Soil cores will be split

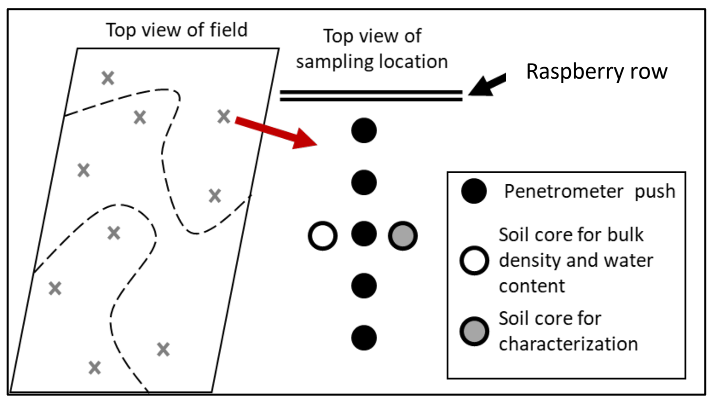

Figure 2. Proposed sampling scheme including locations for samples across the field and locations for multiple penetrometer measurements across the raised bed and alleyway.

Figure 3. Truck-mounted penetrometer similar to the one to be used in this proposed study.

by soil horizon for measurement of soil properties. Field saturated hydraulic conductivity will be measured using a SATURO dual head infiltrometer (METER Group, Inc.).

We will interview participating growers to understand their typical alleyway management regime, e.g. what equipment is used and how often, whether alleyway ground cover is used (Objective 4), and to evaluate relationships between management practices and compaction with the ultimate goal of informing practices to mitigate compaction. We will maintain grower anonymity, with no public identification of specific fields or practices in results.

We propose to collect measurements in late summer after harvests but before fall tillage. Additional timepoints may be identified after talking with growers about key times of alleyway management.

Anticipated benefits and information transfer:

This survey project will help raspberry growers and researchers gain a better understanding of the extent to which compaction is an issue in these systems, 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. Our goal is that this assessment will inform future experiments to test and develop improved compaction management strategies, equipment, and recommendations for raspberry growers. Individual field results will be shared with participating growers, and aggregated results will be shared at the Washington Small Fruit Conference.

Budget:

	2020
Salaries[1/]	$ 6,344
Time-Slip	$ 2,700
Operations (goods & services)	$ 3,150
Travel[2/]	$
Meetings	$
Other	$
Equipment[3/]	$
Benefits[4/]	$ 2,470
Total	**$14,664**

[1/]Betsy Schacht, Scientific Assistant III, 1.5 months at 100% FTE.

[2/] No travel funds are being requested.

[3/] No equipment funds (>$5000) are being requested.

[4/] Benefits: 35% benefit rate for Betsy Schacht. 9.4% benefit rate for time-slip

Funds for Goods and Services include testing for soil texture ($12/sample) and organic matter content ($7 per sample), and supplies including plastic sleeves for a soil sampler ($2 each).

Note: Dr. Haly Neely's program will provide and assist with use of the EM38 and the hydraulic penetrometer, both of which will be purchased and built with her start-up funds.

CURRENT & PENDING SUPPORT

Name: Deirdre Griffin LaHue

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) 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:				
Griffin LaHue, D., Benedict, C., LaHue, G., DeVetter, L.	Washington Red Raspberry Commission	$7070	3/2019-3/2020	5%	Reducing Alleyway Tillage to Decrease Costs and Improve Soil Health
LaHue, G., Griffin LaHue, D., DeVetter, L., Benedict, C.	Washington Blueberry Commission	$15,739	3/2019-3/2020	2%	Valuing Nitrogen Release from High Organic Matter Soils
Griffin LaHue, D.	WSU New Faculty Seed grant	$16,014	5/2019-8/2020	10%	Improving potato system sustainability through locally-relevant soil health indicators
Griffin LaHue, D., McMoran, D., Seefeldt, S.	Northwest Potato Research Consortium	$20,259	5/2019-4/2020	5%	Cover crop alternatives for potato growers
Griffin LaHue, D. Moore-Kucera, J.	American Farmland Trust	$12,000	06/2019-12/2020	3%	A Review of Synergistic Climate-Smart Agricultural Practices for the US Climate Alliance States
Seman-Varner, R. LaHue, D., McGuire, A.	WSDA Specialty Crop Block Grant	$499,996	09/30/2019-09/29/2022	15%	Assessing the soil health of Eastern Washington specialty crops: hops, onion, potato, pulses, sweet corn, tree fruit, and wine grapes
DeVetter et al.	NIFA-SCRI Planning Grant	$49,234	09/1/2019-8/31/2020	1%	New mulch technologies and improved end-of-life management
	Pending:				
Embertson, N.,	NRCS CIG	$415,291		2%	

Clark, C., LaHue, G., Griffin LaHue, D.			01/01/2020- 12/31/2022		Demonstration of the Benefits of Subirrigation Using Water Level Control Structures for Improved Agricultural Irrigation Water Use
Murphy, K., Griffin LaHue, D., LaHue, G., Neely, C., Bruggeman, R., Garland-Campbell, K., McGee, R., Jones, S., Ganjyal, G., Sablini, S., Tang, J., Monsivais, P., Perrigue, M., McCracken, V.	USDA AFRI SAS	$10,000,000	09/2020-09/2025	10%	Optimizing Human Health and Nutrition: From Soil to Society
Griffin LaHue, D., du Toit, L., Gerdeman, B., McMoran, D., Seefeldt, S.	Puget Sound Seed Growers' Association (via NARF)	$12,402	01/2020-01/2021	5%	Evaluating cover crop suitability for improved soil health in vegetable seed systems
Griffin LaHue, D., du Toit, L., Gerdeman, B., McMoran, D., Seefeldt, S.	Washington State Commission on Pesticide Registration	$11,953	01/2020-01/2021	5%	Evaluating potential trade-offs of cover crop species on soilborne pathogens and pests in the context of soil health
Yorgey, G., Hills, K., Griffin LaHue, D. Rajagopalan, K.	WSU ARC	$59,953	01/01/2020- 12/31/2021	2%	Improving the Potential for Nutrient Recovery to Contribute to Improved Nutrient Export and Nutrient Management By Dairies
LaHue, G., Griffin LaHue, D., DeVetter, L., Benedict, C.	WBC	$16,640	01/01/2020- 12/31/2020	2%	Valuing nitrogen release from high organic matter soils
D. Griffin LaHue, C. Benedict, H. Neely, G. LaHue	WBC	$18,046	01/01/2020- 12/31/2020	4%	Measuring and mitigating soil compaction in blueberry fields for improved soil conditions
D. Griffin LaHue, C. Benedict, H. Neely, G. LaHue *(this proposal)*	WRRC	$14,664	01/01/2020- 12/31/2020	4%	Measuring and mitigating soil compaction in raspberry fields for improved soil conditions

CURRENT & PENDING SUPPORT

Name: Gabriel LaHue

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.
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- 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:				
LaHue et al.	Washington Blueberry Commission	$15,739	3/2019 – 3/2020	8%	Valuing nitrogen release from high organic matter soils
Miles et al.	WSU BIOAg Program	$38,969	4/2019 – 3/2020	3%	Evaluating regulated deficit irrigation in cider apple orchards for improved water use efficiency, reduced labor input, and improved fruit quality.
Griffin et al.	Washington Red Raspberry Commission	$7,070	4/2019 – 3/2020	2%	Reducing Alleyway Tillage to Decrease Costs and Improve Soil Health
du Toit et al.	NIFA-SCRI	$3,722,137	10/2019 – 9/2023	5%	Stop the rot: Combating onion bacterial diseases with pathogenomic tools and enhanced management strategies
	Pending:				
Embertson et al.	NRCS-CIG	$415,291	1/2020 – 12/2022	5.8%	Demonstration of the benefits of subirrigation using water level control structures for improved agricultural irrigation water use
Murphy et al.	USDA-SAS	$10,000,000	7/2020 – 7/2025	5%	Optimizing Human Health and Nutrition: From Soil to Society
Miles et al.	WSU Cider Program	$34,816	1/2020 – 12/2020	3%	Evaluating regulated deficit irrigation in cider apple orchards for improved water use efficiency, tree productivity and fruit quality
LaHue et al.	Northwest Agricultural Research Foundation	$13,046	1/2020 – 12/2020	4%	Irrigation scheduling and soil moisture thresholds to maximize spinach seed production
LaHue et al.	Washington State Commission on Pesticide Registration	$10,545	1/2020 – 12/2020	4%	Impacts of irrigation management changes on Stemphylium leaf spot control

LaHue et al.	Washington Blueberry Commission	$16,640	1/2020 – 12/2020	8%	Valuing nitrogen release from high organic matter soils
Griffin et al.	Washington Blueberry Commission	$18,046	1/2020 – 12/2020	2%	Measuring and mitigating soil compaction in blueberry fields for improved soil conditions
Griffin et al.	Washington Red Raspberry Commission	$14,664	1/2020 – 12/2020	2%	Measuring and mitigating soil compaction in raspberry fields for improved soil conditions
LaHue et al.	WSU BIOAg Program	$38,737	1/2020 – 12/2020	4%	Evaluating the contribution of soil organic carbon to improved water-holding capacity through increased compaction resistance

This file MUST be converted to PDF prior to attachment in the electronic application package.

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 - 3/30/20	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
C. Benedict, T. Murray, R. Bomberger	USDA FARMBILL - Improving the First Detector Network in WA ST	$25,529	1/1/18 - 12/31/19	1%	Expanding the Columbia River Invasive Species
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
D. Collins, N. Stacey, C. Benedict, I. Burke, T. Waters	BioAg	$40,000	1/1/19 - 12/31/19	2%	Rotating out of weeds and into soil health: Optimizing cover crops in three Columbia Basin organic production systems.
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
L. DeVetter, S. Galinato, C. Benedict	WA Red Raspberry Commission	$6,635	1/1/19 - 12/31/19	1%	Comparison of Alternate- and Every-Year Production in Summer-Bearing Red Raspberry
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
L. DeVetter,C. Miles, D. Griffin, M. Flury, S. Agehara, S. Wortman, M. Bolda, H. Liu, K. Englund, M. Perez-Garcia, G. Yorgey, T. Marsh, T. Chi, S. Galinato, J. Goldberger, C. Benedict	USDA			1%	Planning Grant: Implementation of New Technologies and Improved End-of-Life Management for Sustainable Use of Agricultural Plastics
			Total % of Active:	**18.00%**	
PENDING:					

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
D. Collins, B. Brouwer, J. Odea, C. Benedict	WSDA SCBG	$199,890	9/3/2020 - 9/29/2023	1%	Winter organic brassica cropping systems: value, weed management, and soil quality
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	WRRC	$10,325	01/01/2020- 12/31/2022	1%	Will Chlorsulfuron Safely Remove Horsetail in Raspberries
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
D. Griffin LaHue, C. Benedict, H. Neely, G. LaHue	WBC	$18,046	01/01/2020- 12/31/2020	2%	Measuring and mitigating soil compaction in blueberry fields for improved soil conditions
D. Griffin LaHue, C. Benedict, H. Neely, G. LaHue	WRRC	$14,664	01/01/2020- 12/31/2020	2%	Measuring and mitigating soil compaction in raspberry fields for improved soil conditions
			Total % of Pending:	**14.00%**	

Project No: WRRC 2019 Contract No 5

Title: Vapam cap, crop termination, and bed fumigation treatments to improve soil fumigation.

Personnel: Thomas Walters (Walters Ag Research), Inga Zasada and Jerry Weiland (USDA-ARS HCRL), Lisa DeVetter (WSU)

Reporting Period: Complete Project Summary (Jan 2017-Dec 2019)

Accomplishments:

- Documented improved weed and root lesion nematode (*Pratylenchus penetrans*) control as well as improved plant growth for two years after bed fumigation with tarping and deeper shanks using Telone C-35 and Strike 60.
- Demonstrated that a Vapam crop termination treatment led to similar reductions in *P. penetrans* population densities as the herbicide treatment.
- Confirmed that shallow-applied Vapam effectively controlled *P. penetrans* with or without deep Strike 60 application in a sandy soil, and that fumigation treatments improved plant growth two years after fumigation.

Results: *Bed fumigation trial.* A field was identified with a history of Phytophthora root rot and a heavy *P. penetrans* infestation. However, this field was cropped to potato for one year and *Phytophthora* was rarely detected via qPCR at this site. A trial area 8 beds wide and 885 ft long was laid out. Four randomly selected beds were fumigated with Strike 60 (14 gpa) and four with C-35 (16.8 gpa) on 10/15/17. Fumigation shanks were kept at standard depth (16" below the top of the bed) for part of each bed, and lowered 2" for a separate section of each bed. A further section of each bed was covered with a TIF tarp (VAPORSAFE®, Raven Industries, Sioux Falls SD) immediately after fumigation. Beds were approximately 14" high when formed.

Because *Phytophthora* was rarely detected, *Phytophthora* inoculum bags were buried at four locations in each bed prior to fumigation; these were retrieved 11/13/17. Unfortunately, data from the inoculum bags were inconclusive, so data were collected on native *Fusarium Verticillium* and *Pythium*, using *Pythium* as a surrogate for *Phytophthora*. None of the treatments significantly reduced detection of *Fusarium*, *Pythium* or *Verticillium*. However, there were some trends that indicated that deep injections or tarped applications of either fumigant have the potential to be more effective than the nontarped application (Figure 1). This effect was particularly noticeable with tarped applications.

Weed control in April 2018 was best in tarped plots, and in plots where shanks were deeper (Figure 2). Similarly, nematode control in Oct 2018 and Sept 2019 was better in these plots (Figure 3). Consistent with our earlier experiments, *P. penetrans* numbers in nontarped plots rebounded within two years of fumigation, but numbers in tarped and deep shanked plots remained low. C-35 generally controlled *P. penetrans* better than Strike 60 did; this difference was significant in tarped plots two years after fumigation. This is probably due to the higher percentage of 1,3-D in C-35.

There were more primocanes per hill in tarped plots as well (Figure 4). In Feb 2019, more canes per hill reached the top wire in tarped plots (Figure 5), and in July 2019, primocanes were taller in tarped plots (Figure 6).

Crop termination trial: Vapam (74 gpa) was applied to old raspberry plants via drip tape on 8/25/17. Foliar symptoms were visible within 5 days. Symptoms were most pronounced when plants were also sprayed with Crossbow and Roundup (Figure 7). Root and soil *P. penetrans* numbers were lower in plots treated with both Vapam and herbicide (Table 1). The field was fumigated by Trident in 2018, and nematodes were not detected in these plots after fumigation. Nematode numbers were not dramatically reduced by crop termination; herbicide treatment reduced the numbers by a similar amount (Table 1).

Vapam cap trials: Two sites were identified; one on Pole Road with a sandy soil, a second on Siper Road with a silt loam soil. Prefumigation deep core samples found *P. penetrans* throughout the soil profile to a 36" depth in the silt loam soil, but only found them to a 12" depth in the sandy soil (Figure 8). At each location, 4 replications of 4 treatments were applied: an untreated check (UTC), Vapam (74 gpa) applied at 5-10" depth, Telone C-35 (35 gpa) applied at 16" depth, or both fumigants. Very few *P. penetrans* were found in post fumigation deep core soil samples. In July 2018, deep core samples of the sandy loam soil found small numbers of *P. penetrans* in Vapam and Vapam + Strike 60 plots (Figure 9), but no nematodes at all in silt loam plots (data not shown). In Sept 2018 and through 2019, substantial numbers of *P. penetrans* were found in soil and roots of UTC plots, but very few in fumigated plots (Figure 10). Once again, no *P. penetrans* were found in the silt loam soil. We sampled elsewhere in the field, and again found no nematodes. Plant growth tended to be better in fumigated plots than in the UTC plots as measured by primocanes per hill, primocane height and primocane weight (Figures 11 and 12).

A Vapam cap performed at least as well as deep-shanked C-35 in the sandy loam soil, and provided superlative control when combined with deep-shanked C-35.

Table 1: Crop termination study *P. penetrans* counts pre- and post- Vapam treatment.

	Pp/50 g soil		**Pp/g root**	
	pretreat	**Post-treat**	**pretreat**	**Post-treat**
UTC	73	83	1955	861
Vapam only	321	136	1490	737
Herbicide only	91	165	922	555
Vapam + Herbicide	124	46	1434	19

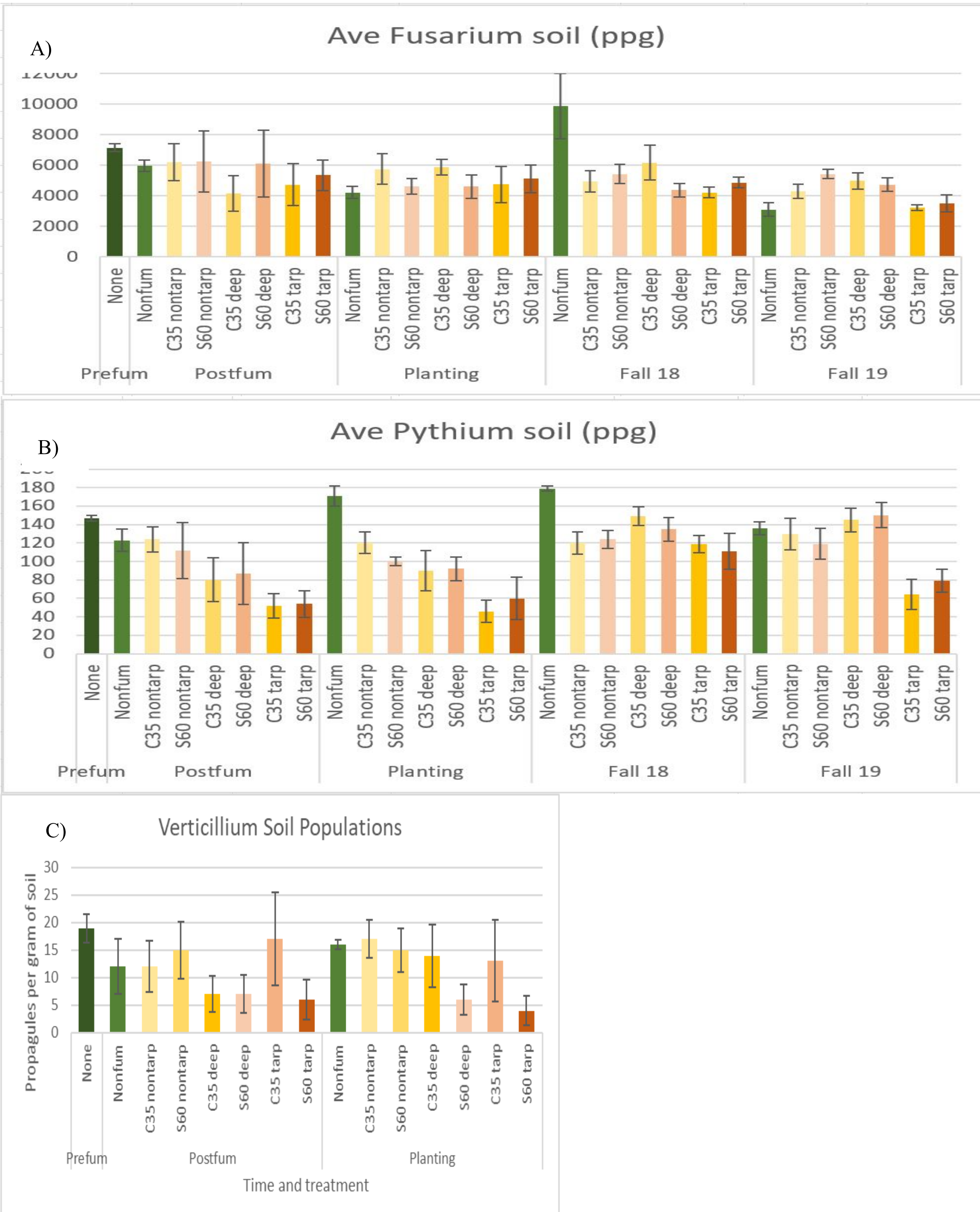


Figure 1. A) *Fusarium*, B) *Pythium*, and C) *Verticillium* populations in bed fumigation trials.

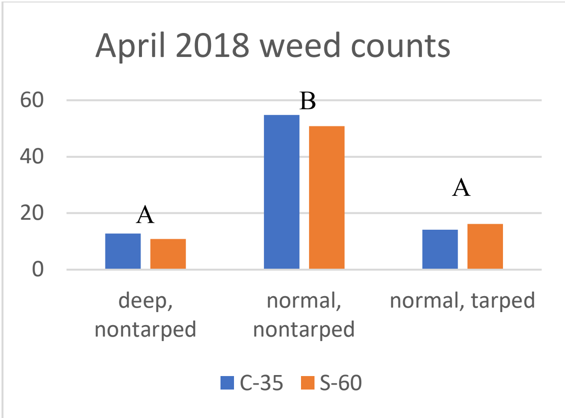


Figure 2. Weed counts in bed fumigation trials April 2018, six months after fumigation.

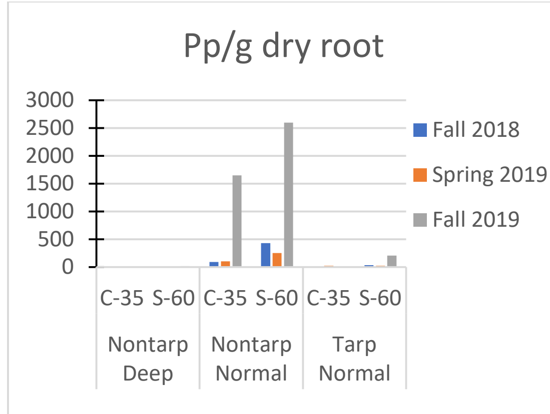


Figure 3. *P. penetrans* per g root in bed fumigation trials October 2018, April 2019 and September 2019, 23 months after fumigation.

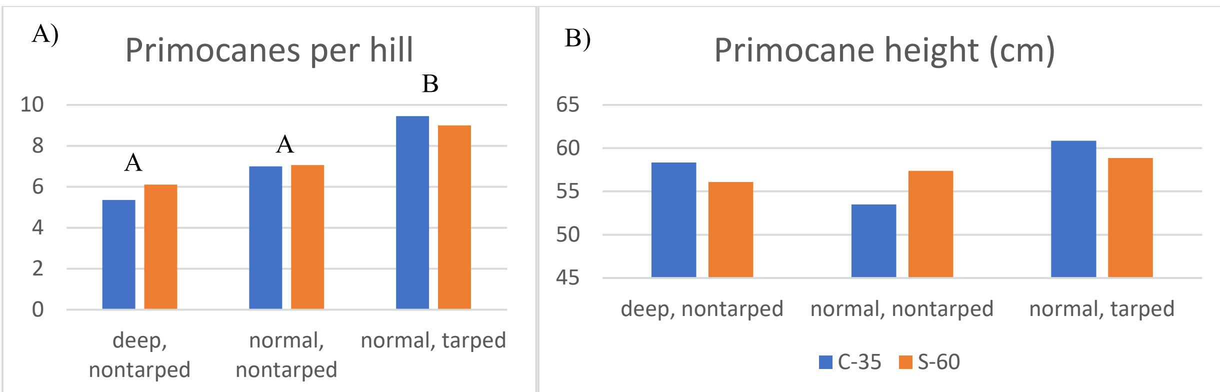


Figure 4. A) Primocanes per hill, and B) primocane height in bed fumigation trials October 2018, 12 months after fumigation.

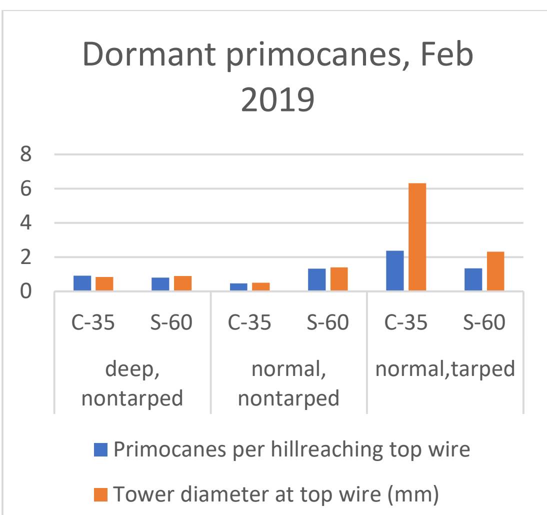


Figure 5. Primocanes reaching top wire per hill, and tower (bundle) diameter at top wire Feb 2019, 16 months after fumigation.

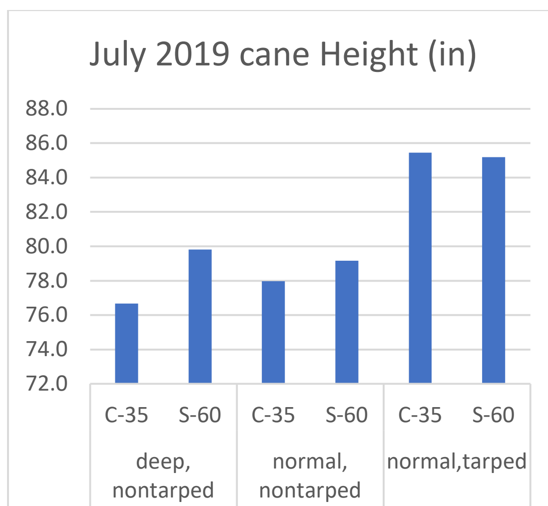


Figure 6. Cane height July 2019, 21 months after fumigation.

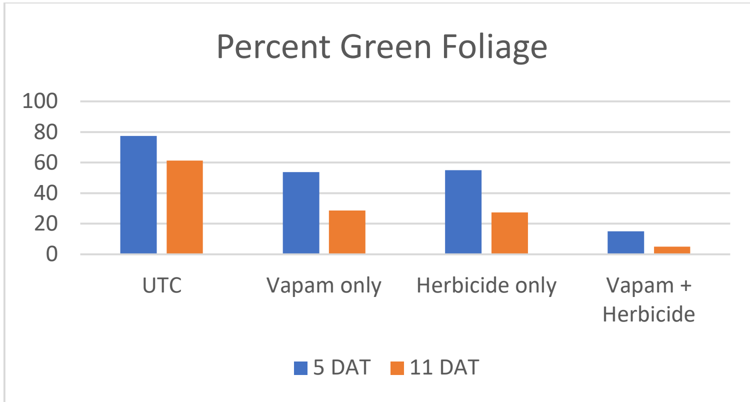


Figure 7. Percent green foliage in crop termination plots treated with Vapam, Herbicide or both 5 and 11 days after Vapam treatment (DAT).

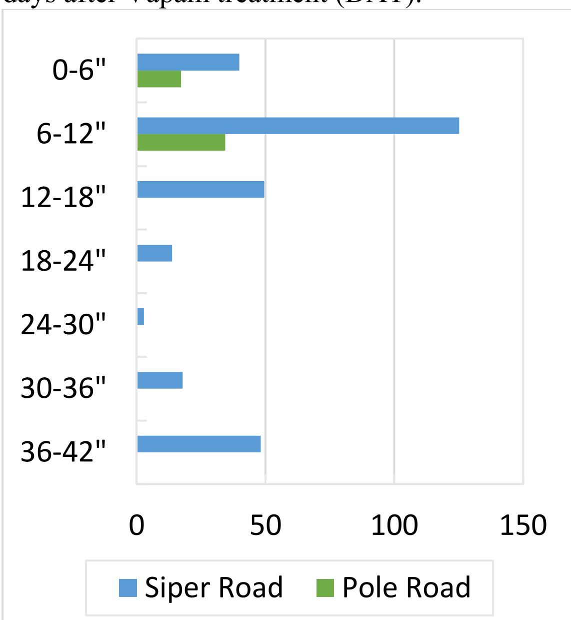


Figure 8. Prefumigation *P. penetrans* per 50 g soil in silt loam (Siper Road) and sandy loam (Pole Road) soils

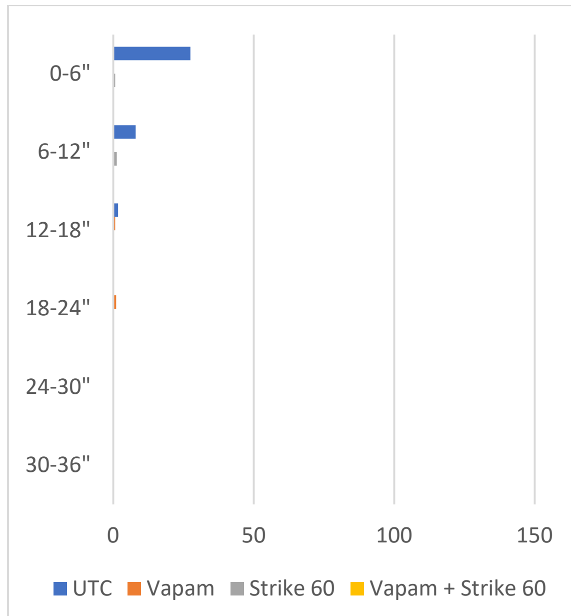


Figure 9. *P. penetrans* per 50 g soil 10 months after fumigation in a sandy loam (Pole Road) soil. No *P. penetrans* were found at the silt loam (Siper Road) location.

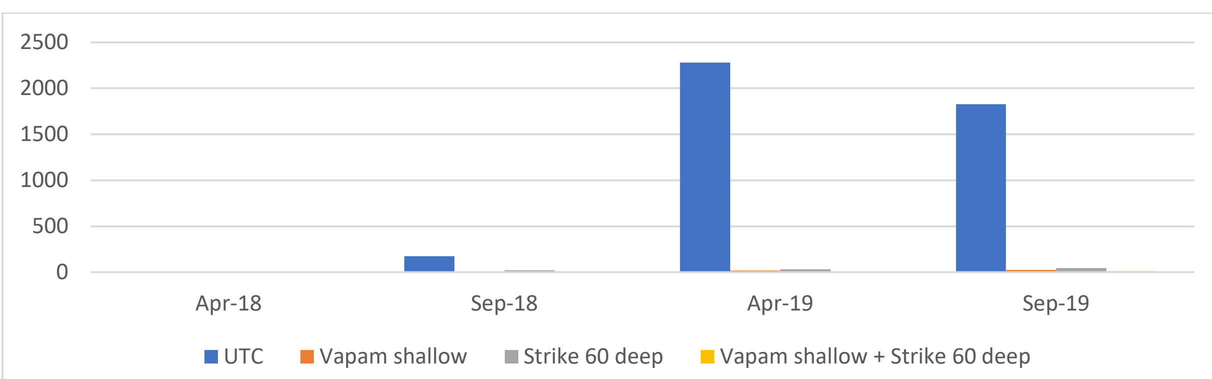
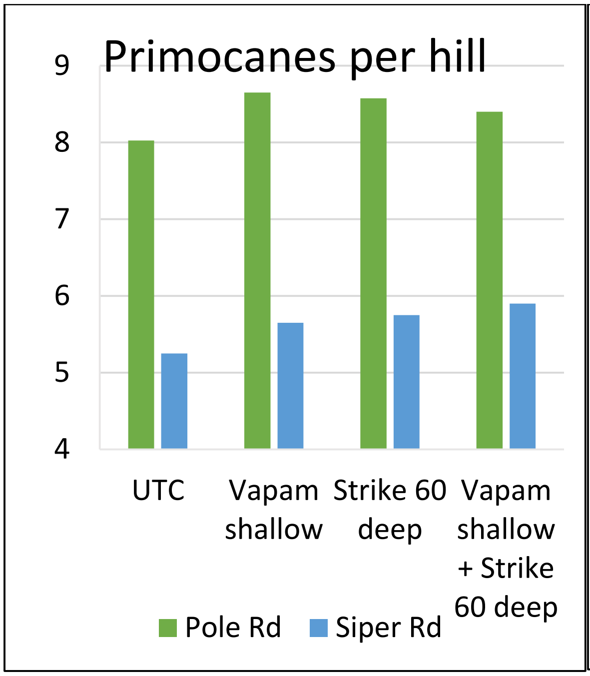


Figure 10. *P. penetrans*/g root in plots up to 23 months after fumigation in a sandy loam soil (Pole Rd).



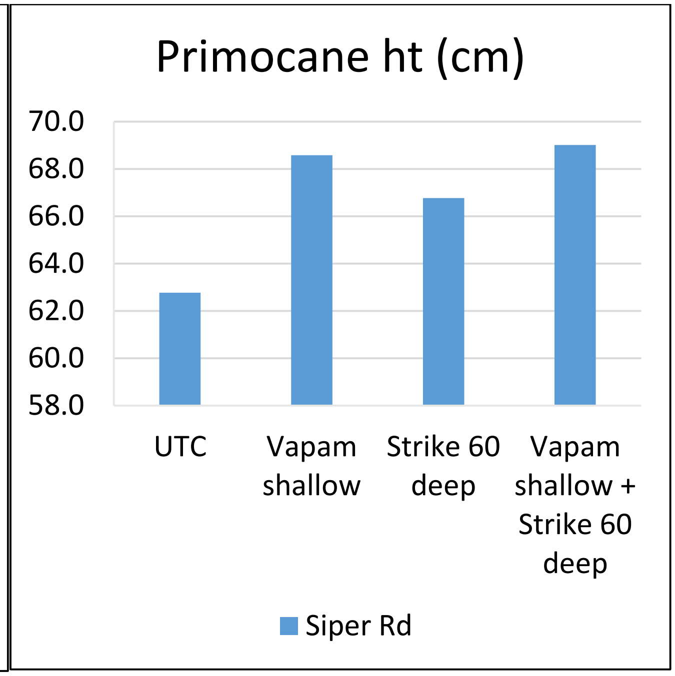


Figure 11. 2018 Plant Vigor (Primocanes per hill and primocane height) at Pole Road and at Siper Road.

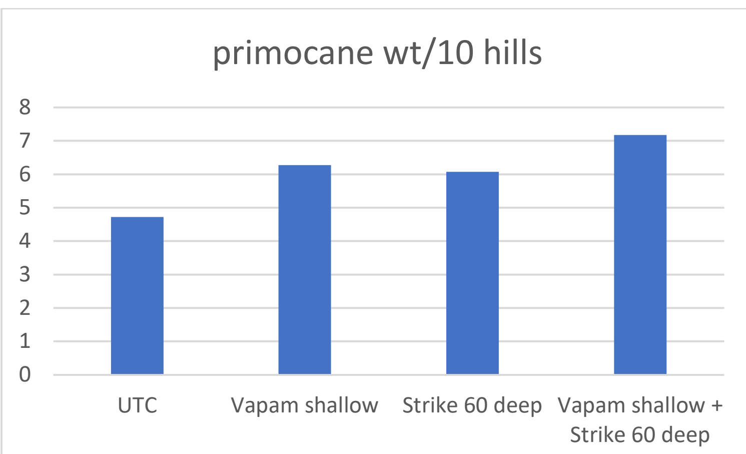


Figure 12. Primocane weight/10 hills at Pole Road March 2019.

2020 WASHINGTON RED RASPBERRY COMMISSION
RESEARCH PROPOSAL

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

Project Title: Fumigant Study Group

PI: Thomas Walters
Owner, Walters Ag Research
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Cooperators: 1-2 grower cooperators TBD

Year Initiated 2020 Current Year 2020 Terminating Year 2020

Total Project Request: Year 1 $3100 Year 2 $ Year 3 $

Other funding sources: DeVetter will use departmental support to fund their travel to California. Zasada will use USDA-ARS funds to support their travel to California or FloridaNone

Description:
This project will study the near-term (5 year) and long-term (10 year) future of soil fumigation for Washington raspberry growers. We will look at the regulatory picture, assessing USEPA, California Department of Pesticide Registration (DPR) and WSDA plans and trends. We will also examine the economics of soil fumigation, bearing in mind the current economic pressures on the Washington raspberry industry. We will also evaluate the potential of alternative practices, such as postplant soil treatments for nematodes and root rot, crop rotation, mustard meals and anerobic soil disinfestation (ASD). Our objectives are to assess the future regulation of commonly used fumigants, their availability and cost futures, and the potential of alternative practices to substitute for or bolster fumigants. The best outcome for this will be for the WRRC to have a plan of action that will guide research on preplant soil treatment for the next 5-10 years.

Justification and Background: (400 words maximum)
Most raspberry growers fumigate their fields prior to planting, and currently have access to practices that work reasonably well. Many growers contract with a custom fumigator (Trident) to apply combinations of 1,3-D and chloripicrin; Trident can apply these as a broadcast treatment or to beds alone, significantly reducing the amount of fumigant used. A couple of growers apply metam products themselves, either alone or in combination with a Trident application. The metam applications are cost effective and work well to manage problems in the upper portions of the soil profile.

However, regulations on soil fumigation have become more restrictive than in the past, and this trend will probably continue. EPA's implementation of buffer zones for chloropicrin application had a significant impact on the way in which broadcast fumigation is conducted in our area, and accelerated the move towards bed fumigation. EPA's current round of soil fumigant reregistration is scheduled to be completed by 2020, with the next round scheduled to start 2022. The state of California currently imposes additional regulations on soil fumigation, and history suggests that these regulations will someday impact Washington growers as well.

Price pressure on raspberry growers calls for a re-evaluation of all practices, especially costly ones like soil fumigation. We will review current and potential practices with an eye to cost effectiveness in this project. We recognize that expensive alternatives to soil fumigation may not be implementable in Washington, even if they work in other systems with higher profit margins.

Why make this assessment? Based on past history, we think that the fumigant picture will probably change in the next 10 years. While the industry could accommodate modest regulatory changes by accelerating the transfer to bed fumigation and by adopting tarps, it's not clear if tarps are affordable in the current economic picture. More dramatic regulatory changes could devastate our industry. Fumigation and similar research is expensive and takes a long time, so we believe that now is a good time to realistically assess the future picture, while we have time to act.

This project will draw upon other projects in the Pacific Northwest, such as Mark Mazzola's apple replant project and potato fumigation research in the Basin. This project will also draw heavily on caneberry and strawberry fumigation and fumigation alternative research in California, Florida and elsewhere. This project would has the potential to benefit raspberry growers in BC and Oregon as well, should WRRC decide to share results with them.

Relationship to WRRC Research Priority(s):
This project directly relates to #3 priority "Soil fumigation techniques and alternatives to control soil pathogens, nematodes and weeds". It also addresses the #2 priority "Understanding soil ecology and soil borne pathogens and their effects on plant health and crop yields", as well as #2 priority "Weed management".

Objectives:

- Assess the future regulation of commonly used fumigants, their availability and cost futures through interviews with regulators and industry members.
- Evaluate the potential of alternative practices to substitute for or bolster fumigants.
- Share these assessments with WRRC members and work with WRRC to develop a research plan based upon these assessments.

Procedures:
We will recruit at least one, preferably two experienced raspberry growers to work with us on this project.

We will conduct in-person and phone interviews with relevant regulatory officials from USEPA, Cal DPR, WSDA and Washington State DOH to assess their perspectives, goals, beliefs and plans for regulation of fumigants currently used by Washington growers, and for regulation of other alternative fumigants. Individuals may conduct the interviews and report back to our group, or we may conduct group interviews with regulators. We will also contact soil fumigant registrants and applicators to get their perspectives on future fumigant price and availability.

Each member of the group will use their own professional networks to gather information about potential practices that could replace or reduce reliance on soil fumigation in the future. The group will work together to decide which practices to include, and to identify pros and cons of each. We will also take suggestions from our grower partners and industry for practices to explore in this assessment.

The group's findings will be presented to growers at the 2020 Washington Small Fruit Conference and will be assembled into a final document for the WRRC to use in developing plans for future research and advocacy. This document may also be distributed through the Small Fruit Update or Whatcom Ag Monthly.

Anticipated Benefits and Information Transfer: (100 words maximum)
This work will provide our industry with a reasonable and informed view towards the 10-year future for soil fumigation. This will allow the WRRC to guide future research or legislative advocacy more effectively. Results will be presented at the 2020 Small Fruit Conference and in a document to the WRRC. The 1-2 growers that participate in this project will also be sources of peer information among the grower community.

References:

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

	2020
Salaries[1/]	$1900
Time-Slip	$
Operations (goods & services)	$
Travel[2/]	$1200
Meetings	$
Other	$
Equipment[3/]	$
Benefits[4/]	$
Total	**$3100**

Budget Justification
[1/]Tom Walters 0.025 FTE, benefits included.

[2/]trip to California or Florida to attend fumigation-related meetings, interview researchers and growers. DeVetter will use departmental support to fund travel to California. Zasada will use USDA-ARS funds to support travel to California or Florida