2019 Research Proposals

and

2018 Research Reports

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

Year	Seat	
21	1	John Clark Lynden
19	2	Randy Honcoop Lynden
20	3	Jessy Ghuman Everson
20	4	Jon Cotton Battle Ground
21	5	Brad Rader Lynden
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Advisory Members
Brett Pehl – Lynden – Agronomy
Joan Yoder – Everson – Food Safety/Treasurer

WRRC Office

Henry Bierlink, Executive Director
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Research Priorities 2019

#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, AY, 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
- Alternative Management Systems – reduce cost of production/lb.
- Maximum Residue Limits (MRL) – residue decline curves, harmonization

#3 priorities

- 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
- Weed management – especially horsetail
- 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

2019 WRRC Proposals and 2018 Research Reports

PAGE	PROJECT TITLE	RESEARCHER (S)	REQUEST	Draft #1	Other $	Source	Approved
PLANT BREEDING			33.11%	0.00%			0.00%
5	Cooperative raspberry cultivar development	Finn	$13,267				
18	Red Raspberry Breeding, Genetics and Clone Evaluation	Moore	$75,000		$32,299	NWCSFR	
24	Coordinated Regional on-farm Trials	Peerbolt	$8,374				
31	Red Raspberry Cultivar Development	Dossett	$10,000				
ENTOMOLOGY			19.78%	0.00%			0.00%
40	Managing SWD with Reduced Insecticide Residues	Schreiber	$17,000		$16,500	WSCPR	
57	Long-term management of BMSB	Gerdeman	$2,346				
63	Factors affecting spider mite outbreaks	Gerdeman	$24,358		$16,922	WSCPR	
71	Development of Biologically-based RNAi Insecticide	Choi	$10,000		$78,300	SCBG	
78	Attract and Kill, New Strategy for SWD Control	Schreiber	$10,000				
WEEDS			0.00%	0.00%			0.00%
82	Determining whether plants should be caneburned - report	Miller					
PHYSIOLOGY			12.05%	0.00%			0.00%
92	Impacts of Mycorrhizal Fungal Colonization	Bunn/DeVetter	$13,822				
102	Comparison of Alternate- and Every-Year Production	DeVetter	$6,349				
107	Multi-season Plastic Mulches for weed mangement and crop growth	DeVetter	$12,625				
116	Application of Biodegradable Mulches in Tissue Culture	DeVetter	$6,022		$6,458	WSCPR	
130	Impact of Nitrogen on Nematode Parasitism	DeVetter					
PATHOLOGY/VIROLOGY			19.96%	0.00%			0.00%
133	Fungicide Resistance in Botrytis in Caneberries	Schreiber	$12,000		$16,000	WSCPR	
155	Control of Cane Blight in Red Raspberries	Schreiber/Jones	$17,750				
159	Biology and control of *Botrytis* fruit rot	Peever	$26,175				
167	Development of novel disease management methods - final report	Stockwell					
169	Refining the microbiome of developing red raspberry fruit tissues	Stockwell	$8,350				
SOILS			6.81%	9.14%			0.00%
175	Vapam Cap, crop termination, bed fumigation treatments	Walters/Zasada	$14,857				
185	Reducing alleyway tillage to decrease costs and improve soil health	Griffin/LaHue	$7,070				
	Total Production Research		**$295,366**	**$0**	**$166,479**		**$0**
	Research Related	WRRC expenses	$5,250	$5,250			$5,250
	Small Fruit Center fee		$2,500	$2,500			$2,500
	TOTAL		**$303,116**	**$7,750**			**$7,750**
	2019 Research Budget		$240,000			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: 2017

Accomplishments: Our goal is develop raspberry cultivars that either 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 commercial suitability 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 are being propagated for more extensive grower trials. All floricane trials were harvested with a Littau machine. Primocane fruiting types have been released and are being adopted for commercial fresh market. Supported in WSU relase of ‘WSU 2166’. We made 45 selections this year (22 floricane, 23 primocane).

Results: In 2018, we made 35 crosses (19 floricane, 16 primocane), made 29 selections (21 floricane, 22 primocane), and planted ~2,500 seedlings. We are now regularly using a Littau machine on our floricane trials and while not perfect, it has worked well. The rose stem girdler that unexpectedly destroyed our new primocanes last year and that lead us to cut those to the ground was largely controlled this year. However it does mean that we did not have any one year old floricanes to harvest. We will harvest them next year. The 2018 results are presented in Tables RY1-RY8. Machine trials in Lynden have pointed to a couple promising selections (Table RY3). In the Lynden Machine harvest trials: 1) While ORUS 4462-2 was only moderate yielding in the 1st year, it was the highest yielding selection in 2018 with good fruit size and firmness similar to ‘Meeker’ and less than ‘Wakefield’, 2) ORUS 4607-2 in its first year looked comparable to ‘Wakefield’ and ‘Cascade Harvest’ with a fairly large berry and fruit firmness similar to or slightly better than ‘Meeker’, 3) Several selections had first year yield similar to ‘Meeker’ and greater than ‘Wake®field’, we will see if this holds up in the second harvest, 4) Most are firmer than ‘Meeker’ and less firm than ‘Wake®Field’. ‘Kokanee’, a primocane fruiter, was released; it is a late season high quality raspberry suited for fresh market sales. Based in part on results from our trials, WSU is releasing ‘WSU 2166’. Multiple ORUS selections were identified as having excellent root rot resistance in Puyallup and will be used in crosses by WSU. 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:

Finn, C.E., Strik, B.C., Peterson, M.E. Yorgey, B.M., Moore, P.P., Jones, P.A., Lee, J., and Martin, R.R. 2018. ‘Kokanee’ primocane-fruiting red raspberry. HortScience. 53:380-383.

Moore, P.P., C.E. Finn, and M. Dossett. 2018. Raspberry, p. 770-771. In: K. Gasic, J.E. Preece, and D. Karp (eds.). Register of new fruit and nut cultivars List 49. HortScience 53:748-766.

Jibran, R., H. Dzierzon, N. Bassil, J.M. Bushakra, P.P. Edger, S. Sullivan, C.E. Finn, M. Dossett, K.J. Vining, R. VanBuren, T.C. Mockler, I. Liachko, K.M. Davies, T.M. Foster and D. Chagné. 2018. Chromosome-scale scaffolding of the black raspberry (*Rubus occidentalis* L.) genome based on chromatin interaction data. Hort. Res. 5:8-,

Bushakra, J.M., M. Dossett, K.A. Carter, K.J. Vining, J.C. Lee, D.W. Bryant, R. VanBuren, J. Lee, T.C. Mockler, C.E. Finn, and N.V. Bassil. 2018. Characterization of aphid resistance loci in black raspberry (*Rubus occidentalis* L.). Mol. Breed. 38:83-102. DOI: 10.1007/s11032-018-0839-5.

VanBuren, R., C. Man-Wai, M. Colle, J. Wang, S. Sullivan, J.M. Bushakra, I. Liachko, K.J. Vining, M. Dossett, C.E. Finn, R. Jibran, D. Chagne, K. Childs, P.O. Edger, T.C. Mockler, and N.V. Bassil. 2018. A near complete, chromosome-scale assembly of the black raspberry (*Rubus occidentalis*) genome. GigaScience 7:1-9

Appendices

Table RY1. Mean yield and berry size in 2017-18 for floricane fruiting raspberry genotypes at OSU-NWREC planted in 2015. Harvested with a Littau (Stayton, OR) machine in 2017-18.

	Berry size (g)	Yield (tons·a^{-1})		
Genotype	2017-18^z	2017	2018	2017-18
2016	4.5 a			3.84 a
2017	3.8 a			4.26 a
2018	3.4 a			4.16 a
Replicated				
ORUS 4607-2	3.7 ab	5.33 a	4.83 a	5.08 a
ORUS 4600-2	4.0 a	4.46 a	5.26 a	4.86 a
ORUS 4600-3	3.3 c	4.21 a	4.57 a	4.39 a
ORUS 4603-1	3.5 bc	3.81 a	4.28 a	4.05 ab
Meeker	3.3 c	3.99 a	3.86 ab	3.93 ab
ORUS 4603-2	3.6 b	3.73 a	2.15 b	2.94 b
Nonreplicated				
ORUS 4611-1	4.2	4.12	2.17	3.14

^{z} Mean separation within columns by LSD, p≤0.05.

Table RY2. Floricane fruiting raspberry genotypes at OSU-NWREC planted in 2016- Would normally be 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.** They look fine for harvest in 2019

Genotype	Berry size (g)^z	Yield (tons·a^{-1})
Replicated		
Nonreplicated		

^{z} Mean separation within columns by LSD, p≤0.05.

Table RY3. Performance of ORUS selections in machine harvest trials in Lynden, Washington at commercial grower fields. Planted in 2016 and 2017.

Genotype	Total yield (tons/acre) 2017	2018	2017-18	Berry weight (g) 2017-18	Firmness (g/mm) 2017	2018	2017-18	Brix (%) 2017	2018	2017-18	Acidity (%) 2017-18	pH 2017-18
Grower 1 2016 planted												
Wake®field	**6.10**	**7.80**	**6.95**	**3.4**	**49.91**	**35.78**	**42.85**	**8.6**	**11.6**	**10.1**	**2.34**	**3.18**
Squamish	**-**	**6.45**	**6.45**	**4.3**	**-**	**30.00**	**30.00**	**-**	**10.7**	**10.7**	**1.74**	**3.32**
Meeker	**4.20**	**7.22**	**5.71**	**3.0**	**37.87**	**13.73**	**25.80**	**10.6**	**11.2**	**10.9**	**1.82**	**3.40**
Cascade Harvest	**3.20**	**7.06**	**5.13**	**5.2**	**34.07**	**24.72**	**29.40**	**9.8**	**11.5**	**10.7**	**1.48**	**3.44**
ORUS 4482-3	2.40	7.67	5.03	5.1	36.10	24.15	30.13	8.8	10.1	9.5	1.78	3.36
ORUS 4089-2	2.60	7.00	4.80	3.3	32.10	23.71	27.91	9.9	10.4	10.2	1.48	3.39
ORUS 4462-2	1.40	8.05	4.72	5.0	30.38	28.44	29.41	8.5	10.9	9.7	1.31	3.55
ORUS 3702-3	3.00	5.48	4.24	5.1	22.26	10.70	16.48	10.2	10.5	10.4	1.43	3.46
ORUS 4373-1	3.00	5.35	4.17	4.5	37.58	28.50	33.04	9.6	9.7	9.7	1.55	3.41

Table RY3. (Cont.)

Genotype	Total yield (tons/acre)	Berry weight (g)	Firmness (g/mm)	Brix (%)	Acidity (%)	pH
Grower 1 2017 planted						
Meeker	**7.91**	**3.85**	**17.65**	**11.6**	**1.4**	**3.53**
ORUS 4371-4	7.46	5.83	25.97	11.3	1.9	3.75
ORUS 4851-1	7.46	6.54	22.80	10.6	1.4	3.42
Cascade Harvest	6.74	5.86	21.38	10.1	1.1	3.64
ORUS 4607-2	6.50	4.86	21.50	10.8	1.8	3.30
ORUS 4465-3	4.98	4.71	17.52	10.1	1.4	3.48
Wake®field	**3.90**	**4.10**	**33.86**	**10.7**	**2.3**	**3.21**
Squamish	**3.72**	**4.67**	**24.54**	**11.0**	**1.8**	**3.27**
Rudiberry	**2.57**	**4.75**	**26.45**	**10.7**	**1.8**	**3.32**

Table RY4. Mean yield and berry size in 2016-2018 for primocane fruiting raspberry genotypes at OSU-NWREC planted in 2015.

Genotype	Berry size (g) 2016-2018	Yield (tons·acre^{-1}) 2016	2017	2018	2016-2018
Non replicated					
Heritage	**1.9**	**1.77**	**5.08**	**5.22**	**4.02**
Kokanee	**3.0**	**2.65**	**1.85**	**2.94**	**2.48**
ORUS 4291-1	2.7	1.96	1.33	2.63	1.97
Vintage	**3.0**	**1.99**	**1.15**	**2.44**	**1.86**
BP1 (Amira)	3.5	1.32	1.58	1.54	1.48

Table RY5. Mean yield and berry size in 2018 for primocane fruiting red raspberry genotypes at OSU-NWREC planted in 2016. Rose stem girdler wiped out 1st harvest in 2017.

Genotype	Berry size (g)		Yield (tons·a^{-1})	
Replicated				
Heritage	**1.9**	**b**	**2.74**	**a**
ORUS 4864-1	2.7	a	1.92	a
Vintage	**2.5**	**a**	**1.89**	**a**
Nonreplicated				
ORUS 4858-2	3.1		4.59	
ORUS 4874-1	2.9		4.50	
Imara	**3.4**		**4.17**	
Kweli	**2.9**		**3.71**	
ORUS 4494-3	4.0		3.71	
ORUS 4873-1	2.4		3.42	
ORUS 4858-3	2.9		3.23	
ORUS 4723-2	4.1		2.79	
ORUS 4872-1	1.9		2.65	
Kokanee	**2.7**		**2.57**	
ORUS 4722-1	3.9		1.90	
ORUS 4722-2	3.6		1.87	
Kwanza	**3.8**		**1.32**	
ORUS 4856-1	2.6		0.86	

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

Table RY6. Mean yield and berry size in 2018 for primocane fruiting red raspberry genotypes at OSU-NWREC planted in 2017.

Genotype	Berry size (g)		Yield (tons·a^{-1})	
Replicated				
Lagorai Plus	**4.2**	**a**	**3.61**	**a**
ORUS 4716-1	2.8	b	2.65	b
Heritage	**2.0**	**b**	**1.86**	**b**
Non replicated				
ORUS 4990-1	3.5		2.19	
ORUS 4988-4	2.4		1.72	
ORUS 5005-1	3.6		1.70	
ORUS 4988-5	2.5		1.47	
Amaranta	**3.0**		**1.35**	
ORUS 5005-3	3.6		1.29	
ORUS 4981-2	2.5		0.91	
ORUS 4989-1	4.7		0.89	
ORUS 4857-1	2.0		0.82	
ORUS 4289-4	1.9		0.74	
ORUS 4291-1	2.1		0.73	
ORUS 4988-2	3.0		0.47	
ORUS 5004-3	3.6		0.42	
ORUS 5004-2	2.6		0.22	
ORUS 5004-5	2.9		0.18	

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 2015 and harvested 2017-18.

Genotype	Year planted	Harvest season 5%	50%	95%	No. years in mean	Rep/ Obsv
ORUS 4611-1	2015	17-Jun	29-Jun	7-Jul	2	Obsv.
ORUS 4607-2	2015	20-Jun	2-Jul	14-Jul	2	Rep
ORUS 4603-2	2015	23-Jun	4-Jul	14-Jul	2	Rep
ORUS 4600-3	2015	24-Jun	4-Jul	16-Jul	2	Rep
ORUS 4600-2	2015	27-Jun	4-Jul	16-Jul	2	Rep
Meeker	**2015**	**26-Jun**	**5-Jul**	**16-Jul**	**2**	**Rep**
ORUS 4603-1	2015	26-Jun	5-Jul	16-Jul	2	Rep

Table RY8. Ripening season for primocane fruiting red raspberry genotypes at OSU-NWREC. Planted in 2016, 2016, or 2017 and harvested 2015-18.

Genotype	Year planted	Harvest season 5%	50%	95%	No. years in mean	Rep/ Obsv
ORUS 4988-2	2017	17-Jul	24-Jul	24-Jul	1	Obsv.
ORUS 4988-1	2017	17-Jul	24-Jul	14-Aug	1	Rep
ORUS 4291-1	2017	24-Jul	31-Jul	21-Aug	1	Obsv.
ORUS 4291-1	2015	4-Aug	5-Aug	19-Aug	3	Obsv.
ORUS 4988-3	2017	17-Jul	7-Aug	14-Aug	1	Rep
Amaranta	**2017**	**17-Jul**	**7-Aug**	**28-Aug**	**1**	**Obsv.**
ORUS 4864-1	2016	24-Jul	7-Aug	21-Aug	1	Rep
ORUS 5005-3	2017	31-Jul	7-Aug	28-Aug	1	Obsv.
ORUS 4981-2	2017	31-Jul	7-Aug	4-Sep	1	Obsv.
ORUS 4289-4	2017	31-Jul	14-Aug	14-Aug	1	Obsv.
ORUS 4858-3	2016	31-Jul	14-Aug	28-Aug	1	Obsv.
ORUS 4873-1	2016	31-Jul	14-Aug	28-Aug	1	Obsv.
ORUS 4988-5	2017	31-Jul	14-Aug	4-Sep	1	Obsv.
ORUS 4872-1	2016	31-Jul	14-Aug	18-Sep	1	Obsv.
ORUS 4988-4	2017	7-Aug	14-Aug	21-Aug	1	Obsv.
Lagorai Plus	**2017**	**7-Aug**	**14-Aug**	**28-Aug**	**1**	**Rep**
ORUS 5005-2	2017	7-Aug	14-Aug	28-Aug	1	Rep
ORUS 5005-1	2017	7-Aug	14-Aug	4-Sep	1	Obsv.
BP-1 (Amara)	**2015**	**27-Jul**	**15-Aug**	**29-Aug**	**3**	**Obsv.**
ORUS 4858-2	2016	31-Jul	21-Aug	4-Sep	1	Obsv.
Vintage	**2016**	**31-Jul**	**21-Aug**	**4-Sep**	**1**	**Rep**
Heritage	**2016**	**7-Aug**	**21-Aug**	**4-Sep**	**1**	**Rep**
Imara	**2016**	**7-Aug**	**21-Aug**	**11-Sep**	**1**	**Obsv.**
ORUS 4494-3	2016	7-Aug	21-Aug	11-Sep	1	Obsv.
ORUS 5004-2	2017	14-Aug	21-Aug	21-Aug	1	Obsv.
ORUS 4289-3	2016	14-Aug	21-Aug	4-Sep	1	Obsv.
Heritage	**2017**	**14-Aug**	**21-Aug**	**11-Sep**	**1**	**Rep**
ORUS 4856-1	2016	14-Aug	21-Aug	11-Sep	1	Obsv.
Vintage	**2015**	**5-Aug**	**22-Aug**	**5-Sep**	**3**	**Rep**
Kokanee	**2015**	**8-Aug**	**22-Aug**	**12-Sep**	**3**	**Rep**
Heritage	**2015**	**12-Aug**	**24-Aug**	**7-Sep**	**3**	**Rep**
Kweli	**2016**	**7-Aug**	**28-Aug**	**11-Sep**	**1**	**Obsv.**
Kokanee	**2016**	**7-Aug**	**28-Aug**	**18-Sep**	**1**	**Obsv.**
ORUS 4857-1	2017	14-Aug	28-Aug	4-Sep	1	Obsv.
Kwanza	**2016**	**14-Aug**	**28-Aug**	**11-Sep**	**1**	**Obsv.**
ORUS 4716-1	2017	14-Aug	28-Aug	11-Sep	1	Rep
ORUS 4723-2	2016	14-Aug	28-Aug	18-Sep	1	Obsv.
ORUS 4874-1	2016	14-Aug	28-Aug	18-Sep	1	Obsv.
ORUS 4990-1	2017	14-Aug	4-Sep	26-Sep	1	Obsv.
ORUS 4722-1	2016	28-Aug	18-Sep	26-Sep	1	Obsv.

ORUS 4722-2	2016	28-Aug	18-Sep	26-Sep	1	Obsv.
ORUS 4989-1	2017	11-Sep	18-Sep	26-Sep	1	Obsv.
ORUS 5004-3	2017	11-Sep	18-Sep	26-Sep	1	Obsv.
ORUS 4861-1	2016	18-Sep	18-Sep	26-Sep	1	Obsv.
ORUS 5004-5	2017	18-Sep	26-Sep	26-Sep	1	Obsv.

Project Title: Cooperative raspberry cultivar development program

PI: Chad Finn,
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Cooperators: Pat Moore, WSU
Michael Dossett Agriculture and Agri-Foods Canada

Year Initiated __2013___ **Current Year** 2019-2020__ **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 industry in the northwest. 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 (Of Note 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.
- Viruses/crumbly fruit, pollination
- Foliar & Cane Diseases – i.e. spur blight, yellow rust, cane blight, powdery mildew, etc.

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 (Of Note Priority).
- To develop cultivars using new germplasm that are more vigorous and that may be grown using reduced applications of nutrients and irrigation (#2 Priority) and that are less reliant on soil fumigation (#1 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 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 Washington and B.C. 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 new raspberry cultivars that either 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.

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-2-5, 4 months)	$9,667
Operations (goods & services)	1,000
Travel[1]	1,500
Other: "Land use charge" ($3,500/acre)	1,000
Total	**$13,267**

[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:					
Strik, BC, and Finn, C.E.	Oregon Blueberry Commission	$18,520	7/2018-6/2019	2	Cooperative Breeding Program-Blueberries
Finn, C.E.	Oregon Blueberry Commission	$11,996	7/2018-6/2019	4	Developing PNW Cultivars That May Resist Blueberry Shock Virus
Strik, B.C. and C.E. Finn	Oregon Raspberry and Blackberry Commission	$38,640	7/2018-6/2019	4	Production System/Physiology Research and Cooperative Breeding Program-Raspberries and Blackberries
C.E. Finn	Oregon Strawberry Commission	$8,679	7/2018-6/2019	2	Breeding day-neutral strawberries in Corvallis, OR
Strik, B.C. and C.E. Finn	Oregon Strawberry Commission	$16,500	7/2018-6/2019	4	Cooperative Breeding Program - Strawberries
Iezzoni, A., C. Peace, K. Gasic, J. Luby, C. Finn, J. Norelli, D. Main and 27 others (including P. Moore)	USDA Specialty Crop Research Initiative	$10 million total; $1.8 million annual; $15K to USDA Breeding	10/2014-9/2019	5	RosBREED: Combining Disease Resistance With Horticultural Quality In New Rosaceous Cultivars
Finn, C.E.	Washington Blueberry Commission	$17,071	7/2018-6/2019	4	Developing commercial blueberry cultivars adapted to the Pacific Northwest with an emphasis on tolerance of Blueberry shock virus (BlShV)
Finn, C.E.	Washington Red Raspberry Commission	$5,000	7/2018-6/2019	2	Cooperative raspberry cultivar development program.
Name(List PI #1 first)					
Pending:					

Finn, C.E.	Washington Red Raspberry Commission	$13,267	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	$38,640	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	$18,147	7/2019-6/2020	4	Developing commercial blueberry cultivars adapted to the Pacific Northwest with an emphasis on tolerance of Blueberry shock virus (BlShV)

Project: 13C-3755-5641
TITLE: Red Raspberry Breeding Genetics and Clone Evaluation
PROJECT LEADER: Patrick P. Moore, Professor
Wendy Hoashi-Erhardt, Scientific Assistant
WSU Puyallup Research and Extension Center
Reporting Period: 2018
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** has been recommended for release by the Release Committee, patent application filed and plants should be available in 2019. **WSU 2166** is an early season selection with large, firm, good flavored fruit that machine harvests very easily. It is not immune to root rot, but appears to have good levels of tolerance. **WSU 2188** will be evaluated again in 2019 and if performance warrants, may be recommended for release.
Crosses/selections. Crosses made in 2018 emphasized parents that are machine harvestable and root rot resistant. Seventy-five of the 79 crosses had at least one parent that has root rot resistance in its background. All of the crosses had at least one parent with good machine harvestability. Thirty-one selections were made in 2018 from seedlings planted in 2016.
Machine Harvesting Trials. A new machine harvesting trial was planted in 2018 in Lynden with 35 WSU selections, 12 ORUS selections and 'Cascade Harvest', 'Meeker' and 'Willamette'. This planting will be harvested in 2020 and 2021. The 2015 and 2016 planted machine harvesting trials were harvested in 2018 and subjectively evaluated.
Grower trials.
Four WSU selections were planted in Grower Trials in 2014. On one site **WSU 1980** and **WSU 2122** did not perform well due to root rot, while **WSU 2166** performed well. **WSU 2188** had some winter damage in 2016 but appeared healthy and vigorous in other years. **WSU 1914, WSU 2010,** and **WSU 2162** were planted in Grower Trials in 2017. These selections will be harvested in 2019 and 2020. **WSU 1914** and **WSU 2010** have parents that are tolerant of root rot. **WSU 2162** appears to be susceptible to root rot, but will continue to be evaluated. **WSU 1962, WSU 2068** and **WSU 2069** were planted in Grower Trials in 2018. Additional selections will be planted in the next Grower Trial.
Selection Trial Puyallup. The 2015 and 2016 replicated plantings at Puyallup were hand harvested in 2018. In the 2015 selection trial, **WSU 2001** and WSU **2088** had the highest yield in 2017 and **Cascade Harvest** and **WSU 2088** had the highest yield in 2018 (**Table 1**). In the 2016 selection trial, **WSU 2087, WSU 2130** and **WSU 2088** had the highest yields (**Table 2**). Problems with the irrigation system in 2018 may have resulted in reduced yields.
Results: Several raspberry selections tested in machine harvesting trials appear very promising: machine harvesting well, productive, with good fruit integrity, good flavor and some with probable root rot tolerance. **WSU 2166** was recommended for release by the Cultivar Release Committee and a patent application has been filed. Plants should be available in 2019.
Publications/Presentations
North Willamette Horticultural Society, Canby, OR. January 11, 2018
Strawberry and Raspberry Cultivar Development at Washington State University. LMHIA, Abbotsford, BC. January 25, 2018
Machine Harvesting Field Day Lynden, WA July 12, 2018

Table 1 2017/18 harvest of 2015 planting, Puyallup, WA.

	Yield (t/a)		Fruit rot (%)		Fruit weight (g)		Fruit firmness (g)		Midpoint of Harvest	
	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017
WSU 2088	4.26 ab	9.12 ab	23.5% ab	4.3% b	3.43 ab	3.36 a	365 a	181 a	7/11 a	7/16
WSU 2001	2.73 c	9.96 a	30.3% b	7.9% b	3.52 a	3.52 a	275 b	132 b	7/11 a	7/16
C Harvest	5.12 a	7.19 bc	18.3% ab	14.6% ab	3.66 a	3.69 a	238 bc	108 bc	7/3 b	7/11
Meeker	4.06 a-c	7.11 bc	18.2% ab	7.2% b	2.89 bc	2.89 b	232 bc	86 cd	7/8 a	7/9
WSU 2133	3.58 bc	7.26 bc	11.3% b	5.7% b	2.64 c	2.27 c	207 c	73 d	7/3 b	7/12
WSU 2299	3.58 bc	7.14 bc	16.6% ab	9.7% ab	2.70 c	2.38 c	154 d	60 d	6/29 b	7/9
Willamette	3.49 bc	5.65 c	16.3% b	7.9% b	3.22 a-c	3.33 ab	227 c	112 bc	7/1 b	7/6
	3.83	7.63	19.2%	8.2%	3.15	3.05	243	107	7/5	7/11

Table 2018 harvest 2016 planting

	Yield (t/a)		Fruit rot (%)		Fruit weight (g)		Fruit firmness (g)		Midpoint of harvest	
WSU 2087	4.83	a	25%	ab	3.00	ab	315	a	7/1	bc
WSU 2130	4.55	ab	14%	c	2.73	ab	247	b-d	6/27	d
WSU 2088	4.02	a-c	22%	a-c	2.77	ab	295	ab	7/4	ab
C.Harvest	3.38	a-d	18%	a-c	3.51	a	234	c-e	6/30	cd
Willamette	2.37	a-d	14%	c	2.44	ab	192	e	6/27	d
WSU 2191	2.31	a-d	14%	c	2.07	b	212	de	6/29	cd
WSU 2162	2.01	b-d	18%	a-c	2.56	ab	185	e	7/5	a
Meeker*	1.79		30%		2.52		171		6/29	
WSU 1962	1.71	cd	17%	bc	2.92	ab	208	de	7/4	ab
WSU 2195	1.05	d	27%	a	2.95	ab	271	a-c	7/7	a
	2.80		20%		2.75		233		7/2	

* only two replications of Meeker harvested in 2018

PROJECT: 13C-3755-5641
TITLE: Red Raspberry Breeding, Genetics and Clone Evaluation
CURRENT YEAR: 2018

PI: Patrick P. Moore, Professor
253-445-4525
moorepp@wsu.edu
WSU Puyallup Research and Extension Center
2606 W Pioneer
Puyallup, WA 98372

Co-PI: Wendy Hoashi-Erhardt, Scientific Assistant
253-445-4641
wkhe@wsu.edu

Year initiated 1987 **Current year 2018** **Proposed Duration:** continuing
Project Request: $75,000 for 2019

Other funding sources: USDA/ARS Northwest Center for Small Fruits Research
Amount Awarded $32,299 for 2018-2019 for both raspberry and strawberry breeding

ORBC
Amount Awarded $4,500 for 2018-2019 "Development of New Raspberry Cultivars for the Pacific Northwest"

Description: The program will develop new red raspberry cultivars for use by commercial growers in the Pacific Northwest. 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. Specific traits to incorporate into new cultivars are high yield, machine harvestability, root rot tolerance, suitability for processing and raspberry bushy dwarf virus (RBDV) resistance with superior processed fruit quality.

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. New cultivars are needed that are more productive, machine harvestable, tolerant to root rot and RBDV resistant while maintaining fruit quality. Replacement cultivars for 'Meeker' and new cultivars that extend the season are needed. With over 90% of the Washington production used for processing, new cultivars need to be machine harvestable.

There has been a history of cooperation between the breeding programs in Oregon, British Columbia, and Washington and material from other programs evaluated. This cooperation needs to continue as cultivars developed by any of these programs will be of value to the entire PNW raspberry industry.

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: Develop summer fruiting red raspberry cultivars with improved yields and fruit quality, and resistance to root rot and raspberry bushy dwarf virus. Selections adapted to machine harvesting or fresh marketing will be identified and tested further.

Procedures: This is an ongoing project that depends on continuity of effort. New crosses will be made each year, new seedling plantings established, new selections made among previously established seedling plantings, and selections made in previous years evaluated.

1. Crosses will be made for summer fruiting cultivar development. Primary criteria for selecting parents will be machine harvestability, root rot tolerance, yield and flavor.
2. Seed from crosses made in 2018 will be sown in the greenhouse in 2018-2019. The goal will be to plant 108 plants in the field for each cross.
3. Selections will be made in 2019 among the seedlings planted in 2017. 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, seedlings will be selected for propagation and further evaluation. Typically, the best 1-2% of a seedling population will be selected.
4. The selected seedlings will be propagated for testing. Shoots will be collected and placed into tissue culture. 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.
5. Eight plants of each selection will be planted in a grower planting for machine harvesting evaluation. Three plants of each selection will also be planted at WSU Puyallup in observation plots.
6. The machine harvesting trials established in 2016 and 2017 will be harvested in 2019. Evaluations will be made multiple times through the harvest season.
7. Samples of fruit from promising selections will be collected and analyzed for soluble sugars, pH, titratable acidity and anthocyanin content.
8. Selections that appear to machine harvest well 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.
9. The replicated plantings established in 2016 and 2017 at WSU Puyallup will be hand harvested for yield, fruit weight, fruit rot and fruit firmness in 2019.
10. Selections identified in machine harvest trials and other evaluations as having potential for release as a new cultivar will be propagated for larger numbers for grower trials.

ANTICIPATED BENEFITS AND INFORMATION TRANSFER:
This program is an ongoing program that will develop new raspberry cultivars that are more productive or more pest resistant. The emphasis of the program is developing machine harvestable cultivars. Such cultivars may result from crosses made this year or may already be under evaluation. When a superior selection is identified and adequately tested, it may be released as a new cultivar and be available for commercial plantings. Plants of WSU 2166 Promising selections and new cultivars will be displayed at field days. Presentations will be made on breeding program activities at grower meetings.

PROPOSED BUDGET:
Funds from the Northwest Center for Small Fruit Research and support provided by WSU Agriculture Research Center will be used to provide partial technical support for the program.

The funds requested will be used for technical support, timeslip labor; field, greenhouse, and laboratory supplies; and travel to research plots and to grower meetings to present results of research. The proposed budget also includes $2,500 for land use fees and 13,000 for machine harvesting trials.

Budget		**2019-20**
00 Salaries[1]		**$33,470**
Scientific Assistant (0.50 FTE)		
Ag Res Tech 2 (0.30 FTE)		
01 Timeslip Labor		**$4,000**
03 Service and Supplies		**$16,935**
Machine Harvest Trials[1]		
Land use fees		
Supplies		
04 Travel[2]		**2,000**
07 Benefits		**$18,595**
SA, ART2	$18,223	
Timeslip	$372	
Total		**$75,000**

[1] Includes: Field, greenhouse, and laboratory supplies; $2,500 for WSU farm service fees and $13,000 for expenses for the following test plantings for evaluation of raspberry selections.

Maintenance and harvest of test plantings

Machine harvesting trial established in 2016 - Honcoop Farms	$3,000
Machine harvesting trial established in 2017 - Honcoop Farms	$3,000
Maintenance of test plantings	
Machine harvesting trial established in 2018 - Honcoop Farms	$3,000
Establishment and maintenance of new test planting	
Machine harvesting trial to be established in 2019	
Will work with the WRRC to identify a suitable grower for the 2019 machine harvesting trial	$4,000

[2] Travel to research plots and to grower meetings to present results of research

Current Support

Name (List PI #1 first)	Supporting Agency and Project #	Total $ Amount	Effective and Expiration Dates	% of time committed	Title of Project
Moore, P.P. and Hoashi-Erhardt	Northwest Center for Small Fruit Research	$32,299	2018-19	5%	Small Fruit Breeding in the Pacific Northwest
Moore, P.P. and Hoashi-Erhardt	Washington Red Raspberry Commission	$70,000	2018-19	10%	Red Raspberry Breeding, Genetics and Clone Evaluation
Moore, P.P. and Hoashi-Erhardt	Oregon Raspberry and Blackberry Commission	$4,500	2018-19	2%	Genetic Improvement of Raspberry
Moore, P.P. and Hoashi-Erhardt	Oregon Strawberry Commission	$5,000	2018-19	2%	Development of new strawberry cultivars for the Pacific Northwest
Moore, P.P. and Hoashi-Erhardt	WSDA	$110,401	2017-20	15%	A thriving fresh market strawberry industry through breeding, horticultural systems, grower resources, and nursery expansion

Washington Red Raspberry Commission
Progress Report 2017

Title: Regional On-farm Trials of Advanced Raspberry Selections

Personnel:
PI: Tom Peerbolt –Peerbolt Crop Management.
Co PIs: Chad Finn – USDA-ARS; Pat Moore – WSU; Julie Enfield – Northwest Plants

Reporting Period: 2018

Accomplishments:

Infrastructure developments to date

- Completed development of the infrastructure to support a functioning, ongoing network of regional on-farm grower trials for evaluating raspberry advanced selections linking participating growers, propagators, breeders, and other industry and commission participants.
- Expanded grower cooperator network to include sites with heavier soils and wider regional distribution.
- Completed practical yearly timeline for trial activities.
- Improved draft overall budget for determining annual costs for an ongoing program.
- Improved protocols for coordinating a joint on-farm trial program with British Columbia and Oregon caneberry growers.

Areas still in need of work

- Developing better protocols for consistent evaluation of trials and site visits.
- Determining more accurate annual fixed costs (labor, office, travel expenses, etc.) for an ongoing program.
- Improving and stabilizing information dissemination.

Information Dissemination Methods

- Cultivar/selection factsheet handouts being produced annually.
- Ongoing inclusion of information in the Small Fruit Update newsletter.
- Posting on the Northwest Berry Foundation Website.
- Email and phone interaction with growers and processors.
- Meeting presentations.

Cultivars/Selections Included in Trials 2012-2016

- Rudi
- Cascade Harvest
- WSU 1912
- WSU 1948
- Lewis
- Squamish (BC 92-9-15)
- WSU 1980
- WSU 2122
- WSU 2166 (Cascade Premier)

Selections planted in Spring of 2017

- WSU 1914
- WSU 2010

- WSU 2162
- WSU 2166

Selections planted in Spring of 2018

- WSU 1962
- WSU 2068
- WSU 2069

Yearly Calendar of On-Farm Caneberry Trials

Mid-November: Propagator and wholesale nursery meeting.

- Decide on selections for following season in collaboration with plant breeders & nurseries.
- Edit list of promising candidate selections for trials 2-3 years in the future.
- Coordinate with wholesale nurseries to decide on plant source and date needed to deliver on farms.

December- March: Winter meetings, production of factsheets, submit reports and funding proposals, web postings.

- Disseminate information to stakeholders through newsletters, meeting presentations, factsheets and websites.
- Coordinate with on farm trials in Washington and British Columbia.
- Collect stakeholder feedback on selections, independent selection trials and commercially planted cultivars.
- Recruit grower cooperators for the coming season.

April-May: Getting new trials planted. First check on ongoing trials.

- Coordinate deliveries with propagators and growers.
- Expedite memorandums of understanding paperwork for growers.
- Evaluate trials in the ground for winter damage, cane vigor, bud break, and any other pest symptoms that might be visible in the early season. (Could be either site visit or a phone interview with grower.)

June-August: Harvest Season

- Site visits during harvest to evaluate: Fruit quality; yield potential; machine harvestability; fruit disease susceptibility.
- Second site visit during third to fourth week of harvest to evaluate: late season fruit quality; revise yield potential; machine harvestability; length of harvest; disease harvestability, etc.
- Visit trials in Washington and British Columbia at least once during the season.

August-October: Post harvest

- Phone interviews with growers for comments on train-ability, pruning methods, etc.
- Determine which plantings should be removed and/or continued.

2019 WASHINGTON RED RASPBERRY COMMISSION
RESEARCH PROPOSAL

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 Initiated 2012 Current Year 2018 Terminating Year 2019

Total Project Request: 2018 $12,200 2019:$8,374

Other funding sources:

1. **Agency name:** Oregon Raspberry and Blackberry Commission
   Amount requested/awarded: (2017) $11,500 No request was made in 2018. 2019: $9,000
   Note: This is a similar project that will allow us to test caneberries in Oregon.

2. **Various industry contributions/sponsorships**
   Amount requested: 2018:0 **2019: Goal-**$5,000
   Note: This year we will solicit funding from industry sources in addition to requesting commission support.

Total Regional Project costs: **Total:** $22,374

Background
For the last seven years the Northwest Berry Foundation has 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 following proposal incorporates revisions intended to:

- Improve regional coordination by:

    - Adding Tom Walters as supervisor for the NW Washington onfarm trials. Tom will facilitate communication between Northwest Plants, the growers and the other project participants as well as supervise new plantings and evaluate established plantings
    - Standardizing evaluation timing and protocols.
- Improve data collection and dissemination by:
    - Increased site visits.
    - Improved, standardized evaluation procedures.
    - Using a new software data collection system (AgReports)
- Increase budget efficiencies by:
    - Minimizing travel time & mileage cost by having three regional supervisors and eliminating reliance on Tom Peerbolt needing to drive to NW Washington to conduct site visits.
- Diversify funding sources by:
    - Soliciting industry sponsors for the project to supplement funding for the WRRC and the ORBC.
- Improve outreach by:
    - Producing an annual variety development update to be sent out to the Small Fruit Update list.
    - Developing and maintaining a variety development section on the Northwest Berry Foundation website

Notes on 2019 season plans:

- Due to the revisions being made to improve this program in the long run no new plantings are planned for the spring of 2019. Fall plantings are possible and, if that happens, a request for plant costs would then be made to the WRRC.
- Work in 2019 would be evaluating the plantings now in the ground as well as implementing the revisions listed above.

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.

More detailed descriptions overall project aspects

- **Three regional divisions**
  While sharing information and project coordination, the caneberry council/commission within each region will be requested to contribute to the financial support of the trials in that region.
    - Oregon/SW Washington: Tom Peerbolt, Northwest Berry Foundation
    - Northwestern Washington: Tom Walters, Walters Ag Consulting
    - B.C.: Eric Gerbrandt, Sky Blue Horticulture Ltd.
- **Shared reporting system: AgReports Software**
  This custom proprietary software has been developed in partnership with Peerbolt Crop Management specifically for the collection and dissemination of field information in specialty crops.
    - Easy and consistent data entry.
    - GPS tagged.
    - Photo posting.
    - Potential drone imaging posting.
    - Potential grower comment inclusion.

- **Regional information dissemination networks**
  - The Small Fruit Update (SFU) weekly newsletter for in-season information and updates
  - The Northwest Berry Foundation (NBF) website for posting and archiving reports & data
  - An Annual Variety development report disseminated to the SFU maillist and posted on the NBF website
- **Locations of trials:**
  - Ongoing private sites: Certain grower sites where the conditions and cooperator warrant it *(Example: Ralph Minaker in Everson, WA. where large plantings of Cascade Bounty and heavy soil conditions make it an ideal site to evaluate root rot tolerance of raspberries)*
  - Rotating grower/cooperator sites.
  - One-time grower/cooperator sites.

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.

This program could strengthen the breeding programs by:
- Giving support to the existing research-station-based field trials by adding a strong, natural link that would improve the present method of sending advanced selections on to the propagators to be multiplied for grower trials.
- Decreasing the time needed to evaluate the commercial potential of selections.
- Increasing the industry-wide knowledge of new releases potential before they are released.
- Increasing the breeding programs and industry's ability to effectively manage its genetic resources using intellectual property tools (e.g. plant patenting and plant breeders' rights) by having information on a cultivar's potential well in advance of its release and patenting.

This program could support the growers by:
- Improving the quality and quantity of information they have for business planning.
- Currently, advanced selections are tested and new cultivars are released based on limited knowledge of their overall commercial potential and viability under various northwest growing conditions. This system forces the grower to either make a decision to plant a new cultivar based on inadequate data, or delay a decision for years until an adequate track record has reduced the risk level.
- Providing new communication links between the growers, nurseries and plant breeders.
- Allowing growers to actively participate in selection evaluations within established protocols and without needing to invest their own resources to pay for the plants and all the planting costs.

This program could strengthen the propagators and wholesale nurseries by:
- Improving their decision-making methods and reducing their risk.
- The present system puts the propagators/wholesale nurseries in the position of guessing how many of which selections and new releases to produce. This has led to economic losses to the nurseries caused by over and/or under production of material. It has created a disincentive for the wholesale nurseries to make available or test new products.
- Providing them with objective evaluations of new material under a variety of growing conditions to pass on to potential customers.

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.

Procedures:

Review of initial project guidelines

- Tissue culture plants will be used.
- Maximum of 5 red raspberry selections each year.
- Minimum of 3 grower sites per selection per year.
- Site guidelines would be representative of the major northwest growing regions.
- Maximum number of plants per selection per trial of machine harvested raspberries would be 1000 plants to produce enough fruit for processing potential. This could be considerably less depending on site and consensus of participants as to the size trial needed.
- Minimum number of plants could be as low as 10 for a fresh market or hand-picked trial.
- 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. They can be removed after this year's harvest. However, if determined useful some could 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. Disseminating and archiving information as needed.

Grower/cooperator arrangements

- Testing agreements would be created and approved by WSU (or WSURF) and by USDA.
- Growers would sign testing agreements that would include: on-site visits by other growers and researchers (arranged and agreed to in advanced); participation in the evaluation process; and a testing agreement which includes 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.

2019 Budget

Salaries[1/]	**$4,224**
Travel[2/]	**650**
Outreach[3/] `	**1,500**
Other (Propagator payments**)**[4/]	**0**
Offices costs (including AgReports**)**	**2,000**
Total	**$8,374**

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—7 days a year at 100 miles per day at $ .50 per mile = $350

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) $0

At this time no new plantings are planned for the spring of 2019. Fall plantings are possible and if made a request for plant costs would then be made to the WRRC.

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

Washington Red Raspberry Commission
Progress Report Format for 2018 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
Michael.Dossett@agr.gc.ca Tel: 604-796-6084

Reporting Period: 2018

Accomplishments:

- In 2018 we established ~5700 new seedlings in the field from crosses made in 2017, and made 94 selections from crosses made in 2015, as well as a handful of new initial selections from 2016 crosses that will be evaluated more closely in 2019.

- 156 BC and WSU selections were evaluated as machine-picked fruit in 5-plant trial plots at the Clearbrook station. WSU 2166 looked outstanding in the 2016 planting, where BC 11-110-11 and BC 7-17-7 both picked very well, but were slightly softer than desirable.

- Three selections were identified from the MH plots, for propagation for larger-scale grower trials. One new seedling from 2016 crosses with outstanding potential was also identified and is being propagated for grower trials:

    - BC 10-79-33 had the highest two-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.

    - BC 10-84-9 is very large and vigorous. Yield was off slightly in 2018, but our plots receive no fungicide sprays and it appears that spur blight infection may have negatively impacted budbreak this last year. 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.

- BC 1653.7 is a new 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 moderately good root rot tolerance.

Fig 2. Fruit of BC 10-79-33, which had the highest combined yield over the last two 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 (g)	Yield 2017 (t/a)	Yield 2018 (t/a)	Combined Yield (t/a)	Comments
10-79-33	**3.9**	**8.1**	**7.4**	**15.5**	**Soft, but holds shape OK, bit lumpy, color? Might be acceptable? Season?**
10-73-19	3.8	10.1	4.5	14.6	Soft, poor quality, large drop in yield from '17-18
96-2R-1	3.3	7.1	6.3	13.4	Round, 1/4 wild, but V good for this.
10-84-9	**5.8**	**7.3**	**5.5**	**12.8**	**V. Large, dark, firm. Beautiful on 2-day pick. 2018 spotty budbreak - spur blight?**
1-64-3	2.9	6.4	6.0	12.4	Very light color, extremely soft.
Chemainus	3.3	6.1	6.2	12.3	Good, firm, consistent
10-52-68	3.2	5.3	6.5	11.8	Good color, bit lumpy, large opening, softish?
1-9-11	4.4	7.7	3.9	11.6	Very light and very soft
96-38R-31	3.4	6.7	4.9	11.6	Beautiful, but very soft. 1/4 wild.
10-84-45	4.3	7.1	4.4	11.5	softish and light colored
10-84-42	4.1	7.6	3.8	11.4	chunky, softens quickly at ripening, probably too light
1-86-11	3.0	5.8	5.6	11.4	Early, looks nice, poor flavor
4-36-17	2.9	5.5	5.7	11.2	cohesive but soft
10-84-10	4.0	6.0	5.1	11.1	Good quality, especially on 2-day pick
K02-15	3.3	6.4	4.7	11.1	Beautiful with good flvr and color, but susceptible to root rot and late
10-83-22	6.7	7.4	3.5	10.9	Very large chunky druplets, uneven.
10-79-61	3.3	6.5	4.0	10.5	Lumpy, glossy, bit soft
1-86-21	4.0	6.2	4.2	10.4	Nice but soft, flvr?
3-19-5	3.1	6.0	4.3	10.3	rough and soft, nice flvr.
1-11-15	3.9	6.5	3.8	10.3	Soft, crumbly. Eliminate
93-26-25	3.8	6.3	3.8	10.1	Bit light? Lots of overripes,
10-84-76	4.2	4.8	5.1	9.9	Firm, doesn't pick until very ripe
10-78-40	3.8	6.0	3.8	9.8	Good color, in good shape, but significant crumbles
10-71-23	3.9	5.3	4.4	9.7	Firm, picks very nice
10-80-9	2.9	5.1	4.3	9.4	Poor color, many orangey
10-71-27	**3.4**	**4.5**	**4.8**	**9.3**	**Firm. A few days before Chemainus, not as early as previously hoped, MH but light**
10-65-1	3.5	5.3	3.6	8.9	Very light, picks well, bit lumpy, but looks V good. Parent for MH
10-84-14	3.8	5.5	3.4	8.9	Good budbreak, healthy plant, tart, firm
10-57-41	3.4	4.8	3.7	8.5	Crumbly mess, has RBDV
10-80-100	2.7	5.2	3.3	8.5	Dark, very nice. Probably best of 10-80s
Meeker	2.5	4.4	3.9	8.3	
Table truncated - 29 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:				

2019 WASHINGTON RED RASPBERRY COMMISSION
RESEARCH PROPOSAL

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

Project Title: Red Raspberry Cultivar Development

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

Cooperators:

Year Initiated__2019__ Current Year_2019_ 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. *This information is still confidential until a formal announcement has been made by the federal Agriculture Minister, and divulging it could jeopardize receipt of the funds, so please keep this quiet.* 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

Washington Red Raspberry Commission

Title: Managing SWD in Red Raspberry with Reduced Insecticide Residues

Personnel: Alan Schreiber and Tom Walters, Agriculture Development Group, Inc.

Camille Holladay, Synergistic Pesticide Laboratory.

Reporting Period: February, 2018 – November 2018

• Accomplishments: Drs. Walters and I were able to complete an SWD efficacy in raspberry and collect samples that were analyzed in a pesticide analytical lab.

• What are the main accomplishments of the project and their significance in terms of the problem solved or enhancements to the industry? We were able to demonstrate that raspberry SWD programs using conventional insecticides in the first half of the season and other insecticides that are tolerance exempt later in the program were as effective at reducing SWD numbers as a full conventional program.

• What has been contributed to science and/or the industry? This is the second year of a program that attempts to build a SWD program in raspberries that will allow growers to meet maximum residue limits that are currently not possible to meet. We believe our results show the pesticide residues can be reduced. However, in the 2018 research effort, SWD pressure was extremely heavy in late season primocane raspberries. As a result the level of efficacy for all of the programs were not commercially acceptable.

Results: SWD population started to increase dramatically at 5 DAT E, and all programs had less SWD larvae counts than untreated check at 5 DAT E and 5 DAT F, except that program 5 had a higher than untreated SWD at 5 DAT F which might be a outlier. However, the relative high variation (LSD) at $P<0.05$ level resulted in non-statistically significant results. The control efficacy of residue reducing purposed programs: 3, 4, 6, and 7 was consistently better than the conventional products dependent program 2 at 5 DAT E, 5 DAT F, and study total. For example, program 2 had only 29% control at 5 DAT E, 15% control at 5 DAT F, and 21% study total control, while others (except the program 5 outlier) showed > 46% control on 5 DAT E, >32% control on 5 DAT F, and >40% overall control (Table1 columns 4, 5, and 6; Figure 1). The residue test data showed that all these residue reducing programs (3, 4, 5, 6, and 7) had lower malathion residue than program 2 with <0.05 ppm malathion at 2 DAT D and <0.02ppm concentration by 2 DAT E, while program 2 reached 0.25 ppm and 0.05 ppm at the same dates (Figure 2). It appears that Brigade and Mustang Max were more persistent than other products, with >0.1ppm concentration for any programs containing these two products (Figure 2). Results suggested better control efficacy from the tested residue reducing programs than the conventional malathion dependent program 2. The three best programs are program 4 (50% total control), program 6 (46% total control), and program 7 (51% total control). The <0.05 ppm malathion concentration at 2 DAT D and 2 DAT E also supported their residue reducing goal (Figure 2). However, both program 4 and 6 used three conventional product while program 7 only had two. Considering program 6 and 4 had similar residual levels of Brigade and Mustang Max, the lower Danitol residue (<0.05 ppm) of program 6 than programs 4 (0.06 to 0.15 ppm) suggested lower residue risk.

In summary, program 6 and 7 are the most comprehensive programs with the least residue risk and best SWD control.

Managing SWD in Red Raspberry with Reduced Insecticide Residues

Alan Schreiber and Tom Walters, Agriculture Development Group, Inc.

Camille Holladay, Synergistic Pesticide Laboratory.

Background and Introduction. The goal of this project is to develop spotted wing drosophila (SWD) management programs in red raspberry that will have reduced insecticide residues without a reduction in efficacy. SWD management programs would be front loaded with "harder" conventional insecticides and would switch to products that are exempted from tolerance or have residues that degrade more quickly. A successful outcome of this program would allow fruit produced under the low residue programs to be exported to markets that are currently challenged by low MRLs. Programs entirely composed of tolerance exempted products or products with residues that quickly decline have been developed for blueberries and blackberries. This project would take elements from those programs and combine them with elements of existing conventional raspberry SWD management programs. Research in 2017 indicated that these proposal programs can significantly reduce SWD infestations and result in decreased insecticide residues that will allow export to countries that currently have restrictive MRLs. However, the level of program efficacy and insecticide residues are not yet at a level that is sufficiently ideally acceptable to the industry.

Materials and Methods

During the summer of 2018, the staff of the Agriculture Development Group, Inc. conducted a research trial at Everson, WA investigating the efficacy of multiple insecticide residue reducing programs for the control of spotted wing drosophila (SWD) in red raspberry. The experimental design for this trial was a RCB with 4 replications and plot sizes of 10ft x 30ft. Applications for this trial were made with an over-the-row sprayer calibrated to apply treatment sprays at 30 gallons per acre (Photo 1). SWD pressure in this trial was very high towards the harvesting.

Six applications were made on Aug-10 (A), Aug-16 (B), Aug-22 (C), Aug-28 (D), Sep-3 (E), and Sep-8 (F) for rotations of different insecticides from 6 programs. Amount of SWD larvae in 100 randomly selected berries per plot were assessed using salt water soaking method (30 minutes soaking before examination of the larva in a tray) at 5 days after treatments B, C, D, E, and F (DAT B, DAT C, DAT D, DAT E, and DAT F). Berry samples were also collected at 2 DAT C, D, and E then sent to Synergistic Pesticide Lab for insecticide residue analysis.

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

Results and Discussion

SWD population started to increase dramatically at 5 DAT E, and all programs had less SWD larvae counts than untreated check at 5 DAT E and 5 DAT F, except that program 5 had a higher than untreated SWD at 5 DAT F which might be a outlier. However, the relative high variation (LSD) at P<0.05 level resulted in non-statistically significant results.

The control efficacy of residue reducing purposed programs: 3, 4, 6, and 7 was consistently better than the conventional products dependent program 2 at 5 DAT E, 5 DAT F, and study total. For example, program 2 had only 29% control at 5 DAT E, 15% control at 5 DAT F, and 21% study total control, while others (except the program 5 outlier) showed > 46% control on 5 DAT E, >32% control on 5 DAT F, and >40% overall control (Table1 columns 4, 5, and 6; Figure 1). The residue test data showed that all these residue reducing programs (3, 4, 5, 6, and 7) had lower malathion residue than program 2 with <0.05 ppm malathion at 2 DAT D and <0.02ppm concentration by 2 DAT E, while program 2 reached 0.25 ppm and 0.05 ppm at the same dates (Figure 2). It appears that Brigade and Mustang Max were more persistent than other products, with >0.1ppm concentration for any programs containing these two products (Figure 2).

Results suggested better control efficacy from the tested residue reducing programs than the conventional malathion dependent program 2. The three best programs are program 4 (50% total control), program 6 (46% total control), and program 7 (51% total control). The <0.05 ppm malathion concentration at 2 DAT D and 2 DAT E also supported their residue reducing goal (Figure 2). However, both program 4 and 6 used three conventional product while program 7 only had two. Considering program 6 and 4 had similar residual levels of Brigade and Mustang Max, the lower Danitol residue (<0.05 ppm) of program 6 than programs 4 (0.06 to 0.15 ppm) suggested lower residue risk.
In summary, program 6 and 7 are the most comprehensive programs with the least residue risk and best SWD control.

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
Part Rated				larvae C	larvae C	larvae C	larvae C	larvae C	larvae C
Rating Date				Aug-21-2018	Aug-27-2018	Sep-2-2018	Sep-8-2018	Sep-13-2018	
Rating Type				count	count	count	count	count	total
Rating Unit				#	#	#	#	#	#
Days After First/Last Applic.				11 5	18 5	23 5	29 5	33 5	
Trt No.	Treatment Name	Rate	Rate Unit / Appl Code	1*	2*	3*	4*	5*	6*
1	Untreated			0.5a	0.0a	2.0a	39.5a	36.5a	78.5a
2	Delegate	170g/a	A	0.3a	0.0a	2.8a	28.0a	31.0a	62.0a
	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						
3	Danitol	1pt/a	A	0.8a	0.0a	2.5a	19.0a	24.5a	46.8a
	Malathion	20fl oz/a	B						
	Mustang Max	4fl oz/a	C						
	Grandevo	3lb/a	D						
	Corn Syrup	3% v/v	D						
	Oxidate	1.25% v/v	D						
	Veberate	6qt/a	E						
	Corn Syrup	3% v/v	E						
	Oxidate	1.25% v/v	E						
	Grandevo	3lb/a	F						
	Corn Syrup	3% v/v	F						
	Oxidate	1.25% v/v	F						
4	Danitol	1pt/a	A	1.8a	0.0a	0.5a	15.3a	21.5a	39.0a
	Malathion	20fl oz/a	B						
	Mustang Max	4fl oz/a	C						
	Venerate	6qt/a	D						
	Oxidate	1.25% v/v	D						
	Grandevo	3lb/a	E						
	Oxidate	1.25% v/v	E						
	Venerate	6qt/a	F						
	Oxidate	1.25% v/v	F						
5	Jet Ag	170g/a	A	0.0a	0.5a	1.0a	21.5a	42.5a	65.5a
	Malathion	20fl oz/a	B						
	Brigade 2EC	6.4fl oz/a	C						
	Grandevo	3lb/a	D						
	Oxidate	1.25% v/v	D						
	Veretran	15lb/a	E						
	Oxidate	1.25% v/v	E						
	Grandevo	3lb/a	F						
	Oxidate	1.25% v/v	F						
6	Delegate	170g/a	A	0.0a	0.0a	0.8a	21.5a	20.0a	42.3a
	Malathion	20fl oz/a	B						
	Brigade 2EC	6.4fl oz/a	C						
	Veretran	15lb/a	D						

Oxidate 1.25% v/v D						
Grandevo 3lb/a E						
Oxidate 1.25% v/v E						
Veretran 15lb/a F						
Oxidate 1.25% v/v F						
7Delegate 170g/a A	0.0a	0.0a	0.0a	**13.8a**	**25.0a**	**38.8a**
Malathion 20fl oz/a B						
Brigade 2EC 6.4fl oz/a C						
Success 6fl oz/a D						
Oxidate 1.25% v/v D						
Grandevo 3lb/a E						
Oxidate 1.25% v/v E						
Success 6fl oz/a F						
Oxidate 1.25% v/v F						
LSD P=.05	2.11	0.56	2.55	19.55	26.81	40.25
Standard Deviation	1.42	0.38	1.72	13.16	18.05	27.09
CV	305.81	529.15	126.52	58.12	62.86	50.88
Levene's F	0.80	1.00	4.759	0.179	0.397	0.289
Levene's Prob(F)	0.581	0.451	0.003*	0.979	0.873	0.935
Skewness	4.3251*	5.2915*	1.1709*	0.3561	2.2738*	0.8626
Kurtosis	20.4196*	28.0*	0.0997	-0.8684	6.7634*	-0.1156
Replicate F	0.821	1.000	0.727	0.929	1.666	1.401
Replicate Prob(F)	0.4992	0.4155	0.5492	0.4470	0.2099	0.2749
Treatment F	0.803	1.000	1.522	1.780	0.850	1.309
Treatment Prob(F)	0.5803	0.4552	0.2272	0.1600	0.5486	0.3033

Figure1. Population of SWD influenced by different treatments at different timing.

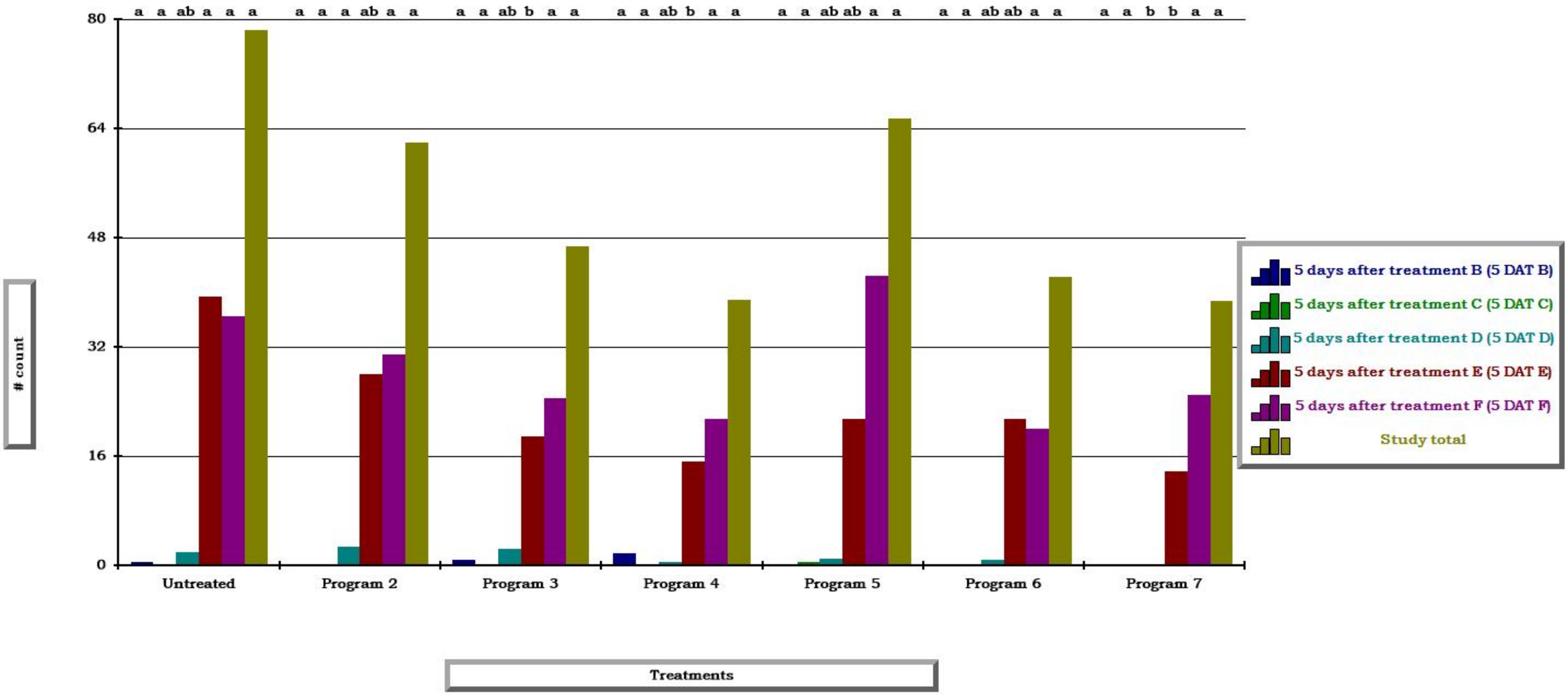


Figure 2. Residue analysis of program 2 for the berries collected at 2 days after treatments C, D, and E.

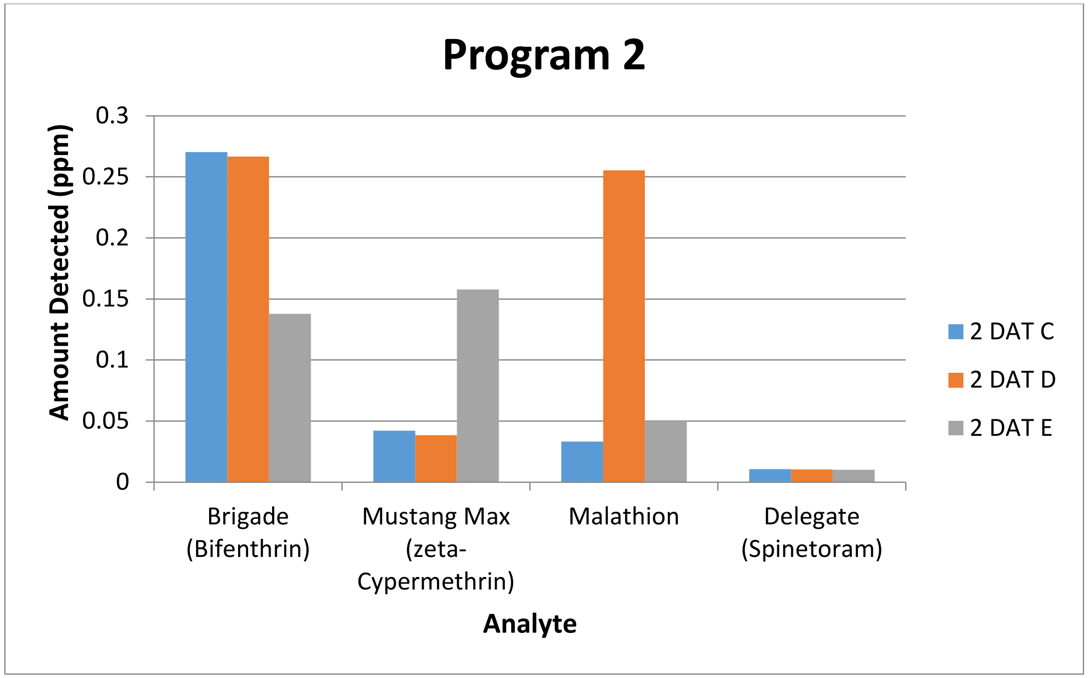


Figure 3. Residue analysis of program 3 for the berries collected at 2 days after treatments C, D, and E.

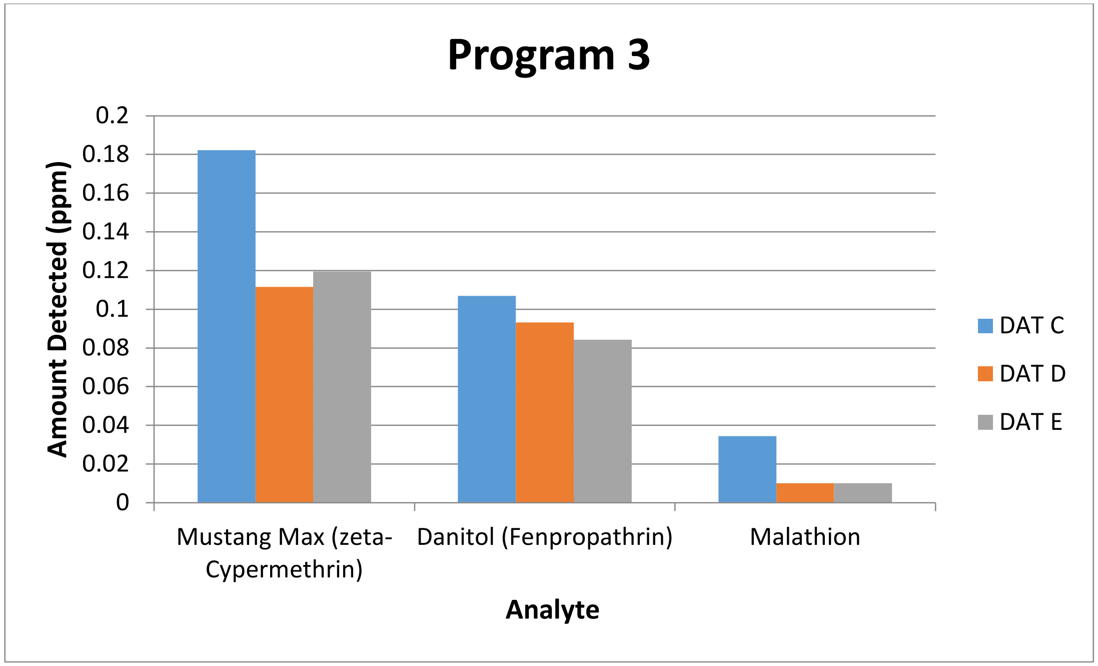


Figure 4. Residue analysis of program 4 for the berries collected at 2 days after treatments C, D, and E.

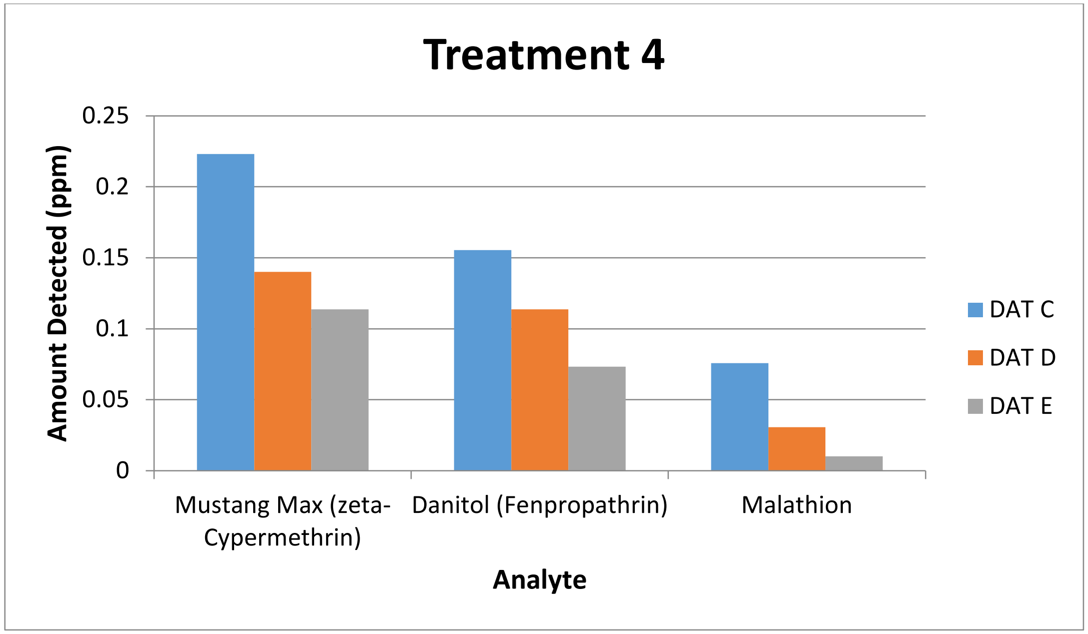


Figure 5. Residue analysis of program 5 for the berries collected at 2 days after treatments C, D, and E.

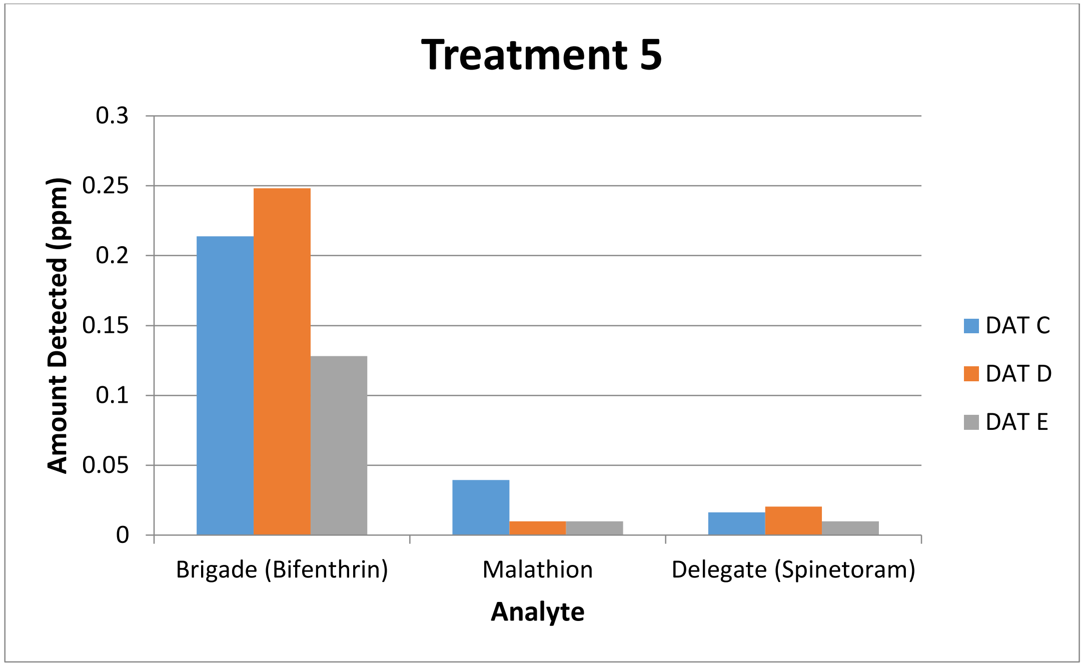


Figure 6. Residue analysis of program 6 for the berries collected at 2 days after treatments C, D, and E.

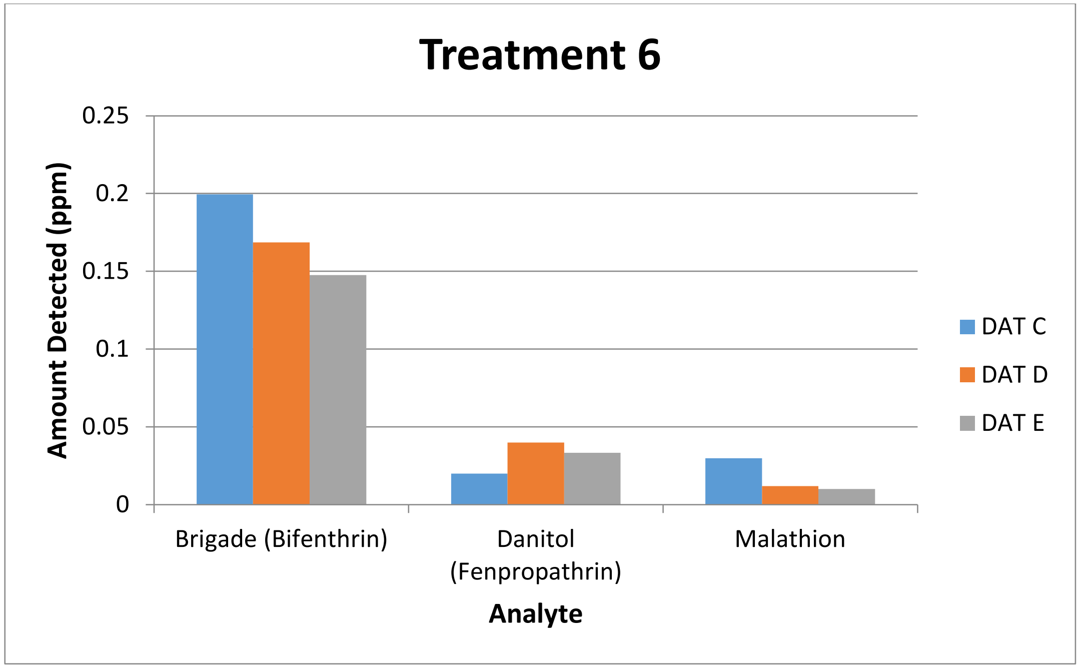
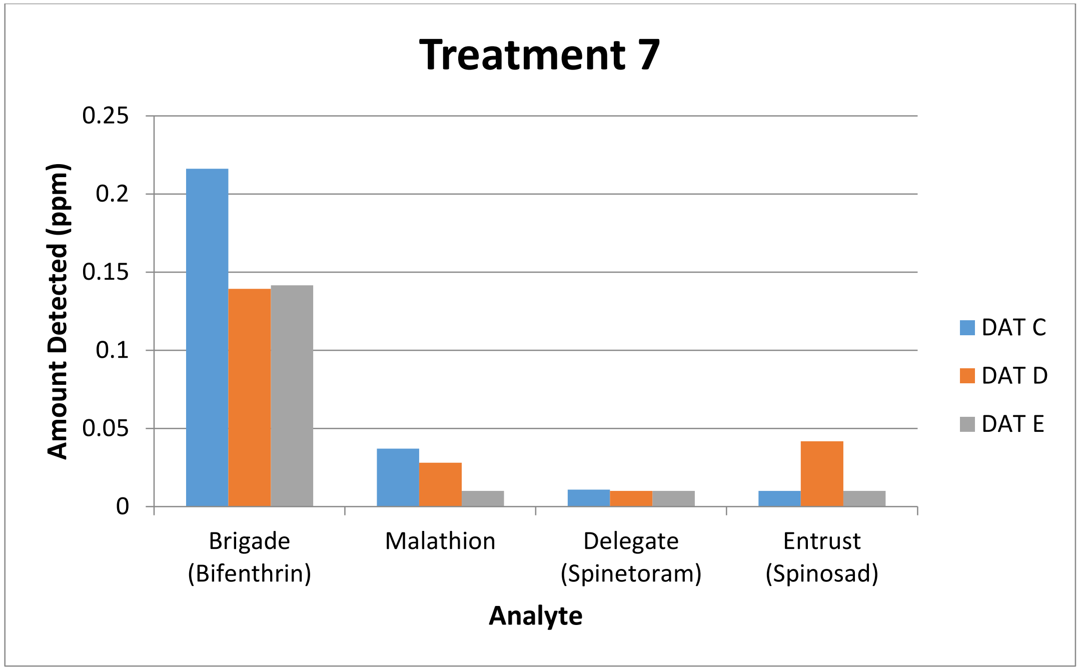


Figure 7. Residue analysis of program 7 for the berries collected at 2 days after treatments C, D, and E.



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

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

PI: Alan Schreiber
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Title: Researcher
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Cooperators: Tom Walters-Walters Ag Research, Camille Holladay, Synergistic Pesticide Laboratory.

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

Total Project Request: Year 1 $15,000 Year 2 $15,000 Year 3 $17,000

Other Funding Sources: We have applied for matching funds from the Washington State Commission on Pesticide Registration.

Description: Approximately 20% of Washington's raspberry production is exported. The primary export markets are Canada and Japan, with smaller amounts going to other Pacific Rim countries. Not only is Washington red raspberry production increasing, the export of raspberry products are also increasing. On a per pound basis, exported raspberries have a higher value than domestic markets, making raspberry export an attractive market. The Washington red raspberry industry has had shipments rejected due to MRL issues, however the bigger problem is that growers/exporters are being shut out of markets because they cannot meet MRL requirements of foreign markets. This project focuses on both of these problems.

The goal of this project is to develop spotted wing drosophila (SWD) management programs in red raspberry that will have reduced insecticide residues without a reduction in efficacy. SWD management programs would be front loaded with "harder" conventional insecticides and would switch to products that are exempted from tolerance or have residues that degrade more quickly. A successful outcome of this program would allow fruit produced under the low residue programs to be exported to markets that are currently challenged by low MRLs. Programs entirely composed of tolerance exempted products or products with residues that quickly decline have been developed for blueberries and blackberries. This project would take elements from those programs and combine them with elements of existing conventional raspberry SWD management programs. Research in 2017 indicated that these proposal programs can significantly reduce SWD infestations and result in decreased insecticide residues that will allow export to countries that currently have restrictive MRLs. However, the level of program efficacy and insecticide residues are not yet at a level that is sufficiently ideally acceptable to the industry. Research in 2018 indicated that residues could be greatly reduced and could aid significantly in meeting MRLs. However, SWD pressure was strikingly high in 2018 as compared to 2017. A third year's data is necessary in order to have sufficient data both in terms of efficacy and reduction of residues.

Justification and Background: Most of the insecticides used for SWD by the Washington raspberry industry have longer preharvest intervals (Asana (7), carbaryl (7), diazinon (7), Danitol (3), Success (3), Delegate (3) and/or residues that do not degrade quickly such as malathion and cabaryl. The blueberry industry has developed an organic program for control of SWD that appears to provide a level of control that is comparable to a conventional program. The level of control for this program is sufficient to produce large volumes (over 20 million pounds) of fresh early and mid-season blueberries having a SWD tolerance level that is lower than processed raspberry. Based on last minute feedback from a raspberry industry, export quality processed raspberries may have a tolerance similar to that of fresh market blueberries (meaning a very low tolerance.) The organic blueberry program was developed in eastern Washington in later season blackberry, a crop that has high SWD pressure. Our thinking is that the program developed for blackberry could be adapted to red raspberry. The goal of this program is not to develop an organic program for raspberry but rather to test some of the products that have proven more effective for SWD control and that are either exempt for tolerance or have shorter life residues than insecticides that are currently being used in raspberry SWD programs.

Based on the SWD efficacy program developed in caneberry for the organic blueberry industry, Entrust (which contains the same active ingredient as Success), Grandevo, Venerate, Veratran and Jet Ag have all shown significant efficacy against SWD. Grandeveo, Venerate and Jet Ag are exempt from tolerances. Entrust/Success have residues that degrade quickly. Delegate, which is very closely related to the active ingredient in Entrust/Success, has not been included in the organic blueberry project as it is a conventional product, but its residues are known to decline relatively quickly and could be included in this program. Residues from Delegate do not degrade as quickly as the residues from Success, but Delegate has higher efficacy. Note: Veratran is not currently registered at this time on raspberry.

In this project, insecticides with longer PHIs and/or having residues that do not decline sufficiently to meet MRLs would be used earlier in the program. In addition to giving these products time for their residues to decline and to come into compliance with PHI requirements, these products are thought to have greater efficacy and would "knock down" SWD populations.

This proposal was circulated among some members of the raspberry industry and received some "critical" reviews. The idea that this type of a program having export permissible insecticide residues and a level of control comparable to existing programs that rely on highly effective insecticides but have MRL issues was challenged by members of the industry (i.e. Bajema, Berendsen and Midboe). I believe that a program can be developed that provides export quality processed raspberries without a significant sacrifice of efficacy. It took four to five years to do this for organic blueberries. I believe such a program could be developed in three years.

Relationship to WRRC Research Priority: This directly addresses two of the top four research priorities for the WRRC "Management options for control of Spotted Wing Drosophila" and "Maximum Residue Limits.

Objectives: Develop SWD management options that will meet MRLs of key trading partners without reducing efficacy.

Procedures: A randomized complete block designed trial with four replications will be overlaid on the botrytis efficacy program. We would be using exclusive or almost exclusive products that have existing tolerances or are exempt from tolerance, so this would not be crop destruct trial. There will be 8 treatments developed in consultation with raspberry industry representatives.

Examples of potential programs from 2018

1. untreated check.

2. malathion, Asana Danitol, Success+Grandevo, Success+Grandevo, Grandevo+Venerate , Grandevo+Venerate.

3. standard 1, standard 2, standard 3, Success+Venerate, Success+Venerate, Venerate+Veratran, Venerate+Veratran

4. standard 1, standard 2, standard 3, Delegate+Grandevo, Success+Grandevo, Venerate+Veratran

5. standard 1, standard 2, standard 3, Delegate, Venerate+Jet Ag, Grandevo+Jet Ag, Venerate+Jet Ag

6. Entrust, Grandevo + Jet Ag, Entrust, Grandevo+Venerate, Veratran+Jet Ag, Gradevo+Jet Ag

7. Standard program 1 – to be selected by the industry.

8. Delegate, Malathion, Actara/Tundra, Malathion, Malathion, Mustang Max, Mustang Max

It is anticipated that the actually programs will be adjusted based on feedback from the industry.

Applications would be made roughly every five to seven days or when conditions or pest pressure would dictate. Prior to each application and seven days after the last application, a berry sample would be collected from each plot and analyzed for SWD larvae. Just prior to harvests and at the end of the control program, samples would be collected and sent to an analytical lab for testing for pesticide residues.

It is noteworthy that there is no evaluation of products novel to the berry industry being conducted on raspberries in the Pacific Northwest. If so directed by the WRRC, this program could be modified to include evaluating new conventional insecticides. This could include new modes of action, products considered more bee safe, shorter pre harvest intervals, lower residues or other components of an SWD use pattern that may be of value to the industry.

The samples would be analyzed by Synergistic Pesticide Labs based in Portland, Oregon.

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

Budget:	**2017**	**2018**	**2019**
Salaries	6,000	6,000	8,000
Operations	6,000	6,000	6,000
Travel	1,500	1,500	1,500
Benefits	1,500	1,500	1,500
Total	$15,000	$15,000	$17,000

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. An estimated $5,000 of operations would be used to cover the cost of laboratory analyses. All travel costs are related to traveling to the site and/or meeting with industry representatives.

Washington Red Raspberry Commission
2018 Report

Project No: 13C-3443-3275

Title: Distribution of BMSB, *Halyomorpha halys* in Skagit and Whatcom Counties

Personnel:
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Reporting Period: 2018

Accomplishments: BMSB traps were placed at 11 sites throughout Skagit County and 24 locations in Whatcom County. Traps were placed at “hot spots" and new locations based on host plants and proximity to trucking and train activity. Trapping locations were moved during the season in order to increase the search area. Four types of BMSB traps were used. Pyramid traps were made of interlocking wooded triangular cut outs fitted with a collecting jar on top. Trécé® Pherocon® Dual Funnel Tube Traps were tied to tree branches. Trécé® Pherocon® STKY™ Dual Panel Adhesive Traps were attached near the top of 4 ft. wooden stakes pounded into the ground. The Alpha Scents BMSB trap was made of corrugated plastic and hung from a tree branch. All trap types were baited using Alpha Scents HALHAL dual component coaster lure packets. Traps were checked twice a week, from late June to late September (Skagit) and late May through early October (Whatcom). During each visit, BMSB were collected from the pyramid and sticky traps, as well as sampled from the surrounding vegetation using a sweep net. Traps were removed following the release of *T. japonicus* adults in late September.

A BMSB colony was established in the lab at NWREC, for the purpose of rearing sentinel egg masses (SEM) to scout for presence of the parasitoid wasp *Trissolcus japonicus*. Egg masses were attached to piece of cardstock with double-sided tape, and pinned to the leaves of host plants. SEMs were placed at Budget Towing, Skagit Publishing, and three sites in Whatcom County including one near a raspberry farm, a hazelnut farm and one located at an industrial site with high interstate traffic. The SEMs were 12-48 hrs old and left for 3-4 days before being brought back to the lab at NWREC for evaluation. Eighteen SEMs were placed in total.

Four *T. japonicus* were released 27 September 2018 in Skagit County near where BMSB immatures were collected. These parasitoids were provided by Betsy Beers (WSU TFREC, Wenatchee) for immediate release with additional parasitized BMSB egg masses provided to establish a *T. japonicus* colony at WSU NWREC. Since then the NWREC *T. japonicus* colony has been established and is thriving.

Results: This was the second year of BMSB trapping in Skagit and Whatcom counties. Adult captures in Skagit County were much lower than 2017 but nymphal catches were higher. This indicates that BMSB are established in Skagit County and multiple reproducing populations are present. In Whatcom County, adult captures were higher and nymphs were captured for the first time. This indicates populations have established and will likely increase in 2019.

Skagit County - The first BMSB was collected on 30 August 2018, near the I-5 Anderson Road exit in south Mount Vernon. This was near the area that BMSB were first discovered in 2017. In total, 3 adults and 76 nymphs were collected in traps during the season (Fig. 1). BMSB were captured in urban areas localized around shipping routes, such as interstate highway exits and railroad yards. After traps were pulled, some additional reports of BMSB were made. When scouted, five more nymphs were collected along LaVenture Rd. in Mount Vernon on 12 October (not included in Fig.1).

Whatcom County – Whatcom County collected a total of nine adult BMSB, four nymphs, and zero egg masses (Fig. 2). The first specimens were collected 14 September 2018. Presence of nymphs from this trapping season indicates that BMSB is now reproducing in Whatcom County. Four *T. japonicus* were also released 2 October 2018 in Whatcom County near where known BMSB were collected.

No parasitoid wasps were recovered from any of the eighteen egg masses placed in Skagit and Whatcom counties. We believe that they have not yet migrated this far north. For this reason, releases of live wasps were made in Skagit and Whatcom counties to promote their spread and help manage BMSB populations. The initial release while small, is similar to initial numbers released by Beers and Wiman (OSU) which have since become established. The *T. japonicus* colony established at NWREC in 2018 will allow additional wasp releases to be made periodically throughout 2019. We will continue to monitor the populations of BMSB in 2019 but focus primarily on *T. japonicus* releases.

The following bullets are a summary of results obtained in this project:

- BMSB populations in Skagit County are increasing.
- Reproducing populations (nymphs) were discovered in Whatcom County.
- No *T. japonicus* were found in Skagit or Whatcom counties.
- *T. japonicus* were released to encourage spread of this beneficial wasp.

Publications and Presentations: The Skagit County Board of Commissioners will be informed of these findings 20 November. Results will be presented to growers and Henry Bierlink, Executive Director of the Washington Red Raspberry Commission, at the annual Red Raspberry Commission Research Review, 2 November 2018. Alan Schreiber, Director of the Washington Blueberry Commission and blueberry growers will be informed of these findings at the annual Blueberry Research Review, 1 November 2018 and results will be reported to the Washington State Commission on Pesticide Registration. Dependent on 2019 funding for maintaining the colonies, an article is anticipated to be submitted to the Whatcom Ag Monthly to provide information on the status of *T. japonicus* releases and recovery.

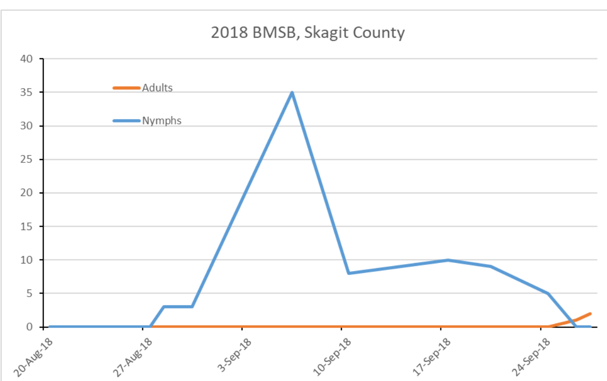

Figure 1. Number of adult and immature brown marmorated stink bugs collected during 2018 (courtesy of Charles Coslor, WSU Skagit County Extension).

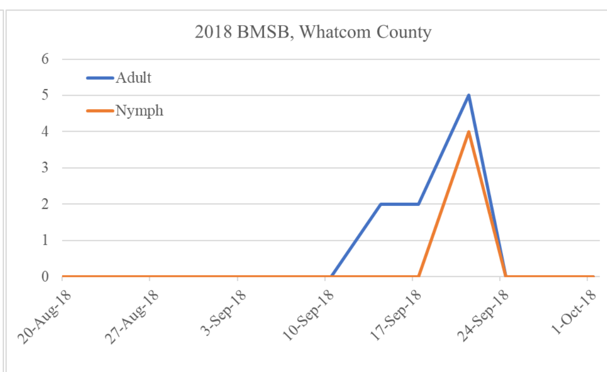

Figure 2. Number of adult and immature brown marmorated stink bugs collected during 2018 (courtesy of Chris Benedict, WSU Whatcom County Extension).

2019 WRRC Proposal

Project Title: Trickle releases of *Trissolcus japonicus*, a parasitoid for long-term management of BMSB, *Halyomorpha halys*, in Skagit and Whatcom Counties

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Year Initiated: 2018 Current Year: 2018 Terminating Year: 2019
Total Project Request: $2,346
Other Funding Sources: Seeking funding from WSCPR, WBC, and NARF

Description:
Small fruit production (caneberries and blueberries) in Western Washington is estimated at $21.5 million. The brown marmorated stink bug, *Halyomorpha halys*, BMSB, is a serious, direct pest of small fruit with few natural predators in North America, allowing it to quickly spread throughout the United States. BMSB is well entrenched in Western Washington and numbers exploded in Skagit County in 2017, since its first detection in 2016, with increasing numbers in Whatcom County.

BMSB will feed and reproduce on blueberries, raspberries and blackberries (Wiman et al 2015, Zhou et al 2016). Buds and fruit of both wild and cultivated *Rubus* spp. are prone to BMSB attack and infestations can result in off-flavors. In addition, BMSB is a machine harvest contaminant with the potential to impact domestic trade and initiate international quarantine trade restrictions. It has already resulted in economic damage in SW Washington on apples and pumpkins but pertinent economic data for small fruits is not yet available. Therefore, its potential impact in NW Washington, the #1 producer of blueberries and #2 producer of red raspberries, is unknown but concern is warranted for this highly polyphagous pest.

Egg parasitoids are the key natural enemies that have helped keep numbers in check in its home Oriental region but native North American egg parasitoids thus far, have exhibited low levels of parasitism. The main Asian parasitoid, *Trissolcus japonicus*, exhibiting 60-90% rate of BMSB parasitization, was detected in SW Washington State, in 2015 by Betsy Beers, WSU TFREC (Weiford 2015), and in Walla Walla in 2017 (Milnes pers. comm.). This is significant and could be a game-changer for the small fruit industry but efforts to detect *T. japonicus* in Skagit and Whatcom Counties in 2018 were not successful. BMSB populations in the PNW are currently at levels most susceptible to biological control mass releases but this window may be closing. 2018 research indicated that BMSB is increasing in both counties. In response to this increase, we propose to make trickle releases of the parasitoid throughout the 2019 BMSB season.

Justification and Background:
Raspberry production in the US is highest in Washington state. Much of this production is local to Whatcom and Skagit counties. Raspberry is one among the numerous potential hosts of BMSB. Hazelnuts are are also produced in Skagit County, and acreage is increasing. This could provide a large refuge for BMSB, in addition to the many ornamental trees in homeowners' yards which would be a challenge to manage with pesticides. Presence of *T. japonicus* will provide a longterm solution to managing BMSB.

Relationship to WRRC Research Priority:
The Washington Red Raspberry commission has management options for control of brown marmorated stink bug listed as a #3 priority. BMSB is difficult to control with pesticides. BMSB populations in the PNW are currently at levels most susceptible to biological control mass releases. Lack of the key parasitoid will result in releases to accelerate its establishment in NW berry growing region providing the best chance for a long-term BMSB management solution. Releases of an effective natural enemy would lessen chances of a build-up of populations and movement into berry crops.

Objectives:
- Trickle releases of *T. japonicus* from May – October 2019 to accelerate establishment, to provide a long-term management solution for BMSB.
- Perform egg parasitoid surveys in Whatcom and Skagit Counties in late summer 2019 to recapture *Trissolcus japonicus* and confirm establishment.

Procedures:
Rearing BMSB for egg masses
WSU NWREC will maintain a colony of BMSB to provide fresh egg masses for the *T. japonicus* colony and the sentinel egg mass survey based on USDA ARS recommendations (Herlihy et al 2014). Reproductive pairs of BMSB will be placed into screened rearing containers 61 cm x 61 cm x 61 cm along with potted bean plants to provide moisture and egg laying substrate. The containers will be exposed to 16-h photoperiod (16:8 h L:D) at 22°C ±2 and 50-55% RH. BMSB adults will be provided organic green beans, seeds, and jelly beans to promote egg development. Egg masses will be used to sustain the *T. japonicus* colony and for sentinel egg masses.

T. japonicus releases
T. japonicus from the WSU TFREC Entomology laboratory will be used to establish a colony at WSU NWREC. Wasps will be kept in 16oz soup containers and filter paper wetted with 50:50 honey water will be added to sustain adults. BMSB egg masses from the BMSB colony will be provided to maintain their reproduction. Parasitoids will be released in batches of 10 in Whatcom and Skagit Counties. Releases will begin in May and continue twice a month through September.

Deployment and collection of BMSB sentinel egg masses
Sentinel egg masses will be set out at release sites in order recapture parasitoids. Egg masses on cards will be stapled to the underside of leaves as high as possible in the canopy, with attached flagging for assistance to relocate. Egg masses will be retrieved after 72 hours to prevent losses from predation and weathering and returned to WSU NWREC. Any parasitoids found on the egg masses in the field will be collected using an aspirator and returned to WSU NWREC for

identification. Parasitized egg masses will be held for emergence in Petri dishes under 16-h photoperiod (16:8 h L:D) at 22°C ±2 and 50-55% RH.

Anticipated Benefits and Information Transfer:
This research is anticipated to accelerate the spread of *T. japonicus* in the region. Guaranteeing the presence of the egg parasitoid in NW Washington will provide growers with the best longterm management solution for BMSB without any use of insecticides.

Results will be reported to WRRC. Stakeholders will be provided information at the annual Small Fruit Conference in Lynden. Information will be available to growers on the Skagit County Extension webpage http://extension.wsu.edu/skagit/ and the Whatcom County Extension website http://whatcom.wsu.edu. All funding sources will share responsibility in evaluating the progress of the project.

Proposed Budget 2018

Salaries and Wages:	
.5 month @ 50% for Plant Technician I (Scott $2,647)	**$675**
Non-student time-slip employee (Coslor) $18/hour for 10 hours/week for 4 weeks	**$720**
Benefits:	
.5 month Plant Tech I @ 92.51%	**$624**
Non-student time-slip @ 9.5%	**$67**
Goods and Services	$0
Operations	$0
Travel – Releasing T. japonicus will require occasional trips to field sites in Whatcom and Skagit Counties @ $0.54/mile X 130 miles	**$260**
Total	**$2,346**

References:

Bergmann, Eric, Karen M. Bernhard, Gary Bernon, Matthew Bickerton, Stanton Gill, Chris Gonzales, George C. Hamilton, Chris Hedstrom, Katherine Kamminga, Carrie Koplinka-Loehr, Greg Krawczyk, Thomas P. Kuhar, Brian Kunkel, Jana Lee, Tracy C. Leskey, Holly Martinson, Anne L. Nielsen, Michael Raupp, Peter Shearer, Paula Shrewsbury, Jim Walgenbach, Joanne Whalen, and Nik Wiman. Host Plants of the Brown Marmorated Stink Bug in the U.S. Stop BMSB. http://www.stopbmsb.org/where-is-bmsb/host-plants/

Herlihy, M. N. Erwin and D. Weber. 2014. Marmorating a day in the life of BMSB rearing at USDA ARS Beltsville. https://www.ars.usda.gov/ARSUserFiles/30842/Herlihy-Erwin-Weber-BMSB-rearing-3Dec2014.pdf

Rice, K.B., C.J. Bergh, E.J. Bergmann, D.J. Biddinger, C. Dieckhoff, G.P. Dively, H. Fraser, T.D. Gariepy, G.C. Hamilton, T. Haye, D.A. Herbert, K.A. Hoelmer, C.R.R. Hooks, A. Jones, G. Krawczyk, T.P. Kuhar, H. Martinson, W.S. Mitchell, A.L. Nielsen, D.G. Pfeiffer, M.J. Raupp, C.R. Rodriguez-Saona, P.W. Shearer, P.M. Shrewsbury, P.D. Venugopal, J. Whalen, N.G. Wiman, T.C. Leskey, and J.F. Tooker. 2014. Biology, ecology and management of brown marmorated stink bug (*Halyomorpha halys*). Journal of Integrated Pest Management 5(3): 1-13 http://jipm.oxfordjournals.org/content/5/3/A1 http://dx.doi.org/10.1603/IPM14002

Weiford, L. 2015. New 'Alien' wasp discovered in Washington state. WSU NEWS Posts. https://news.wsu.edu/2015/10/22/new-alien-wasp-discovered-in-washington-state/

Washington Red Raspberry Commission

2018 Progress Report

Project No: 13C-3443-3276

Title: Investigating Spider Mite Outbreaks in PNW Red Raspberry

Reporting Period: 2018 Report

Accomplishments:

- High tolerance or resistance in Whatcom County red raspberry twospotted spider mites to the insecticide/miticide, bifenthrin.
- Highest susceptibility to abamectin (Agri-Mek).
- Dataset indicated Banter (bifenazate) 5-fold less effective than Acramite.
- Growers play a role in maintaining their resident mite susceptibility to miticides.
- WSU NWREC research is working toward rapid resistance detection through comparison between bioassays and molecular analyses.
- WSU NWREC research is refining DNA barcoding for easier spider mite species identification.

Results:

Bioassays were performed to determine resistance. The bioassays were adapted from the standard FAO leaf residue method (Dittrich et al, 1982). Ten adult field-collected spider mites were transferred to 1” bean leaf discs and treated using 3 rates of three acaricides (Agri-Mek, Acramite and Banter) and using deionized water as the control. Treatments were made using a Potter Precision spray tower (Burkard Scientific, UK).

The dataset represents 3 fields (1 ‘Wakefield’ and 2 ‘Meeker’) and 2 growers. The results show there was a significant difference between efficacy of Acramite and Banter at different rates and bifenthrin underperformed as a miticide (Fig. 1). The difference in performance between the 2 formulations of the same active ingredient, bifenazate is not understood but we are reporting its occurrence in these studies. Prevalence of this trend in other Whatcom red raspberry field populations is unknown. Bifenthrin’s under performance indicates resistance is likely present in Whatcom County spider mite populations. Twospotted spider mites, *Tetranychus urticae*, are the most resistant arthropod in the world and resistance to bifenthrin has been reported to occur in as little as 4 years, from first detection to control failure in Australia cotton (Herron et al 2001).

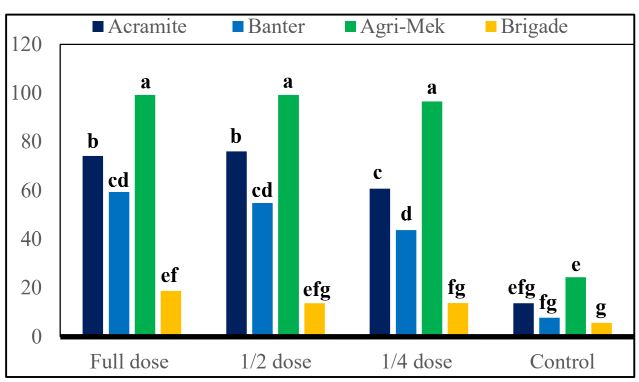

Fig. 1. Percent efficacy of 3 products against twospotted spider mite populations in Whatcom County red raspberry fields.

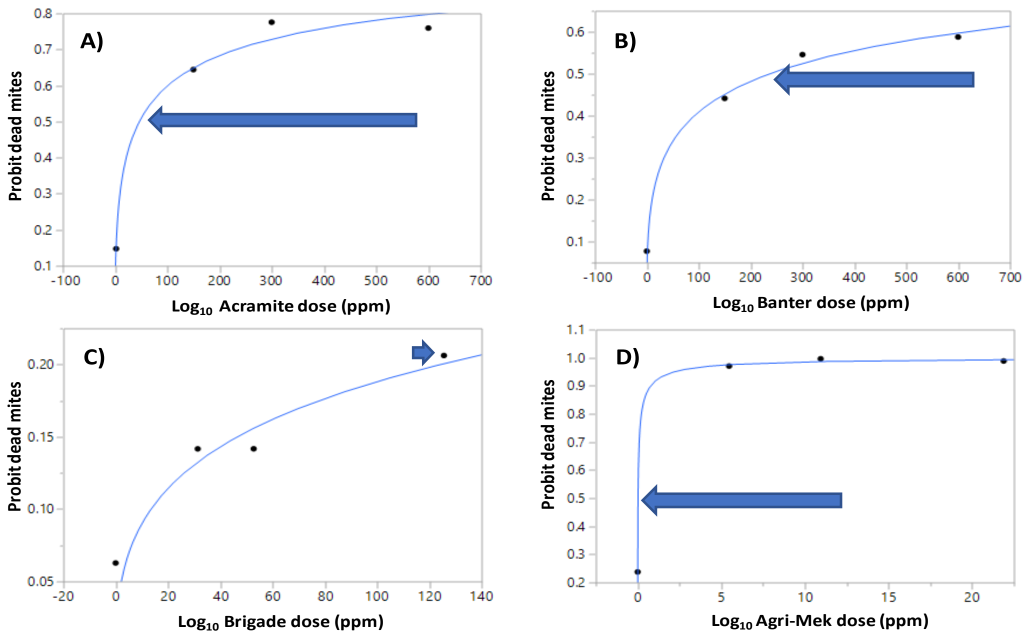

Fig. 2. In the probit analysis, the LC_{50} comparison indicated the mites were highly susceptible to Agri-Mek. The results also showed a 5-fold difference between Banter and Acramite and little activity by bifenthrin.

Conclusions:

While the results of the experiments indicated high susceptibility to Agri-Mek followed by Acramite and Banter, it does not tell the entire story. Most miticide applications are made postharvest when spider mite and predatory mites peak. Predatory mites eliminate spider mite populations and return in high numbers each year, following the end of spotted wing drosophila weekly sprays at the end of the harvest season. Abamectin will eliminate spider mites but is hard on predatory mites, reducing field populations and their availability as a resource for control failures. However, selecting either Acramite or Banter (bifenazate) will knock down the populations while allowing predators to increase, resulting in control and preservation of these natural enemies for subsequent years and in times of need.

Publications: No publications to report at this time, however growers were presented these results at the 2018 Small Fruit Conference in Lynden.

References:

Dittrech, V, J. Cranham, L. Jepson and W. Helle. 1982. Revised method for spider mites and their eggs (e.g. Tetranycus spp. And Panonychus ulmi Koch), FAO method No. 10a. In: FAO plant production and protection paper 21, pp. 49-53. FAO, Rome.

Herron, G. J. Rophail and L. Wilson. 2001. *The development of bifenthrin resistance in two-spotted spider mite (Acari: Tetranychidae) from Australian cotton*. Experimental and applied acarology 25:301-310. Available from: https://www.researchgate.net/publication/11746257_The_development_of_bifenthrin_resistance_in_two-spotted_spider_mite_Acari_Tetranychidae_from_Australian_cotton [accessed Dec 10 2018].

2018 WRRC Progress Report
Title: Determination of bifenthrin and bifenazate resistance in red raspberry spider mite.

Project Description:
In 2018, bioassays of twospotted spider mites collected from three Lynden fields revealed that bifenthrin resistance was present in these populations. So that bioassay results can be validated, the development of molecular assays to detect resistance in spider mite populations is in progress. Populations will also be screened for resistance to bifenazate since reduced efficacy was observed.

Mutations within the voltage gated sodium channel (VGSC) and cytochrome B genes, confer resistance to bifenthrin and bifenazate, respectively. Polymerase chain reaction (PCR) amplification and DNA sequencing of target regions within these genes can identify whether these mutations are present in each individual identified as resistant by the bioassay. Based on a previous study (Piraneo et al. 2015), three domains of the VGSC (II, II-III inter linker, and domain III) and one region of the cytochrome B region will be amplified and sequenced.

To identify spider mites to species, a molecular assay will be used to amplify and sequence a region within the internal transcribed spacer region (ITS). Putatively resistant individuals to will be identified to species so that frequency of resistance can be reported as percent of resistant individuals within each spider mite species occurring in each field population.

Work completed:
To date, DNA has been extracted from 38 individuals from three fields. The PCR protocol to identify mites to species is being optimized. Optimization of the PCR protocol to detect bifenthrin resistance has been completed for three of four primer sets needed to amplify all three gene regions and PCR and DNA sequencing for those regions has been completed for one WA individual. Sequence data for the mite was aligned with reference resistant and susceptible spider mite sequence data. Based on these results, the does not have the mutations conferring bifenthrin resistance.

Work in progress:
To complete genetic screening of spider mites for bifenthrin resistance, the PCR protocol for the last primer set must be optimized. Then, complete genetic screenings for bifenthrin resistance can be run for the remaining collected individuals. PCR protocols will be optimized for two primer sets needed to screen the cytochrome b gene region that confer bifenazate resistance.

The previously published primer set (Osakabe et al. 2008) used to amplify the ITS region for identification may not be as specific as previously thought. The ITS region is present most organisms and this primer set may be amplifying the ITS region of mite associated ecto- and endosymbionts. While a fragment of the expected band size (approximately 1163 bp) is observed (Fig. 1.), additional fragments of approximately 750bp and 1250bp are also present. These results suggest that direct sequencing of the PCR product is not possible. Cloning of PCR products is in progress and will allow for the isolation of the desired band downstream identification analyses by either restriction digestion or sequencing.

Figure 1. Photograph of the ITS amplification banding pattern of one spider mite individual. A band fragment of approximately 1160 bp is the expected band size for spider mite species *Tetranychus urticae*.

Benefits to growers:
This research is anticipated to further investigate the subject of resistance in twospotted spider mite populations in Whatcom County red raspberry fields, using bifenthrin and bifenazate as models. The project will establish the baseline frequency of resistance in current spider mite populations so that shifts in resistance within populations can readily be identified. And, the development of these molecular assays will provide a more rapid and efficient screening tool to monitoring these future populations.

2019 WRRC Proposal

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

PI: Beverly Gerdeman
Assistant Research Professor, Entomology
Phone: 360-848-6145
Email: bgerdeman@wsu.edu
Organization: Washington State University
Address: 16650 State Route 536
Mount Vernon, WA 98273-4768

Year Initiated: 2018 Current Year: 2018 Terminating Year: 2019
Total Project Request: $24,358
Other Funding Sources: Seeking funding from WSCPR

Description:
In 2018 we performed bioassays of twospotted spider mites collected from three Lynden fields in order to compare 3 products. We detected resistance in the populations to bifenthrin, the industry standard clean-up spray. We also performed molecular assays to screen spider mite populations for miticide resistance. Together, bioassays and molecular assays combine the most current methods for detecting resistance in a spider mite population by addressing the problem from 2 different directions. We are proposing to continue with this approach combining bioassays with molecular assays and with the addition of high thoroughput capabilities following the 2018 season, we will now be able to screen many locations at once, moving the process in the second step in the direction of "real-time" capabilities.

Justification and Background:
Washington State produces approximately 75% of the total US production of frozen red raspberries and Whatcom County is directly responsible for Washington's #1 red raspberry production ranking (NASS 2015). Washington Red raspberry growers broke a record with 78.2 million pounds produced in 2016 resulting in $0.90/ pound for growers. Spotted wing drosophila, *Drosophila suzukii*, has been the top priority for red raspberry growers since it first entered the state in 2009. In response, growers adopted a weekly spray schedule to protect their berries due to zero tolerance for larvae in fruit. Spider mites are prone to resistance development and are considered the world's top resistant pest (Van Leeuwan et al. 2010). TSSM resistance has been reported from 60 countries and includes abamectin, bifenazate, bifenthrin, hexythiazox and fenpyroximate in addition to 90 other insecticides. Weekly sprays to protect berries from SWD are pushing spider mites toward resistance. The 2017 spider mite outbreaks were unprecedented for Whatcom County red raspberries and both preliminary bioassays in 2017 and bioassays performed in 2018 indicated bifenthrin resistance in the population but not yet to bifenazate. With the possibility of resistance to bifenthrin detected, it is important to carefully monitor spider mite populations because additional resistance could limit a grower/s treatment options.

Bioassays to determine resistance levels in spider mites require skill, are laborious and lima beans must be grown to serve as the leaf discs for treating the field-collected spider mites which require planting, soil, tending and greenhouse space and time required is upwards of 3 months. Bioassays have long been the standard to detect tolerance and susceptibility to products and will likely remain that way for some time. On the other hand, molecular assays can minimize the labor and cost associated with assessing miticide resistance in a population. Genetic screening of spider mite populations for miticide resistance can provide an important layer of support that could eventually replace laboratory bioassays. Molecular assays generate results more rapidly than bioassays while reducing labor and cost. Increasing spider mite screening efficiency for miticide resistance while understanding the risk factors for outbreaks in red raspberry will provide the best insurance to avert spider mite resistance. Funding from WRRC will support the validation of molecular screening methods against the traditional bioassay procedures while also establishing baseline resistance currently present in fields. The results from this study could be used for the future development of an in-field, molecular diagnostic assay for "real-time" resistance detection.

Relationship to WRRC Research Priority: The Washington Red Raspberry Commission has mite management listed in the # 2 priority category but the recent severe outbreaks in 2017 coupled with our preliminary findings of resistance in the spider mite in 2018, indicate spider mites are becoming a serious problem in Whatcom County. The development of a more rapid and efficient method of resistance detection for spider mites in red raspberry fields will provide growers with a more accurate baseline measurement of miticide tolerance.

Objective:

The project addresses the following objective:

- Further explore resistance levels of Whatcom County red raspberry twospotted spider mite populations to bifenazate (Acramite®) and bifenthrin (Brigade®) or additional products, dependent on grower input. This will include screening corresponding spider mite populations to determine if results correlate to those of the bioassay and determine % incidence of resistant mites by species in field populations.

Procedures:

Acaricide Bioassay

Beginning in July, bush beans will be planted and grown in the greenhouse in cages to maintain clean leaves by preventing accidental infestation of spider mites or whiteflies. Twospotted spider mites, *Tetranychus urticae* (TSSM), from multiple, widely separated infested red raspberry fields in Whatcom County, will be collected and transported to the WSU NWREC laboratory for bioassays. Leaf discs, 2.45 cm in diameter, will be punched from bush bean leaves and 2 discs will be arranged/Petri dish on a deionized water-soaked cotton pad. Ten adult twospotted spider mites, will be transferred from the infested raspberry leaves to each bean leaf disc using a fine artist's brush, totaling 30 mites per site and 90 mites per rate/site. Each of the products will be prepared at the full field rate, then serially diluted to ½ and ¼ rates. A Petri dish representing each site, will be topically treated with 2 ml of deionized water serving as the control, using a Potter Precision Laboratory Spray Tower (Burkard Scientific), totaling 90 mites. Each leaf disc represents a replicate with 3 replicates/rate/treatment/site for a total of ~1170 spider mites including the control. Each Petri dish will be topically treated with 2 ml of each concentration of each active ingredient, as above. After 24 hours, mites will be recorded as dead or alive based on whether a mite can walk a body length when prodded with a blunt probe. Statistics will be performed to determine if tolerance to an active ingredient is detected.

Molecular Assay

DNA Extraction, polymerase chain reaction, and sequencing. Live and dead spider mites from bioassays will be screened using molecular methods. Individual spider mite DNA will be extracted using the Qiagen DNEasy Blood and Tissue Kit (Dusseldorf, Germany). Previously designed primer sets (Piraneo et al. 3025) will be used to amplify and sequence domains II and III of the voltage-gated sodium channel and cytochrome b genes, which are the target loci of bifethrin and bifenazate, respectively. Sequences will be compared to reference sequences from previously characterized, susceptible and resistant spider mites (Tsagkarakou et al. 2009).

Data Analysis

Correlation analyses using Proc Corr (SAS 9.3) will be run to determine if detection of resistance within a population based on bioassays corresponds to detection based on molecular assays.

Determine % incidence of resistant mites by species in field populations.

Twenty individual spider mites from multiple sites in Whatcom County will be collected and DNA will be extracted as described above. Individuals will be identified to species using morphology and identification confirmed with PCR amplification and sequencing. The primer set 5'-TGATTTTTGGTCACCCAGAAG-3' and 5'-TACAGCTCCTATAGATAAAAC-3' (Navajas et al. 1998) will be used to amplify and sequence the cytochrome oxidase subunit 1 region. Sequence data will be compared to reference sequences in NCBI GenBank (Benson et al. 1993). Loci conferring to bifenthrin and bifenazate resistance will be PCR amplified and sequenced as above.

Data analysis

% incidence of resistant mites for each product by species for each field sampled will be calculated by:

% incidence = no. mites with resistance gene mutations/total mites

Anticipated Benefits and Information Transfer:

This research is anticipated to further investigate the subject of resistance in twospotted spider mite populations in Whatcom County red raspberry fields, using bifenthrin and bifenazate as models to develop high thoroughput methods and how they compare with traditional laboratory bioassays by expanding the numbers of field populations tested. This research is moving toward a more rapid method of resistance detection with the goal of in-field resistance detection.

Results will be reported to WRRC at grower meetings including the annual Small Fruit Conference in Lynden and as an article in the Whatcom Ag Monthly. A peer-reviewed journal article is also a goal of this project.

Proposed Budget 2018

Salaries and Wages:	
2 months @ 62.5% FTE for Ag Research Tech III ($4,360/mo)	$5,451
2.5 @ 49.02% FTE for Ag Tech I (Morgan) ($2,891/mo)	$3,543
2.5 months @ 49.02% FTE for Ag Research Tech I (Scott) ($2,700/mo)	$3,309
Non-student time-slip ($13/hr @ 8 hr/week/16 weeks)	$1,664
Benefits:	
1.25 months Ag Research Tech III @ 42.6%	$2,319
1.25 months Ag Tech I (Morgan) @ 53.47%	$1,894
2 months Ag Research Tech I @ 92.5%	$3,061
Non-student time-slip employee @ 9.3%	$155
Goods and Services	
Petri dishes, filter paper, cotton, paper sacks, artists brushes	$2,526
Travel – Weekly trips to Whatcom County @ $0.54/mile	$436
Total	**$24,358**

References:

Field, L. M., Davies, T.E., O'Reilly, A.O., Williamson, M.S., and Wallace, B.A. Voltage-gated sodium channels as targets for pyrethroid miticides. European Biophysics Journal, 46. 7: 675-679.
Gerson, U., and E. Cohen. 1989. Resurgences of spider mites (Acari: Tetranychidae) induced by

synthetic pyrethroids. Experimental and Applied Acarology 6: 29-46.

James, D. and T. Price. 2002. Fecundity of twosppotted spider mite (Acari: Tetranychidae) is increased by direct and systemic exposure to imidacloprid. Journal of Economic Entomology, 27: 151-156.

Piraneo, T.G., Bull, J., Morales, M.A., Lavine, L.C. Walsh, D.G. and Zhu, F. 2015. Molecular mechanisms of *Tetranychus urticae* chemical adaptation in hop fields. Scientific reports, 5: 17090.

Tatman, K., C. Dieckhoff, D. Hoelmer and C. Hooks. 2013. Using sentinel egg masses (colony-produced) & wild egg masses (laid in field) to monitor BSB parasitism & predation. USDA ARS BIIR, Newark DE & Univ. Maryland, College Park. Rev 26 Feb 2013.

Tsagkarakou, A., Van Leeuwen, T., Khajehali, J., Ilias, A., Grispou, M., Williamson, M.S., Tirry, L. and Vontas, J. 2009. Identification of pyrethroid resistance associated mutations in the para sodium channel of the two-spotted spider mite *Tetranychus urticae* (Acari: Tetranychidae). Insect molecular biology, 18. 5:583-593.

Washington Blueberry Commission
Progress Report for 2018 Projects

Title: Development of Biologically-based RNAi Insecticide to Control Spotted Wing Drosophila

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

Reporting Period: 2017 - 2018

Accomplishments:
- Constructed and biosynthesized double-stranded RNAs (dsRNAs) of 32 SWD RNAi targets.
- Screened 3 potential RNAi targets from 13 potential RNAi targets from SWD.
- Three housekeeping RNAi targets have been knock downed by dsRNA injection into SWD.
- Selected and found a significant target from three additional receptors genes in SWD.

Results:
For optimal impact of dsRNA delivered to target cells through feeding, RNAi target genes should focus on systemic RNAi if dsRNA can be internalized into the target cells through feeding. We have selected over thirty (>30) RNAi targets based on the previous studies for insect RNAi targets and biological functions. These target genes include essential housekeeping genes that are required for the maintenance of basic cellular functions, neuropeptide (NP) hormones and receptors for SWD life stages.

Inject dsRNA into adult flies and monitor RNAi impacts: During two years the 1st screening with more than 13 RNAi candidates was completed with over 3,000 nano-injections to flies. We found effective phenotypic impacts, mainly mortality, from some of the RNAi injection into SWD flies.

Genotypic impact of the housekeeping genes for RNAi targets: We investigated the gene expression levels to find whether those genes are being suppressed or not after target RNAi (dsRNA) injected into SWD. Using the quantitative gene analysis we found all three RNAi target genes have been knock downed by dsRNA introduction to SWD.

RNAi impact of a neurohormone receptor on SWD adult: We examined the gene expression levels of neurohormone receptors after target RNAi (dsRNA) applied to SWD. Using the quantitative PCR gene analysis (qPCR) we found the receptor was significantly suppressed by dsRNA introduction in SWD adults.

Continue and ongoing study - For next year we will continue the evaluation of Objective 3-1 (Inject RNAi into adult flies and monitor RNAi impacts) on SWD, and to move for Objective 3-2 (Feed RNAi selected into larvae and/or adults, and monitor RNAi impacts on SWD).

Publications:
1. Choi, M.-Y. H. Lucas, R. Sagili, D. H. Cha, and J. C. Lee. 2018. Effect of erythritol on *Drosophila suzukii* (Diptera: Drosophilidae) in the presence of naturally-occurring sugar sources, and on the survival of *Apis mellifera* (Hymenoptera: Apidae). Journal of Economic Entomology (*in press*).
2. Tang, S.B., J.C. Lee, J.K. Jung and M.-Y. Choi. Effect of erythritol formulation on the mortality, fecundity and physiological excretion in *Drosophila suzukii*. Journal of Insect Physiol. 101:178-184. 2017.

2019 WASHINGTON RED-RASPBERRY COMMISSION RESEARCH PROPOSAL

Continuing Proposal

Title: Development of Biologically-based RNAi Insecticide to Control Spotted Wing Drosophila

Year Initiated 2017 **Current Year** 2019 **Terminating Year** 2021

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

Cooperators: Dr. Jana Lee, Research Entomologist, USDA-ARS, Dr. Seung-Joon Ahn, Postdoctoral Associate, Oregon State University, 3420 NW Orchard Ave. Corvallis, OR 97330

Justification and Background:
SWD is a serious invasive pest from Asia that is now in the United States, Canada, Mexico, South America, and Europe. The severe damage caused by this destructive pest affects ripening small fruits, and the infestation area is rapidly spreading through North America as well as Europe. Growers are facing economic losses by increased spending on management costs, the loss of production and market values, and rejection of exports if unacceptable levels of insecticide residues and damage are found. Current control of SWD relies heavily on chemical insecticides which have negative impacts on agricultural ecosystems affecting non-target insects, pollinators, and human health. In addition, there is an inevitable risk that SWD populations in the field will develop insecticide resistance with the continuous use of chemical controls. Therefore, the heavy reliance on chemical insecticides should be replaced or at least complemented with biologically-based environmentally friendly alternatives.

During the past decade the availability of insect genomics and computational biology has further enabled the implementation of RNAi technology to target economically important insect pests. It has shown striking results in various insect groups, suggesting that it will be a promising tool for the next generation of pest management. Recently, intensive studies of the RNAi application for insect pest management in academia and commercial entities has enabled a breakthrough by having the first RNAi product as a commercial bio-pesticide in the field soon. To date, a variety of RNAi targets are being screened and evaluated for specific impacts applicable to pest management of agricultural crops or insect vector-borne diseases.

To successfully develop RNAi applications, a critical initial step is screening for appropriate RNAi target genes because degrees of gene silencing impacts vary from RNAi target genes and insects. The challenge with gene selection is to select suitable insect-specific target genes that provide fast-acting mortality or suppression and long-term population suppression without affecting other non-target organisms. Therefore, it is important to screen multiple and key RNAi candidates to improve the chance for identifying an effective RNAi target. To find the most effective RNAi target(s), our project proposal will be focused on the screening of RNAi targets in SWD.

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

Objectives: The goal of this research objectives is the development of a novel environmentally-friendly control that is non-toxic insecticide and non-genetically modified strategy to control SWD as well as other potential pests. RNAi approach to pest management consider three major challenges: 1) selection and identification of suitable target genes, 2) cost effective RNAi material production, and 3) development of a suitable delivery method into target pest. A large scale production of RNAi in vitro using kits is too expensive, and not a practical approach for growers (#2). Therefore, there is required a mass production system to synthesis dsRNA through a microbial-based process provides more practical application. To solve this problem, we have established a mass production system using a microbial-induced dsRNA production to increase the feasibility of RNAi application for SWD control. To control SWD the strategy of our RNAi approach is non-planted incorporated delivery method such as spray and/or bait-station application (#3).

In the present proposal, therefore we focus on the screening and identification of suitable RNAi target(s) from SWD (#1). A feasible approach for RNAi target gene screening is to search previous targets or systems observed already from same or similar insect groups. Therefore, our approach for RNAi target gene screening is based on our current RNAi research and previous RNAi results. We recently started the screening of RNAi candidates from SWD, and currently evaluate their impacts on the fly. In this proposal we continue to screen more target genes from SWD, and evaluate and identify suitable RNAi targets. In order to achieve this goal the following specific objectives need to be accomplished in this project:

1. Cloning and identify potential RNAi target genes from SWD (Yr. 1)- *completed*
2. Construct, design and biosynthesis dsRNAs for target genes (Yrs. 1 & 2) – *completed*
3. Screen for efficacy using bioassay to measure RNAi impacts on SWD (Yrs. 2& 3) - *ongoing*
   3-1. Inject dsRNA into adult flies and monitor RNAi impacts (Yrs. 2& 3) – *partially completed*
   3-2. Feed dsRNA to larvae and adults, and evaluate RNAi impacts (Yr. 3) - *ongoing*

Procedures

PI has expertise on insect RNAi and published research results in four peer-reviewed papers as a lead or co-author (Choi et al., 2012, 2014, 2018; Gundersen-Rindal et al., 2017) and the USDA-ARS news (USDA-ARS, 2014) that demonstrated the selection of RNAi targets, construct dsRNA, micro-injection and bioassay in insect pests. In addition, those research results have been published four RNAi patents (Vander Meer and Choi, 2013, 2015, 2017, 2018) to develop RNAi control method, and are being developed for practical use. Therefore, PI is well-positioned to conduct all experimental procedures, and supervise technical assistants or graduate students for this project.

1. Identify potential RNAi target genes: We will employ a BLAST search with the published SWD genome to identify homologous genes in SWD. Using routine molecular biology techniques and software, specific primers and/or degenerate primer set will be designed to amplify target genes. Once confirmed the sequence DNA fragments will served as the template for dsRNA synthesis. With PI's molecular biology knowledge and experience this approach is expected to be straightforward without possible pitfalls.

2. Evaluate RNAi impact(s) on SWD: DsRNAs of each target SWD gene will be dissolved in RNase free water and injected into pupal or adult stages of SWD using a nanoliter injector. PI has experience with micro-injecting dsRNA into small insects such as ants. After injection SWD will be monitored for negative impacts including mortality, longevity, fecundity and other parameters. Dr. Lee's lab has developed a system to monitor longevity and fecundity of flies. Dr. Martin's lab has experience and tools to investigate the silencing of RNAi-targeted genes. Once we identify best RNAi target genes, feeding assays will be conducted if incorporated into a bait and kill approach.

3. Screening RNAi targets of SWD: For adult feeding assays, various dsRNA concentrations determined from the injection experiment will be mixed in a dry bread yeast. The mixed yeast with dsRNA material will be sprayed on the surface of the artificial diet in a petri-dish to allow adult flies to feed in the cage. After feeding, flies will be monitored for phenotypic changes, and verified for gene silencing as described above.

List of Accomplishments

Identify partial and/or full sequences for more target genes, and obtain actual DNA data.

Design templates for dsRNA synthesis, synthesis dsRNAs for all target genes and evaluate each dsRNA amount and purity.

Determine negative phenotype and/or genotype impacts on SWD, obtain narrowed down SWD RNAi targets for further evaluation.

Describe how this research will benefit Washington blueberry growers: At the completion of these studies we expect to have identified potential RNAi target(s) that can be used to develop a biologically-based insecticide as a chemical insecticide alternative to control SWD for blueberry growers and other pests of small fruits. We also expect to identify specific physiological impacts from RNAi treatments on SWD. Thus, outcomes are not only expected to address specific questions in RNAi research for SWD control, but also to have fundamental impacts for the application of RNAi for biological pest control.

References selected:

Choi, M.Y. and Vander Meer, R.K. 2018. Phenotypic Effects of PBAN RNAi Using Oral Delivery of dsRNA to Corn Earworm (Lepidoptera: Noctuidae) and Tobacco Budworm Larvae. J. Econonmic EEntomol. (*in press*).

Gundersen-Rindal, D.E., S.L. Adrianos…, M.-Y. Choi, …, and B.S. Coates. 2017. Arthropod genomics research in the United States Department of Agriculture Agricultural Research Service: Applications of RNA interference and CRISPR gene editing technologies in pest control. Trends in Entomol. 13:109-137.

Choi, M.Y., Vander Meer, R.K., Coy, M., Scharf, M.E., 2012. Phenotypic impacts of PBAN RNA interference in an ant, *Solenopsis invicta*, and a moth, *Helicoverpa zea*. J Insect Physiol 58, 1159-1165.

Huvenne, H., Smagghe, G., 2010. Mechanisms of dsRNA uptake in insects and potential of RNAi for pest control: a review. J Insect Physiol 56, 227-235.

Lee, J.C., Bruck, D.J., Dreves, A.J., Ioriatti, C., Vogt, H., Baufeld, P., 2011b. In Focus: Spotted wing drosophila, *Drosophila suzukii*, across perspectives. Pest management science 67, 1349-1351.

Vander Meer, R.K., Choi, M.Y. 2018. Double-Stranded RNA Constructs to Control Insect Pests. Patent No US10093928.

Vander Meer, R.K., Choi, M.Y. 2017. Lepidopteran Moth Control Using Double-Stranded RNA Constructs, Patent No US9617542.

Vander Meer, R.K., Choi, M.Y. 2015. Control of insect pests through RNAi of Pheromone Biosynthesis Activating Neuropeptide Receptor, Patent No US9000145.

Vander Meer, R.K., Choi, M.Y. 2013. Formicidae (Ant) control using double-stranded RNA constructs, Patent No US 8575328.

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Budget

This project is being submitted to OBC, WBC, ORBC and WRRC ($10,000 each) for FY19-20. USDA-ARS base funds in Dr. Choi's programs will be used to fund additional technical support and supplies for the project.

	2019	**2020**
Salaries[1/]	$25,500	$26,200
Time-Slip	$0	$0
Supplies & Services	$5,000	$4,500
Travel[2/]	$1,000	$800
Meetings	$0	$0
Other	$0	$0
Equipment[3/]	$0	$0
Benefits[4/]	$8,500	$8,500
Total	**$40,000**	**$40,000**

Budget Justification

[1/]Postdoctoral associate (0.5FTE) - 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 (~$1,780 per month).

Total Budget for Project 2019 $40,000

Funding Breakdown
WRRC, WBC, OBC, and 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	OBC, ORBC, WBC & WRRC	$35,000	01/01/2018 - 12/31/2018	10	Development of biologically-based RNAi Insecticide to control spotted wing drosophila
Choi/Martin	OR Association of Nursery	$22,000	01/01/2018- 12/31/2018	5	Genomic sequencing of gray garden slug: A molecular foundation for slug research
Choi/Martin/ Rao	Agricultural Res. Foundation	$12,500	01/01/2018- 12/31/2019	3	Identification of antennal odorant receptors for biological targets to control Spotted Wing Drosophila
Choi/Lee	WA Tree Fruit Research	$48,260	01/01/2018- 12/31/2018	10	Non-toxic RNAi-based biopesticide to control spotted wing drosophila
Choi/Martin	OR Seed Council	$20,000	01/01/2018- 12/31/2018	5	Screening of target genes to develop an RNAi-based biopesticide to control gray garden slug (*Deroceras reticulatum)*
Choi/Lee	WA Tree Fruit Research	$3,8060	01/01/2018- 12/31/2018	5	Non-nutritive sugar-based control strategy for spotted wing drosophila
Mc Donnell/Denver/Choi/Martin	OR Department of Agriculture	$174,853	10/01/2018- 03/31/2021	5	Development of new biological control strategies for pest slugs

	Pending:				
Choi	OBC, ORBC, WBC, WRRC	$40,000	01/01/2019-12/31/2019	10	Development of biologically-based RNAi Insecticide to control spotted wing drosophila
Choi/Lee	WA Tree Fruit Research	$44,000	01/01/2018-12/31/2018	5	Non-nutritive sugar-based control strategy for spotted wing drosophila
Choi/Martin	OR Association of Nursery	$24,500	06/01/2018-05/31/2019	5	Identify biological targets including RNAi to develop thrips management for nursery crops
Choi/Lee	WA Tree Fruit Research	$48,260	01/01/2018-12/31/2018	10	Non-toxic RNAi-based biopesticide to control spotted wing drosophila

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

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

PI: Alan Schreiber
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Title: Researcher
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Cooperators

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

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

Spotted wing drosophila (SWD) control is based largely on calendar sprays of organophosphate, carbamate, neonicotinoid and pyrethroid insecticides with some reliance on products such as Delegate and Exirel. These programs create problems with Maximum Residue Limits (MRLs) for export, occasionally flare aphid and mite problems and have other issues such as preharvest intervals, cost and some concerns associated with human health and the environment. In some cases, environmental conditions such as rain and wind can cause problems with applications, and ultimately efficacy.

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 formed the basis of products that are used for pink bollworm control in cotton using a pheromone, for control of mountain pine beetle in forestry using a repellent, to control fall armyworm in corn, carob moth in dates and a fruit fly that infests tropical fruits, among other applications. The company that developed the SPLAT Technology, ISCA Technologies, has developed a new formulation, called Hook SWD, which specifically targets SWD with an attract-and-kill strategy.

The active ingredient in Hook SWD is spinosad. The company has recently teamed up with the IR-4 Project and Driscoll's to evaluate the efficacy of this product on fresh raspberry and blackberries grown under tunnels in California. UC Cooperative Extension Agent, Mark Bolda is conducting this trial. Rutgers University Cesar Rodriguez-Saona and University of Florida Oscar Liburd are conducting trials with this product in blueberries. The product is applied to the base of berry plants and does not come into contact with the fruit and thus has the potential for insecticide residue free fruit-assuming it is effective.

ISCA Technology 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 include cost of the product and application, number of applications required, ease of use, irrigation and rain fastness. Because the product is not registered, the cost is unknown. However, based on the costs of other formulations with this a.i., the registrant has an approximate potential material cost of $22.50 per acre per application.

A model that might be similar to this is codling moth mating disruption. Almost all apple growers use mating disruption 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.

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, Jesse Saroli, on how to set up this trial. The minimum plot size should be at least 2 acres (approximately 210 x 206 feet) and should have four replicates meaning the trial would require 8 acres per treatment. We are proposing three treatments, so this would require a field that is at least 24 acres. We would like to do this trial in two locations.

The treatments would be 1) grower standard SWD program, 2) grower 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. 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 evaluation would be how much additional control the Hook SWD programs provided to the program. Once efficacy of SWD has been established, future trials might include Hook SWD only treatments.

The product would be applied in a band to the base of the canopy by backpack sprayer in 1 yard strips every 4 to 5 five yards. Depending upon SWD pressure, 200- 800 fruit would be collected from each plot each week and analyzed for SWD larvae using the salt dunk method. Results would be analyzed by analysis of variance.

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, mites or scale 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.

Budget:

	2019	**2020**	**2021**
Salaries[1/]	$4,000	$4,000	$5,000
Time-Slip	$	$	$
Operations	$	$	$
Travel[2/]	$1,000	$1,000	$1,000
Meetings	$	$	$
Other	$	$	$
Other – Contract Research	$4,000	$4,000	$5,000
Benefits[4/]	$1,000	$1,000	$1,250
Total	**$10,000**	**$10,000**	**$12,500**

WEEDS

Project Number: 13C-3419-7297

Title: Weed Control in Red Raspberries

Personnel: Timothy W. Miller, WSU Mount Vernon NWREC
Steven Seefeldt, WSU Mount Vernon NWREC

Reporting Period: 2016-18

Accomplishments: Two raspberry trials were conducted during 2016-18: the WRRC and RIDC caneburning trial and a baby raspberry trial. The first trial was conducted at the Honcoop Farm near Lynden, WA, the second at WSU NWREC. Data for both trials are reported here and will presented at the Northwestern Washington Small Fruit Conference in Lynden and the Lower Mainland Horticulture Improvement Association Short Course in Abbotsford in January, 2019.

Results:

<u>*Caneburning trial*</u>. The objective of this trial was to determine how raspberry vigor may influence the effects of caneburning treatments and potentially affect stand longevity. The 2018 trial was established in 2017 at Lynden (Randy Honcoop, cooperator) at two ends of the same 'Meeker' field. Two rows at the eastern end of the field were designated as "low vigor", while two rows at the western end of the field were "high vigor". Both sections received identical caneburning treatments as follows, and individual plots received the same treatments each year:

1. No in-row treatments; late treatment with Aim to sides of the bed;
2. Early treatment with Aim to full bed; no late treatment to sides of the bed;
3. Standard treatment with Aim to full bed; no late treatment to sides of the bed;
4. Early treatment with Aim to full bed; late treatment with Aim to sides of the bed;
5. Standard treatment with Aim to full bed; late treatment with Aim to sides of the bed;
6. No in-row treatments; late treatment with Goal to sides of the bed;
7. Early treatment with Goal to full bed; no late treatment to sides of the bed;
8. Standard treatment with Goal to full bed; no late treatment to sides of the bed;
9. Early treatment with Goal to full bed; late treatment with Aim to sides of the bed;
10. Standard treatment with Goal to full bed; late treatment with Aim to sides of the bed;
11. No caneburning (nontreated check).

Early treatments were applied when first primocanes were less than 2-inches tall (March 31, 2017 and April 9, 2018). Standard treatments were applied when first primocanes were 4- to 6-inches tall (April 14, 2017 and April 20, 2018). Late treatments were applied only to the sides of the bed using a shielded sprayer so primocanes in the row weren't treated. If the full bed had not been previously treated, the late treatments were applied April 25, 2017 and April 27, 2018. If the full bed had been treated at the early timing, the late treatments were applied May 19, 2017 and May 14, 2018. Finally, if the full bed had been treated at the standard timing, the late treatments were applied May 25, 2017 and May 22, 2018.

Each plot measured 25 ft long, centered on a single row of raspberry. Floricanes were counted at the beginning of the experiment to determine if raspberry vigor categories were correctly assigned and to set a baseline for each plot. The only summer measurement on these plots was to sample berries on the east side of canes along 1 meter of each plot (July 11, 2017 and July 2. 2018). The experiment was a randomized complete block design with three replicates. Means were separated using Tukey's Honestly Significant Difference statistic ($P \leq 0.05$).

Initial vigor estimates showed that low vigor plots contained fewer floricanes than high vigor plots (77 and 101 canes/25 ft, respectively) (data not shown). Floricane count in individual plots did not differ prior to application of caneburning treatments for each of the two two vigor categories (Table 1). After one year of different caneburning treatments, strong vigor raspberries averaged 137 floricanes/plot, significantly more than the 104 floricanes/plot in weak vigor section (data not shown). All plots increased in floricane number during 2017 except low vigor canes treated late with Aim only to the sides of the bed (Treatment 1) (Table 1). The biggest "winner" in low vigor raspberries were those not caneburned in 2017 (Treatment 11, net increase of 67 floricanes/plot, a 183% increase), although Treatments 2 and 7 also resulted in significantly more floricanes/plot. For high vigor raspberries, Treament 11 also resulted in the greatest numerical increase in floricane count, although all treatments except Treatment 1 were statistically equal. As in low vigor raspberries, Treatment 1 resulted in the lowest increase among all treatments in high vigor canes.

In 2017, berry sample yield was greater in high vigor plots than in low vigor plots (327 and 290 g/m, respectively), as were 50-berry weights (1.9 and 1.8 g/berry, respectively) (data not shown). In 2018, however, neither sample yield nor 50-berry weights differed between vigor categories, with high vigor raspberries yielding 464 g/m compared to 448 g/m for low vigor raspberries, and fruit size averaging 2.4 and 2.3 g/berry for the two vigor classifications, respectively (data not shown).

Sample yield did not differ by caneburning treatment in either vigor classification or in overall sample yield across the two vigor classes in either year (Table 2). There was a trend toward lower berry production in non-caneburned raspberries in both low and high vigor raspberries,. Low vigor raspberries also tended to produce poorly in Treatment 1, while high vigor raspberries tended to produce less fruit in Treatments 6, 8, and 9. The overall (low and high vigor raspberry) response tended toward lower sample yield in Treatment 1 and in non-caneburned raspberry plants.

Fifty-berry weight also did not differ among the treatments in low vigor raspberries in 2017, or in high vigor raspberries in either year (Table 3). Low vigor raspberries did, however, exhibit increased fruit size in Treatment 4 (2.9 g/berry) compared to Treatments 1 or 2 (2.0 or 2.1 g/berry) in 2018. This increase in Treatment 4 also resulted in greater overall (both low and high vigor raspberries) fruit size in 2018.

From these data, it appears that 2017 was a good year for primocane production, and caneburning program appeared to be of lower importance to final floricane population going into 2018. While berry yield was significantly greater in 2018 than in 2017, yield parameters were not greatly affected by caneburning program although there was a trend toward increased productivity with primocane management than without. Floricane counts this winter (2018-19) will reflect two years of the same caneburning treatments and may therefore provide more greater specificity as to best and worst caneburning treatments in relation to floricane counts for these two vigor classes. But at this moment, it appears that caneburning otherwise healthy older raspberry plantings does not negatively affect floricane or fruit production, regardless of whether plants were initially classed as either low or high in vigor.

Baby Raspberry Trial. Tissue-culture 'Cascade Harvest', 'Meeker', 'Squamish', and 'Wakefield' red raspberry plugs were obtained from Northwest Plant Company and were transplanted by hand at WSU NWREC May 26, 2016. In 2017 and 2018, 'Meeker', 'Squamish', and 'Wakefield' red raspberry plugs were transplanted May 24, 2017 and May 8, 2018. Three plants of each cultivar were planted sequentially into a single row in each plot. In 2016, all herbicides were applied post-transplant over the top of each row May 18; in 2017, pre-transplant (PRETR) herbicides were applied May 23 and post-transplant (POSTR) herbicides were applied May 26, while in 2018 PRETR and POSTR herbicides were applied May 7 and May 8, respectively. Weed control was estimated on July 26 and September 12, 2016, July 18 and October 16, 2017, and June 15 and October 12, 2018. All plots were hand-weeded after mid-season weed control was rated; therefore, late season weed control represents a combination of early herbicide and hand weeding. Length of the longest cane on each plant was measured at the mid-season and late-season timings, except for 2018, when mid-season measurements were made August 6. The experiments were randomized complete block designs, each with three replicates. Means were separated using Tukey's Honestly Significant Difference statistic ($P \leq 0.05$).

The best mid-season weed control in 2016 ranged from 78 to 98% (Table 4), while weed control with Devrinol (40%), Prowl H2O (60%), and Trellis (75%) was less effective (Table 4). By September, only Fierce was still providing an acceptable level of weed control (87%), although control ratings were quite variable among the plots. In 2017, weed control was quite variable at both evaluations and did not differ by treatment (Table 4). Most products not providing acceptable weed control at mid-season (0 to 83%, control). This is likely due to extreme dry conditions from the time of herbicide application through mid-season measurements that resulted in poor herbicide incorporation in the soil. Continued dry weather limited additional weed seed germination through the rest of the summer, however, resulting in weed control of 33 to 92% among the treatments by October. In 2018, initial weed growth was rapid, necessitating hand weeding to be done in June. Following hand weeding, however, some at-planting herbicides maintained good to excellent weed control through October.

Average raspberry plug response to certain herbicides was rapid in 2016. In particular, crop injury was excessive due to POSTR treatments with Chateau or Fierce (data not shown). Applying these products PRETR resulted in much greater safety in 2017 and 2018. Cane length in 2016 was reduced by POSTR Chateau at both rates, Fierce, and Matrix in both July and September (Table 5). In 2017, treatment with Chateau at 12 oz/a (PRETR), Matrix, or Sandea slightly reduced raspberry growth by mid-season. By October, raspberry growth was maximized by Zeus, Chateau (both rates PRETR), Fierce (PRETR), and Prowl H2O. In 2018, no treatment reduced mid- or late-season raspberry growth as compared to nontreated raspberries. Average raspberry growth (1, 2, or 3 years) in October was best with Chateau (either rate) or Fierce, followed closely by Prowl H2O. Based on the average October growth response, Matrix POSTR may not be a good choice for raspberry plugs, and perhaps for Sandea and Trellis as well.

Cultivars differed significantly in their response to herbicide treatments, but not to specific treatments. This may indicate that cultivars were more sensitive to the herbicides, or were differentially injured by transplanting operations from greenhouse flats to the field. In 2016, cane growth was greatest with 'Meeker' at both evaluations (Table 6). In 2017, 'Wakefield' had the longest canes in July, although cultivars did not differ in their growth by October. **NOTE:** While 2- and 3-year raspberry growth response values are given, be aware that 2016 late values were taken in September compared to October in 2017 and 2018. Chateau and Fierce were applied differently in the first year, and only single-year measurements were generated for those treatments and for Devrinol in 2016. 'Meeker' produced the longest canes in both years whether measured at mid- or late season, followed by 'Wakefield' and 'Squamish'. 'Cascade Harvest' was only tested in 2016, but cane growth was lowest among tested cultivars in that year.

These plots will be mowed in December, 2018, then treated with glyphosate in February, 2019 to control emerged weeds. Plots will then be retreated with the same herbicides prior to shoot emergence. Weed control and final growth numbers will be evaluated in June, 2019.

Table 1. Floricane counts among “low” and “high” vigor ‘Meeker’ raspberry prior to application of caneburning herbicides (2017).

	Start, 2017	End, 2017			Start, 2017	End, 2017			Overall change
Treatment	Low vigor	Low vigor	Change	Change	High vigor	High vigor	Change	Change	
	No./plot	No./plot	No./plot	%	No./plot	No./plot	No./plot	%	%
1. No in-row treatments; late treatment with Aim to sides of the bed	76.0	72.3 c	-3.7 e	96 c	100.8	115.3	14.5 b	114	106
2. Early treatment with Aim to full bed; no late treatment to sides of the bed	72.3	113.0 abc	40.7 abc	160 ab	92.5	140.3	47.8 ab	152	154
3. Standard treatment with Aim to full bed no late treatment to sides of the bed	60.8	92.5 bc	31.7 bcd	152 ab	106.5	139.5	33.0 ab	131	139
4. Early treatment with Aim to full bed; late treatment with Aim to sides of the bed	72.8	97.3 abc	24.5 bcd	131 bc	108.5	153.0	44.5 ab	141	138
5. Standard treatment with Aim to full bed; late treatment with Aim to sides of the bed	75.0	98.8 abc	23.8 bcd	132 bc	104.5	135.8	31.3 ab	130	131
6. No in-row treatments; late treatment with Goal to sides of the bed	84.0	94.3 bc	10.3 de	112 c	104.3	129.0	24.7 ab	124	119
7. Early treatment with Goal to full bed; no late treatment to sides of the bed	80.3	128.0 ab	47.7 ab	160 ab	105.0	149.3	44.3 ab	142	150
8. Standard treatment with Goal to full bed; no late treatment to sides of the bed	85.3	107.3 abc	22.0 b-e	127 bc	99.3	127.0	27.7 ab	128	127
9. Early treatment with Goal to full bed; late treatment with Aim to sides of the bed	83.5	96.8 bc	13.3 de	112 c	98.0	142.3	44.3 ab	145	132
10. Standard treatment with Goal to full bed; late treatment with Aim to sides of the bed	78.3	99.3 abc	21.0 cde	128 bc	93.3	114.8	21.5 ab	123	125
11. No caneburning (nontreated check)	82.0	149.0 a	67.0 a	183 a	100.3	159.3	59.0 a	159	169

Means within a column are not significantly different ($P \leq 0.05$).

Table 2. Berry weight in “low” and “high” vigor ‘Meeker’ raspberry after application of caneburning herbicides (2017-2018).

Treatment	Low vigor			High vigor			Overall		
	2017	2018	Average	2017	2018	Average	2017	2018	Average
	g/m of row	g/m of row	g/m of row	g/m of row	g/m of row	g/m of row	g/m of row	g/m of row	g/m of row
1. No in-row treatments; late treatment with Aim to sides of the bed	266.5	369.9	318.2	360.0	457.8	408.9	313.3	363.6	413.9
2. Early treatment with Aim to full bed; no late treatment to sides of the bed	308.3	611.6	460.0	329.8	488.7	409.2	319.0	434.6	550.1
3. Standard treatment with Aim to full bed no late treatment to sides of the bed	282.5	437.0	359.8	302.0	524.3	413.1	292.3	386.4	480.6
4. Early treatment with Aim to full bed; late treatment with Aim to sides of the bed	281.5	390.7	336.1	323.3	527.2	425.2	302.4	380.7	458.9
5. Standard treatment with Aim to full bed; late treatment with Aim to sides of the bed	267.5	433.7	350.6	326.0	461.8	393.9	296.8	372.2	447.7
6. No in-row treatments; late treatment with Goal to sides of the bed	331.8	395.7	363.7	347.3	392.4	369.8	339.5	366.8	394.0
7. Early treatment with Goal to full bed; no late treatment to sides of the bed	303.8	450.8	377.3	324.0	445.6	384.8	313.9	381.0	448.2
8. Standard treatment with Goal to full bed; no late treatment to sides of the bed	307.5	478.0	392.8	310.3	402.6	356.4	308.9	374.6	440.3
9. Early treatment with Goal to full bed; late treatment with Aim to sides of the bed	272.3	447.7	360.0	342.0	409.4	375.7	307.1	367.8	428.5
10. Standard treatment with Goal to full bed; late treatment with Aim to sides of the bed	321.5	526.5	424.0	335.8	553.9	444.8	328.6	434.4	540.2
11. No caneburning (nontreated check)	250.5	390.9	320.7	302.0	440.4	371.2	276.3	345.2	415.6

Means within a column are not significantly different ($P \leq 0.05$).

Table 3. Fifty-berry weight in "low" and "high" vigor 'Meeker' raspberry after application of caneburning herbicides (2017-2018).

Treatment	Low vigor			High vigor			Overall		
	2017	2018	Average	2017	2018	Average	2017	2018	Average
	g/berry	g/berry	g/berry	g/berry	g/berry	g/berry	g/berry	g/berry	g/berry
1. No in-row treatments; late treatment with Aim to sides of the bed	1.6	2.0 b	1.8	2.0	2.5	2.3	1.8	2.2 b	2.0
2. Early treatment with Aim to full bed; no late treatment to sides of the bed	1.8	2.1 b	1.9	1.8	2.4	2.1	1.8	2.2 b	2.0
3. Standard treatment with Aim to full bed no late treatment to sides of the bed	1.8	2.1 ab	2.0	1.9	2.4	2.1	1.8	2.3 b	2.0
4. Early treatment with Aim to full bed; late treatment with Aim to sides of the bed	2.1	2.9 a	2.5	2.0	2.5	2.2	2.0	2.7 a	2.4
5. Standard treatment with Aim to full bed; late treatment with Aim to sides of the bed	1.7	2.4 ab	2.0	2.0	2.5	2.2	1.8	2.4 ab	2.1
6. No in-row treatments; late treatment with Goal to sides of the bed	1.9	2.3 ab	2.1	1.9	2.3	2.1	1.9	2.3 ab	2.1
7. Early treatment with Goal to full bed; no late treatment to sides of the bed	1.7	2.2 ab	1.9	1.9	2.3	2.1	1.8	2.2 b	2.0
8. Standard treatment with Goal to full bed; no late treatment to sides of the bed	1.8	2.3 ab	2.0	1.9	2.3	2.1	1.9	2.3 ab	2.1
9. Early treatment with Goal to full bed; late treatment with Aim to sides of the bed	1.7	2.3 ab	2.0	1.9	2.1	2.0	1.8	2.2 b	2.0
10. Standard treatment with Goal to full bed; late treatment with Aim to sides of the bed	1.8	2.1 ab	2.0	2.0	2.4	2.2	1.9	2.3 b	2.1
11. No caneburning (nontreated check)	1.8	2.3 ab	2.1	1.9	2.5	2.2	1.8	2.4 ab	2.1

Means within a column are not significantly different ($P \leq 0.05$).

Table 4. Weed control in newly-planted red raspberry after treatment with several herbicides (2016, 2017, and 2018).

Treatment[a]	Rate	Mid-season[b]				Late season[c]			
		2016	2017	2018	Avg.	2016	2017	2018	Avg.
	product/a	%	%	%	%	%	%	%	%
Zeus	8 fl.oz	77 bcd	0 c	58 abc	45 de	12 de	72 ab	68 ab	51 b-f
Chateau POSTR	6 oz	95 abc	---	---	95 a	65 abc	---	---	65 a-e
Chateau, POSTR	12 oz	95 abc	---	---	95 a	70 ab	---	---	70 a-d
Fierce, POSTR	6 oz	98 ab	---	---	98 a	87 a	---	---	87 a
Chateau, PRETR	6 oz	---	82 ab	72 abc	77 abc	---	87 a	82 a	84 a
Chateau, PRETR	12 oz	---	95 a	83 a	89 ab	---	95 a	93 a	94 a
Fierce, PRETR	6 oz	---	82 ab	70 abc	76 abc	---	93 a	88 a	91 a
Devrinol	8 lb	40 e	---	---	40 e	37 b-d	---	---	37 ef
Alion	5 fl.oz	---	13 c	62 abc	38 e	---	75 ab	83 a	79 ab
Prowl H2O	3 pt	60 de	82 ab	73 ab	72 a-d	22 cde	63 ab	67 ab	51 b-f
Surflan	6 qt	92 abc	37 bc	58 abc	62 b-e	48 a-d	80 ab	87 a	72 a-d
Trellis	1.5 lb	75 cd	15 c	47 abc	46 de	50 a-d	78 ab	93 a	74 abc
Matrix	4 oz	83 abc	10 c	35 cd	43 e	75 ab	47 b	23 c	48 c-f
Sandea	2 oz	78 a-d	10 c	40 bcd	43 e	67 ab	72 ab	63 ab	67 a-e
Simazine	4 lb	100 a	10 c	48 abc	53 cde	50 a-d	45 b	32 bc	42 def

Means within a column and followed by the same letter, or not followed by a letter, are not significantly different ($P \leq 0.05$).

[a]Raspberries were transplanted May 16, 2016, May 24, 2017, and May 5, 2018; herbicides (POSTR only) were applied May 18, 2016, May 23 (PRETR) and May 26 (POSTR), 2017, and May 7 (PRETR) and May 8 (POSTR), 2018.

[b]Mid-season weed control was measured July 26, 2016, July 20, 2017, and June 15, 2018.

[c]Late season weed control was measured September 12, 2016, October 16, 2017, and October 12, 2017.

Table 5. Cane length of newly-planted red raspberry after treatment with several herbicides (2016-2017).

Treatment[a]	Rate	Mid-season[b]				Late season[c]			
		2016	2017	2018	Avg.	2016	2017	2018	Avg.
	product/a	cm	cm	cm	cm	cm	cm	cm	cm
Zeus	8 fl.oz	22.1 ab	24.4 abc	27.2 bcd	24.3 bcd	78.8 abc	90.7 bc	100.8 ab	89.0 d
Chateau POSTR	6 oz	12.3 d	---	---	12.3 ef	65.2 cd	---	---	65.2 f
Chateau, POSTR	12 oz	11.6 d	---	---	11.6 f	61.0 d	---	---	61.0 f
Fierce, POSTR	6 oz	13.5 cd	---	---	13.5 ef	59.0 d	---	---	59.0 f
Chateau, PRETR	6 oz	---	28.7 ab	36.4 abc	32.5 a	---	134.4 a	116.1 a	125.3 a
Chateau, PRETR	12 oz	---	20.9 cde	39.5 a	30.2 ab	---	116.8 ab	114.0 a	115.4 ab
Fierce, PRETR	6 oz	---	21.8 bcd	35.6 abc	28.7 ab	---	111.8 ab	115.0 a	113.4 abc
Devrinol	8 lb	26.0 a	---	---	26.0 bc	81.8 abc	---	---	81.8 de
Alion	5 fl.oz	---	26.6 abc	31.4 a-d	29.0 ab	---	80.1 cd	101.9 ab	91.0 d
Prowl H2O	3 pt	22.4 ab	30.2 a	39.0 ab	29.7 ab	84.8 ab	131.2 a	116.0 a	108.1 bc
Surflan	6 qt	21.4 ab	26.2 abc	35.4 abc	27.0 abc	89.5 ab	96.0 bc	107.7 ab	96.9 cd
Trellis	1.5 lb	23.0 ab	24.8 abc	33.5 a-d	26.7 abc	89.7 ab	76.3 cd	99.8 ab	88.7 de
Matrix	4 oz	17.6 bcd	13.7 e	23.5 d	18.2 de	75.2 bcd	53.4 d	87.5 b	72 ef
Sandea	2 oz	22.3 ab	15.5 de	27.0 cd	21.7 cd	87.0 ab	59.9 d	99.3 ab	82.5 de
Simazine	4 lb	19.8 abc	23.7 abc	32.4 a-d	24.7 bc	84.1 ab	75.7 cd	112.2 a	90 d
Nontreated	---	26.2 a	26.4 abc	25.8 cd	26.1 abc	95.9 a	76.7 cd	95.8 ab	90.1 d

Means within a column and followed by the same letter, or not followed by a letter, are not significantly different ($P \leq 0.05$).

[a]Raspberries were transplanted May 16, 2016, May 24, 2017, and May 5, 2018; herbicides (POSTR only) were applied May 18, 2016, May 23 (PRETR) and May 26 (POSTR), 2017, and May 7 (PRETR) and May 8 (POSTR), 2018.

[b]Mid-season cane lengths were measured July 26, 2016, July 20, 2017, and August 6, 2018.

[c]Late season cane lengths were measured September 12, 2016, October 16, 2017, and October 12, 2017.

Table 6. Cane length of newly-planted red raspberry cultivars[a] after treatment with several herbicides (2016-2017).

Cultivar	Mid-season[b]				Late season[c]			
	2016	2017	2018	Avg.	2016	2017	2018	Avg.
	cm	cm	cm	cm	cm	cm	cm	cm
Cascade Harvest	12.0 c	---	---	12.0 c	55.7 d	---	---	55.7 d
Meeker	36.7 a	21.4 b	35.9 a	31.3 a	121.8 a	88.4 b	114.0 a	108.1 a
Squamish	15.8 b	23.4 ab	30.7 b	23.3 b	64.2 c	88.8 b	98.5 b	83.8 c
Wakefield	14.8 bc	25.8 a	30.1 b	23.6 b	77.8 b	98.6 a	104.1 b	94.2 b

Means within a column and followed by the same letter, or not followed by a letter, are not significantly different ($P \leq 0.05$).

[a]Raspberries were transplanted May 16, 2016, May 24, 2017, and May 5, 2018; herbicides (POSTR only) were applied May 18, 2016, May 23 (PRETR) and May 26 (POSTR), 2017, and May 7 (PRETR) and May 8 (POSTR), 2018.

[b]Mid-season cane lengths were measured July 26, 2016, July 20, 2017, and August 6, 2018.

[c]Late season cane lengths were measured September 12, 2016, October 16, 2017, and October 12, 2017.

PHYSIOLOGY

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

Project Title: Impacts of Mycorrhizal Fungal Colonization on Raspberry Plant Growth (NEW)

PI: Rebecca A. Bunn
Organization: Western Washington University
Title: Associate Professor, Dept. of Environmental Sciences
Phone: 360-650-4597
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Address: 516 High St, MS-9181
City/State/Zip: Bellingham, WA 98225

Co – PI: Lisa W. DeVetter, Assistant Professor, Small Fruit Horticulture, WSU-NWREC, 16650 State Route 536, Mount Vernon, WA 98273, phone: 360-848-6124, lisa.devetter@wsu.edu

Cooperators: Erika Whitney, MS Candidate at WWU, will conduct Study 1 as part of her thesis work. Qianwen Lu, PhD Candidate at WSU, will conduct Study 2 as part of her dissertation work. Dr. Inga Zasada will assist with *P. penetrans* extractions and Dr. Jerry Weiland will provide *P. rubi* isolates. Both Dr. Zasada and Dr. Weiland are Plant Pathologists at ARS, USDA, Corvallis, OR.

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

Total Project Request: $13,822 **Year 1**: WWU $10,526 WSU $3,296

Other funding sources: Yes, pending

Agency: WWU Research and Sponsored Programs

Amount Requested: WWU RSP: $1,997 (supplies for Study1, pending for Year 1)

Notes: Erika Whitney has applied for a grant through the Enhancement of Graduate Research and Scholarship fund to provide additional support for Study 1 at WWU.

Description
Our study will help determine if introducing arbuscular mycorrhizal (AM) fungi and associated microbial communities to raspberry (*Rubus ideaus* 'Meeker') tissue culture plants prior to planting benefits host plants in ways that could increase plant growth and the number of years a field is economically productive. In two greenhouse experiments, we will quantify differences in mycorrhizal and non-mycorrhizal raspberry plants' 1) resistance to the root rot (*Phytophthora rubi*) and root lesion nematodes (*Pratylenchus penetrans*), and 2) acquisition of nutrients from different fertilizers (pelleted manure and synthetic). Because AM fungal taxa vary in their abilities to provide pathogen protection and nutrient acquisition for raspberries, we will test different sources of AM fungi and associated microbial communities (i.e. bio-inoculants). We will test three commercially available bio-inoculants, one constructed bio-inoculant including eight divergent taxa, and a bio-inoculant from an established raspberry field free of *P. rubi* and *P. penetrans*. Our study will provide data allowing us to quantify the effects of different bio-inoculants on plant biomass, disease progression, and nutrient content, which will help growers assess the potential benefits of these products in their own fields.

Justification and Background

Raspberry productivity in the Pacific Northwest has declined in recent years, requiring frequent renovation and reducing grower profits. One factor contributing to the decline is a buildup of soil-borne pathogens, particularly *Phytophthora rubi* and *Pratylenchus penetrans.* Furthermore, common practices of synthetic fertilizer applications and field fumigation can inadvertently reduce beneficial soil biota. The result is an increasingly negative effect of soils on plants.

The intentional and well-timed introduction of a key group of beneficial soil biota, arbuscular mycorrhizal (AM) fungi, may shift this soil effect back in the positive direction. AM fungi form intimate symbioses with plants which appear to 'jump-start' the plant's immune system, allowing plants to respond more quickly to pathogen attacks (Jung et al 2012). In addition, AM fungi work in conjunction with other soil biota to mobilize and transfer organically-bound nutrients to plants (e.g. Zhang et al 2014), thereby potentially increasing the effectiveness of nutrient uptake from different materials (Thirkell et al 2016).

The potential for AM fungi to increase raspberry pathogen resistance is high for two reasons. First, raspberries readily form mycorrhizae with a range of AM taxa (Taylor and Harrier 2000). Second, AM fungi can reduce effects of the key pathogens and closely related pathogens in many crop species. AM fungi can reduce *P. penetrans* infections in many crops including tomato, carrot, apple, and strawberry (Talavera et al 2001, Forge et al 2001, Harrier and Watson 2004). To our knowledge, no work has yet been completed on AM fungi and *P. rubi*, but AM fungi have controlled other *Phytophthora* species on pineapple, strawberry, sweet orange, and tomato (reviewed by Whipps 2004). However, for mycorrhization to induce pathogen resistance, fungal colonization has to be well established prior to pathogen arrival (Whipps 2004) and available taxa should promote strong pathogen resistance.

Field fumigation reduces AM fungal communities (An et al 1993). Thus, current methods of planting raspberries into fumigated fields may result in low or ineffective mycorrhization which does not confer the desired effects. This project will help determine if introducing AM fungi during raspberry plant establishment promotes a net positive feedback from soils by 1) increasing plant resistance to pathogens, and/or 2) increasing the effectiveness of nutrient uptake. Additionally, it will provide guidance as to which AM fungal bio-inoculants are most effective for raspberry.

Relationship to WRRC Research Priorities:

By examining interactions between different AM fungal inoculum, pathogens of concern, and fertilizer treatments, this project addresses a #2 priority of understanding soil ecology and soil-borne pathogens and their effects on plant health. By examining interactions between AM fungal inoculum and pathogens, this project also addresses 'alternatives to control soil pathogens and nematodes, a # 3 priority.

Objectives:

1. Assess whether AM fungal colonization increases plant growth, nutrient status, and pathogen resistance (to complete in 2019).
2. Determine which AM fungi inoculum (including commercially available bio-inoculants) lead to increased colonization of raspberry roots and quantify resulting effects on plant growth and nutrient status using different fertilizer sources (to complete in 2019).

Procedures

Study 1 WWU Biology Greenhouse

1. Plants grown in Deep Pots and heat-sterilized modified soil medium, temperatures recorded continuously, humidity and light measurements collected weekly.
2. 4 AM fungal inoculum treatments (control, MycoApply, divergent community, raspberry field community) x 4 pathogen treatments (control, *P. penetrans*, *P. rubi*, both) x 10 reps = 160 pots.
3. March and April 2019: Grow plants with inoculum treatments. At 8 weeks measure plant height and leaf mass area (ratio of single leaf dry mass to its circumference), visually assess plant vigor.
4. May 2019: Apply pathogen treatments: *P. penetrans* extracted from infected field roots (Zasada lab), cultured *P rubi* isolates (Weiland lab). Grow additional 8 weeks.
5. June 2019 - October 2019: Harvest, wash roots and subsample for analysis of *P. penetrans* and AM fungal colonization, dry shoots and roots (60°C for 48 hr), send shoots out for nutrient analysis (Brookside labs), measure plant biomass, make/score colonization slides.
6. November- December 2019: Analyze results, submit progress report to WRRC, and present results at Small Fruit Conference.

Study 2 WSU NWREC Greenhouse

7. Plants grown as above (1).
8. 5 AM-fungal inoculum treatments (control [i.e. no inoculants], Micronized Endo. Inoculant, MycoApply, MYKOS, raspberry field community) x 3 fertilizer treatments (control [no fertilizer], composted and pelleted manure, synthetic fertilizer urea) x 8 reps = 120 pots. Fertilizer [0.5 oz N/plant (as manure or urea)] applied evenly at 2, 6, and 10 weeks after planting. We will also supplement with P and K as needed to achieve consistent application of N, P, and K across manure and urea treatments.
9. March-July 2019: Grow plants with inoculum and fertilizer treatments; measure plant height, cane number, and chlorophyll content (using a SPAD meter) every two weeks.
10. Aug. 2019-October 2019: Harvest, wash roots, and subsample for AM fungal colonization; dry shoots and roots (60°C for 48 hr) and determine biomass; send shoots out for nutrient analysis (Brookside labs); make/ score colonization slides.
11. November-December 2019: Analysis and reporting as above (6).

Details of AM fungal inoculum

12. Micronized Endomycorrhizal Inoculant (Bio-Organics LLC, New Hope, PA)
13. MycoApply Endo (Mycorrhizal Applications, Grants Pass, OR)
14. MYKOS (Xtreme Gardening, Gilroy, CA)
15. Divergent community (eight phylogenetically divergent AM fungal taxa from INVAM cultures, West Virginia Univ., Morgantown, WV)
16. Raspberry field community (AM fungi from field free of *P. penetrans* and *P rubi*)

Anticipated Benefits and Information Transfer

Information from this project will inform growers and crop consultants regarding the potential benefits of AM fungi and bio-inoculants for plant protection and for improving nutrient status in raspberry. Results will inform future field trials to further test and provide recommendations for growers considering use of AM fungi. These experiments will be part of Erika Whitney's and Qianwen Lu's theses. Results will be shared with the raspberry industry at the Small Fruit Conference and at national meetings. Information will also be published online in the Whatcom Ag. Monthly (http://extension.wsu.edu/wam/) and in peer-reviewed journals.

References

An, Z.-Q. et al. The influence of crop rotation and soil fumigation on a mycorrhizal fungal community associated with soybean. *Mycorrhiza* **3,** 171-182 (1993)

Forge, T. et al. Effects of preplant inoculation of apple (*Malus domestica* Borkh.) with arbuscular mycorrhizal fungi on population growth of the root-lesion nematode, *Pratylenchus penetrans*. *Plant Soil* **236**, 185–196 (2001)

Harrier, L.A. & Watson, C.A. The potential role of arbuscular mycorrhizal (AM) fungi in the bioprotection of plants against soil-borne pathogens in organic and/or other sustainable farming systems. *Pest Manage. Sci.* **60**, 149-157 (2004)

Jung, S.C. et al. Mycorrhiza-induced resistance and priming of plant defenses. *J. Chem. Ecol.* **38**, 651–664 (2012)

Talavera, M. et al. Reduction of nematode damage by root colonization with arbuscular mycorrhiza (*Glomus* spp.) in tomato-*Meloidogyne incognita* (Tylenchida: Meloidogynidae) and carrot-*Pratylenchus penetrans* (Tylenchida: Pratylenchidae) pathosystems. *Appl. Entomol. Zool.* **36**, 387–392 (2001)

Taylor, J. & Harrier, L.A. Comparison of nine species of arbuscular mycorrhizal fungi on the development and nutrition of micropropagated *Rubus idaeus* L. cv. Glen Prosen (Red Raspberry). *Plant Soil* **225**, 53-61 (2000)

Thirkell, T.J. et al. Resolving the 'nitrogen paradox' of arbuscular mycorrhizas: fertilization with organic matter brings considerable benefits for plant nutrition and growth. *Plant Cell Environ.* **39**, 1683–1690 (2016)

Zhang L. et al. Hyphosphere interactions between an arbuscular mycorrhizal fungus and a phosphate solubilizing bacterium promote phytate mineralization in soil. *Soil Biol. Biochem.* **74**, 177–183 (2014)

Budget

	WWU	WSU	**Overall**
Salaries	$5,760	$600	$6,360
Operations (goods & services)	$4,130	$2,432	$6,563
Travel	$60	$0	$60
Benefits	$576	$263	$839
Totals	$10,526	$3,296	**$13,822**

Notes

1. Salaries: 8 weeks at 40 hours per week, $18 per hour for MS Student Erika Whitney (8wks*40hr/wk*$18/hr = $5,760); 40 hours at $15 per hour for lab technician (40hrs*$15/hr = $600)
2. Operations: Nematode assessment ($25/sample x 120 samples = $3,000), Plant tissue analysis by Brookside Analytics ($9/sample x 200 samples = $1,800), WSU greenhouse space at $60/month (12 mo x $60/mo = $720). Plant starts and supplies (chemicals, slides, tools, and protective equipment) for assessment of mycorrhizal fungal colonization of roots ($979). WA state sales tax on supplies (.065 x $979 = $64)
3. Travel: Bellingham to WSU Extension office in Mount Vernon, 56 miles round trip. (56 miles/trip x 2 trips x $0.535/mile = $60)
4. Benefits: graduate student at 10% ($576) and technician at 44% ($263)

Current and Pending Support:

Name: Rebecca Bunn

Instructions:

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

NAME (List.PI #1 first)	SUPPORTING AGENCY AND AGENCY ACTIVE AWARD/PENDING PROPOSAL NUMBER	TOTAL $ AMOUNT	EFFECTIVE AND EXPIRATION DATES	% OF TIME COMMITTED	TITLE OF PROJECT
Bunn, R.	Western Washington University – Research and Sponsored Programs (WWU RSP)	$1,664	4/2018-4/2019	1%	How are plant responses to the mycorrhizal symbiosis altered under different light regimes?

PENDING:

Bunn, R.	WWU RSP	$6,000	7/2019-8/2019	9%	Applying structural equation modeling to plant-soil feedbacks
Bunn, R. and L.W. DeVetter	WRRC	$13,914	1/2019-12/2019	2%	Impacts of mycorrhizal fungal colonization on raspberry plant growth

Current and Pending Support:

Name: Lisa Wasko DeVetter

Instructions:

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

NAME (List.PI #1 first)	SUPPORTING AGENCY AND AGENCY ACTIVE AWARD/PENDING PROPOSAL NUMBER	TOTAL $ AMOUNT	EFFECTIVE AND EXPIRATION DATES	% OF TIME COMMITTED	TITLE OF PROJECT
L. DeVetter, G. Hoheisel, and J. Davenport	Northwest Center for Small Fruits Research (NCSFR)	$114,311	6/2017-12/2019	5%	Optimizing nutrient management for organically grown blueberries in eastern Washington
L. DeVetter and W. Gan	Northwest Agricultural Research Foundation (NARF)	$3,883	1/2018-12/2018	2%	Enhancing blueberry pollination through an improved understanding of pollen biology and implementation of in-field practices in western Washington
L. DeVetter, W. Gan	Washington Blueberry Commission (WBC)	$11,646	1/2018-12/2018	2%	Enhancing blueberry pollination through an improved understanding of pollen biology and implementation of in-field practices in western Washington
L. DeVetter, W. Yang, F. Takeda	WBC	$18,429	1/2018-12/2018	2%	Improving machine harvest efficiency and fruit quality for fresh market blueberry
L. DeVetter, J. Davenport, and G. Hoheisel	WBC	$17,638	1/2018-12/2018	2%	Impacts of post-harvest nitrogen cut-off times in 'Duke' blueberry
G. Hoheisel, L. DeVetter, L. Khot, and D. Gibeaut	WBC	$33,745	1/2018-12/2018	3%	Modeling blueberry cold hardiness in Washington
DeVetter, L.W., H. Zhang, C. Miles, C. Benedict, and I. Zasada	Washington State Department of Agriculture Specialty Crop	$249,960	10/2018-9/2021	3%	Promoting productivity and on-farm efficiencies in red raspberry

	Block Grant (WSDA-SCBG)				systems through application of biodegradable plastic mulches
DeVetter, L.W., F. Takeda, W. Yang, J. Chen, and S. Korthius	WSDA-SCBG	$178,328	10/2018-9/2020	3%	Improving machine harvest efficiency and fruit quality for fresh market blueberry
Yang, W., F. Takeda, J. Chen, and S. Korthius	Oregon State Department of Agriculture	$172,630	5/2019-4/2021	1%	Improving fresh blueberry quality with innovative harvesting and sensor technology
P. Moore, W. Hoashi-Erhardt, L.W. DeVetter, J. Pond, J. Peterson, T. Peerbolt, K. Gallardo, and T. Thornton	WSDA-SCBG	$110,401	10/2017-4/2020	2%	Breeding, horticultural systems, grower resources, and nursery expansion for a thriving fresh strawberry industry in the Pacific Northwest
P. M Ndegwa, H. Tao, L. DeVetter	WSDA-SCBG	$249,973	10/2017-9/2020	2%	Concentrating and blending of manure nutrients to enhance sustainable production
L.DeVetter, B. Snyder, B. Gerdeman, and M. Arrington	Washington State University Biologically Intensive Agriculture (WSU-BIOAg)	$31,134	1/2017-12/2018	2%	Evaluating the impacts of border vegetation patters on multifunctional biodiversity and crop production in Washington blueberry
A. Iezzoni (PD) et al.	USDA Specialty Crop Research and Extension (USDA-SCRI)	$10,000,00 0	9/2014-8/2019	2%	RosBREED: Combining disease resistance with horticultural quality in new rosaceous cultivars
D. Main (PD) et al.	USDA-SCRI	$2,741,575	10/2014-9/2019	2%	Genome database for Rosaceae: Empowering specialty crow research through big-data driven discovery and application in breeding
L. DeVetter, W. Yang, F. Takeda	Oregon Blueberry Commission	$11,088	1/2018-12/2018	1%	Improving machine harvest efficiency

	(OBC)				and fruit quality for fresh market blueberry
L. DeVetter, C. Benedict and S. Galinato	Washington Red Raspberry Commission (WRRC)	$5,110	1/2018-12/2018	1%	Comparison of alternate- and every-year production in summer-bearing red raspberry
L. DeVetter and I. Zasada	WRRC	$10,536	1/2018-12/2018	2%	Impact of nitrogen on nematode parasitism of red raspberry
L. DeVetter, C. Miles, I. Zasada, C. Benedict, and S. Ghimire	WRRC	$10,500	1/2018-12/2018	2%	Application of biodegradable mulches in tissue culture red raspberry: impacts on weed control, parasitic nematodes, and crop growth
PENDING:					

DeVetter, L., C. Miles, D. Griffin, M, Flury, M. Bolda, S. Wortman, S. Agehara, C. Benedict, H. Liu, T. Marsh, T. Chi, S. Galinato, K. Englund, M. Perez-Garcia, G. Yorgey, J. Goldberger, and L. McGowen	USDA SCRI	$49,796	9/2019-8/2020	2%	Planning grant: Implementation of new technologies and improved end-of-life management for sustainable use of agricultural plastics
Karkee, M., L. DeVetter, F. Takeda, W. Yang, C. Benedict, C. Seavert, Q. Zhang	USDA SCRI	$1,700,000	9/2019-8/2023	2%	Increasing caneberry profitability through modified horticultural systems and mechanization for cane pruning and training
Bryla, D., T. Flemming, G. LaHue, D. Griffin, L. DeVetter, E. Smith, and J. Williamson	USDA SCRI	$1,800,000	9/2019-8/2023	2%	Investigation of the biological benefits of biostimulants and development of comprehensive management strategies for their use in blueberry
Lukas, S., L.W. DeVetter, B. Strik, D. Bryla, C. Finn, Y. Zhao, D. Rupp, G. Fernandez, and A. Volder	USDA SCRI	$5,500,000	9/2019-8/2023	3%	Expanding the berry crops industry across multiple climactic conditions through breeding and modification of

					horticultural systems
Iorizzo, M., P. Munoz, J. Zalapa, N. Bassil, D. Main, D. Chagne, L. Giongo, K. Gallardo, E. Canales, A. Atucha, L.W. DeVetter	USDA SCRI	$7,900,000	9/2019-8/2023	1%	VacciniumCAP: Leveraging genetic and genomic resources to enable development of blueberry and cranberry cultivars with improved fruit quality attributes
LaHue, G., D. Griffin, L.W. DeVetter, and C. Benedict	WBC	$25,334	1/2019-12/2020	1%	Determining soil organic matter and mineralization in blueberry (*draft title*)
DeVetter, L.W., W. Gan, and A. Melathopoulos	WBC	$18,099	1/2019-12/2019	2%	Enhancing blueberry pollination through an improved understanding of pollen biology and implementation of in-field practices in western Washington
DeVetter, L.W., W. Gan, and A. Melathopoulos	NARF	$9,746	1/2019-12/2019	2%	Enhancing blueberry pollination through an improved understanding of pollen biology and implementation of in-field practices in western Washington
DeVetter, L.W., J. Davenport, and G. Hoheisel	WBC	$19,519	1/2019-12/2019	2%	Impacts of post-harvest nitrogen cut-off times in 'duke' blueberry
G. Hoheisel, L. DeVetter, L. Khot, and D. Gibeaut	WBC	$27,775	1/2019-12/2019	3%	Modeling blueberry cold hardiness in Washington
Bunn, R. and L.W. DeVetter	WRRC	$13,914	1/2019-12/2019	2%	Impacts of mycorrhizal fungal colonization on raspberry plant growth
DeVetter, L.W, C. Benedict, and S. Galinato	WRRC	$6,246	1/2019-12/2019	1%	Comparison of alternate- and every-year production in summer-bearing red raspberry
DeVetter, L.W., H. Zhang, C. Miles, and C. Benedict	WRRC	$12,625	1/2019/12/2019	2%	Multi-season plastic mulches for improved weed management and crop growth
DeVetter, L.W., H. Zhang, C. Miles, C.	WRRC	$8,744	1/2019-12/2019	1%	Application of polyethylene mulch

Benedict, and I.A. Zasada					in summer-planted tissue culture red raspberry: impacts on weed control, parasitic nematodes, and crop growth and yield
DeVetter, L.W., H. Zhang, C. Miles, C. Benedict, and I.A. Zasada	Washington Commission on Pesticide Registration (WSCPR)	$6,458	1/2019-12/2019	1%	Application of polyethylene mulch in summer-planted tissue culture red raspberry: impacts on weed control, parasitic nematodes, and crop growth and yield
Walters, T., I.A. Zasada, J. Weiland, and L.W DeVetter	WRRC	TBD	1/2019-12/2019	1%	Vapam cap, crop termination, and bed fumigation treatments to improve soil fumigation

Washington Red Raspberry Commission Progress Report for 2018

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: This report presents data from 2018 (3 years after the project was initiated)

Accomplishments:

- AY and 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.
- 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 newsletter article to be published in the *Whatcom Ag Monthly* (*WAM*) is in preparation and should be published July 2019. Information will also be posted on DeVetter's program website (https://smallfruits.wsu.edu/).

Results: ***1) AY/EY Experiment:*** Primocane height was greatest in the AY treatment and was 11 inches greater than the EY treatment ($P < 0.0001$). Primocane node number was greatest in the AY treatment, whereas internode length was greatest in the EY treatment ($P < 0.0001$ for both variables). Thus, primocanes were on average taller with more nodes but with shorter internode lengths in the AY treatment. There were no differences in primocane number/hill in 2018 ($P = 0.28$). Macro- and micro-nutrient data are similar between treatments. However, tissue nitrogen was numerically greater in the EY treatment at 3.1%, whereas it was 2.7% in the AY treatment. No yield nor fruit quality data were collected from the AY treatment, as 2018 was an "off" year. Average yield per row, primocane number/hill, and primocane height across the four years of the study are 2,632 lbs/row, 3 canes/hill, and 5 inches greater in the EY treatment relative to the AY treatment, respectively. This reduction in productivity in the AY treatment may be due to winter injury this treatment experienced in 2016/2017 and the plants appear to be recovering. As expected with this type of study, there are significant year, treatment, and year x treatment interactions ($P < 0.0001$). Economic analyses will be completed in 2020. ***2) Modified Bed Experiment***. Primocane height, number/hill, node number, and internode length differed by cultivar with height, number/hill, and node number being greatest in 'Meeker'. No differences in these variables were attributed to our bed size treatments with the exception of 'WakeField' primocane height and number/hill. Height and number/hill were greatest at the larger bed dimensions. Tissue nutrients differ more by cultivar than treatment, with 'Meeker' tissue nitrogen highest at 4.5% and lowest in 'WakeHaven' at 3.5%. No yield data were collected, as the planting was established in 2018. Unmanned aerial vehicle (UAV) data are being analyzed.

Publications: No publications for 2018, although an enterprise budget was published by Galinato and DeVetter in 2016. A newsletter article is in preparation and should be published in the *WAM* by July 2019 and posted on DeVetter's program website.

2018 WASHINGTON RED RASPBERRY COMMISSION RESEARCH PROPOSAL

Project number: 3455-6640 **Proposed Duration:** 6 years

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

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Cooperators/Co-PI: Jonathan Maberry, Maberry Packing LLC

Year Initiated 2015 **Current Year** 2018 **Terminating Year** 2020

Total Project Request: $48,648

Year 1 $8,958 **Year 2** $8,277 **Year 3** $6,635 **Year 4** $5,110 **Year 5** $6,349 **Year 6** $13,319

Other funding sources: *None at this time.*

Description:
Increasing costs and decreasing availability of labor are compromising the economic viability of commercial red raspberry production in western Washington. The grower community needs alternative production systems that maximize efficiency, minimize labor needs, maintain productivity, and are economically viable. This project addresses that need by evaluating the economic viability of alternate-year (AY) production relative to traditional every-year (EY) production systems. Specific sub-objectives of this projects are to: 1) Evaluate differences in plant productivity and yield between AY and EY production systems; and 2) Complete a benefit-cost analysis to assess the on-farm net benefits of AY relative to traditional EY production systems. A new sub-objective added in 2018 is: 3) Determine if wider raised beds increase plant productivity and/or decrease the cost of production per linear foot relative to traditional production systems. Results of this project will be disseminated at conferences, field days, and through a Washington State University extension publication. Overall, this long-term project will provide valuable information regarding potential labor savings and the economic feasibility of

alternative systems of red raspberry production.

Justification and Background:
The increasing cost of labor has become a constraint for profitable production of floricane red raspberry. Floricane raspberry is particularly labor intensive, with annual pruning and tying of canes representing approximately 10% of total annual costs during established bearing years (personal communication with grower). Access to labor is also challenging for growers. These issues demonstrate a need to investigate alternative production systems that reduce growers' dependency on labor and promote on-farm profitability.

AY production, which entails removal of spent floricanes and producing fruit on an every-other-year cropping cycle, represents one potential system. AY production is practiced in 33% of 'Marion' blackberry fields in Oregon, while total production is estimated to be 50% AY (Yang, OSU Berry Crops Extension Agent, personal communication). Average two-year yields are reduced by 10-30% relative to EY production, but several advantages including decreased labor costs, reduced pesticide applications, and improved cold hardiness contribute to its adoption (Bell et al., 1992; Bullock, 1963; Martin and Nelson, 1979). Minimal research on AY production systems have been completed in floricane red raspberry. In a six-year study performed in Vancouver, Washington, with 'Meeker' and 'Willamette', investigators found yield was reduced by 60% in an AY system (Barney and Miles, 2007). However, it is unknown if primocane suppression occurred during the study, which can impact yield potential.

Our grower-cooperator also recently proposed evaluating wider raised bed dimensions, as they have the potential to decrease overall costs on a linear foot basis. Furthermore, wider raised beds may allow the root system a greater volume of soil to utilize and in turn promote yields. Wider raised beds may be especially beneficial for vigorous cultivars. However, research on the productivity and economic impacts of wider raised bed dimensions is lacking, particularly among newer cultivars. These alternative systems of production may be economically viable given the current scenario of high labor costs and reduced availability.

The increasing problems related to costs and availability of labor need to be addressed and this project proposes to address this need through two experiments that evaluate impacts of AY production and wider raised bed dimensions on yield, plant vegetative growth, and cost-benefits in red raspberry.

Relationship to WRRC Research Priority(s):
This project addresses #2 (Alternative Management Systems – AY, reduce cost of production/lb) and #3 (Labor saving practices – ex. Pruning, AY, public/private technology partnerships) tier priorities.

Objectives:
The overall objective of this project is to evaluate the economic viability of alternative production systems that have the potential to reduce costs of production and improve on-farm profitability through enhanced production efficiencies. Specific sub-objectives are: 1) Evaluate differences in plant productivity and yield between AY and EY production systems; 2) Complete a benefit-cost analysis to assess the on-farm net benefits of AY production relative to traditional

EY production systems (to be completed at the end of the project in 2020); and 3) Determine if wider raised beds increase plant productivity and/or decrease the cost of production per linear foot relative to traditional production systems.

Procedures:
Experiment #1 – Comparison of AY and EY Systems. Treatment plots of 'Meeker' raspberry were established in spring 2015 with Mr. Jon Maberry in Whatcom County, Washington. The experimental design is a randomized complete block, with two treatments (AY and EY production) replicated three times. During fruiting years in the AY plots (2015, 2017, and 2019), primocanes will be suppressed and fruit will be machine harvested. All canes will subsequently be removed in AY plots during the winter following harvest. Primocanes will then only be grown in 2016, 2018, and 2020 (i.e. "off year" with no fruit). EY plots will be managed according to commercial standards throughout the duration of the project, which will entail annual pruning and tying. Data collection began in 2015, in which a baseline enterprise budget was developed through a focus group with growers. This budget will be used as benchmark for assessing and estimating changes in net profit due to AY production. Yield and plant growth will continue to be measured and include total machine harvestable yield, leaf macro- and micro-nutrient concentrations, and primocane height, number, node number, and internode length. This will be a long-term project that will collect harvest data from AY plots for three cropping seasons, which translates into a six-year project.

Experiment #2 – Modified Raised Beds. Maberry Packing established 'Meeker', 'Whatcom', 'WakeHaven', and 'WakeField' raspberry on 6 ft wide raised beds on 12 ft centers in Spring 2018. Adjacent rows of these cultivars grown with standard raised bed and alleyway dimensions are being used as the experimental controls. Plant growth (primocane number, height, node number, and internode length), machine harvestable yield (2019 only), and leaf macro- and micro- nutrient concentrations will be determined during the first two years of establishment by DeVetter, Benedict, and Maberry. Plant growth will also be monitored with a UAV fitted with a multi-spectral camera (RedEdge M, MicaSense, Seattle WA) to assess plant growth on a monthly basis. If treatment effects are observed, continued yield measurements and assessments of root architecture and biomass will be proposed in 2020.

Anticipated Benefits and Information Transfer:
Completion of this project will provide growers with information about potential cost savings and plant growth impacts of the evaluated alternative production systems. Both information derived from the benefit-cost analysis and evaluations of plant growth and productivity will be shared at grower conferences and through two WSU Extension Publication (Fact Sheet and Excel Workbook). Results will also be shared annually with the cooperator and a newsletter article in the WSU Whatcom Ag Monthly is planned for July 2019. Final project information will also be available on the WSU Small Fruits Horticulture website (http://smallfruits.cahnrs.wsu.edu/) and published in a research publication.

References:

1. Barney, D.L. and C. Miles (eds.). 2007. Commercial Red Raspberry Production in the Pacific Northwest. PNW 598.
2. Bell, N., E. Nelson, B. Strik, and L. Martin. 1992. Assessment of winter injury to berry crops in Oregon, 1991. Oregon State University Agricultural Experiment Station, Special Report 902, July, 1992. 23 pp.

3. Bullock, R.M. 1963. Spacing and time of training blackberries. Oregon Hort. Soc. Proc. 55:59-60.
4. MacConnell, C. and M. Kangiser. 2007. Washington Machine Harvested Red Raspberry Cost of Production Study for Field Re-establishment. Washington State University Whatcom County Extension.
5. Martin, L.W. and E.H. Nelson. 1979. Establishment and management of 'Boysenberries' in Western Oregon. Oregon State University Agr. Expt. Sta. Circ. 677.
6. Washington Red Raspberry Commission (WRRC). 2017. Statistics – PNW Red Raspberry Production. WWRC. Accessed 12 Nov. 2017 at: <https://www.red-raspberry.org/statistics>.

Budget and Justification:

	2019	**2020**
Salaries[1/]	$3,955	$7,134
Time-Slip[2/]	$480	$499
Operations (goods & services)[3/]	$50	$1,050
Travel[4/]	$238	$1,938
Meetings	$	$
Other	$	$
Equipment[4/]	$	$
Benefits[5/]	$1,626	$2,698
Total	**$6,349**	**$13,319**

[1/] Research Associate (co-PI Mrs. Suzette Galinato) at the WSU School of Economic Sciences [2.08% FTE in 2019 (0.25 month at $1,452); and 6.25% FTE in 2020 (0.75 month at $4,531)]; Scientific assistant in Small Fruit Horticulture program (Mr. Sean Watkinson) at 5% FTE per year ($2,503 in 2019; and $2,603 in 2020); yearly salaries include 4% inflation.
[2/]Timeslip in 2019-2020 for plant growth and fruit quality data collection: $12/hr x 40 hr/week x 1 week = $480; include 4% inflation.
[3/]Field supplies (e.g, sample bags, flagging tape, etc.) @ $50/year; Journal and extension publication charges @ $1,000 in 2020.
[4/]Research Associate will meet with growers in order to collect and validate data for the alternate-year raspberry enterprise budget (2020). Research associate will also co-present with PI key results of the study at a grower conference in 2020 (e.g., Washington Small Fruit Conference); travel for research associate is @ $1,700 in 2020 only; travel for PI to commute from Mount Vernon, WA, to field site for data collection in Lynden, WA @ $238/year (88 miles RT x 5 trips/year x $0.54/mile = $238/year.
[5/]No equipment funding requests.
[6/]Benefits are calculated at 33.2% of monthly salary for Research Associate ($483 in 2019; and $1,506 in 2020); Benefits for Scientific Assistant is 43.9% ($1,098 in 2019, and $1,142 in 2020). Benefits for timeslip at 9.3%.

**Please note costs have risen due to increases in salary at WSU for both Watkinson and Galinato and because of increases in timeslip rates.*

Washington Red Raspberry Commission
Progress Report for 2018 Projects

Project No: 3455-6642 (0640)

Title: Application of Biodegradable Mulches in Tissue Culture Red Raspberry: Impacts on Weed Control, Parasitic Nematodes, and Crop Growth

Personnel: L.W. DeVetter (PI), C.A. Miles, S. Ghimire, I. Zasada, and C. Benedict. H. Zhang is the PhD student funded on this project.

Reporting Period: This report presents data from 2018.

Accomplishments: The overall goal of this project is to develop knowledge and practical strategies to manage weeds while improving establishment and yield in commercial red raspberry planted as tissue culture (TC) transplants. Our main accomplishments for 2018 include: 1) Collecting all data as planned (additional data on plant moisture status, photosynthetic rates, soil removed during mulch removal, and plant and soil macro- and micro-nutrient content were also collected); and 2) Extension of project information through 2, 4, 1, 4 and 4 presentations held at international, national, regional, state, and local levels, respectively. Publication of project information also occurred through one international proceeding article and a scientific article is in review. This project is the first study to investigate PE mulch and BDMs application in floricane raspberry production and is one of the few studies that evaluate plastic mulches in a perennial fruit production system. Information from this study demonstrates that both polyethylene (PE) mulch and biodegradable plastic mulches (BDMs) managed weed and improved TC transplant establishment and fruit yield.

Results: 1) ***Spring-planted trial*****:** PE mulch was removed by the grower in mid-March while BDMs still remain in the field. Primocane emergence on 5 July 2018 was greatest in the bare ground (BG) control and lowest in Bio360 0.5 and PE, while all remaining treatments were similar. There were no differences in primocane height and number in September 2018 across all treatments and the average primocane height and number for all treatments was 126 inches and 6 primocanes/plant, respectively. Yield was determined from 13 harvests during harvesting season. Average total fruit yield was 34% greater across all mulched treatments relative to the BG control. There were no differences in average berry size among treatments. In September 2018, soil treated with PE mulch had greater root lesion nematode (RLN) population densities than soil treated with Novamont 0.5. Root population densities of RLN were higher for plants treated with PE mulch relative to BASF 0.6 and BG control. **2)** ***Summer-planted trial*****:** BDMs were removed in mid-March as thery were torn by winds during the winter while PE mulch still remains in the field. PE mulch managed weeds compared to the BDMs and BG control and had higher primocane growth than the BG control in September 2018. There were no differences in RLN populations among treatments and RLN population densities remained low across all treatments from the samples collected in May and October 2018.

Publications/Outputs:

Scientific articles:

- Zhang, H., C. Miles, S. Ghimire, C. Benedict, I. Zasada, and L.W. DeVetter. 2018. Polyethylene and biodegradable plastic mulches improve growth, yield, and weed management in floricane red raspberry. Scientia Horticulturae. *Submitted*.

Proceeding:

- Zhang, H., C. Miles, S. Ghimire, C. Benedict, I. Zasada, and L.W. DeVetter. 2018. Application of biodegradable plastic mulches in small fruit production. Horticultural Growers' Short Course 2018 Proceedings. Lower Mainland Horticulture Improvement Association. Pp. 34-37.

Presentation:

A. International

- DeVetter, L.W (presenter), H. Zhang, C. Miles, S. Ghimire, C. Benedict, and I. Zasada. 2018. Application of biodegradable plastic mulches in small fruit production. Lower Mainland Horticulture Improvement Association/Pacific Agriculture Show Grower Short Course. Abbotsford, British Columbia, Canada.
- Miles, C. (presenter), H. Zhang, S. Ghimire, C. Benedict, I. Zasada, and L.W. DeVetter. 2018. Application of biodegradable mulch in red raspberry production. Ontario Fruit and Vegetable Conference, Niagara Falls, Canada.

B. National

- Zhang, H. (presenter), C. Miles, S. Ghimire, C. Benedict, I. Zasada, and L.W. DeVetter. 2018. Promoting productivity and on-Farm efficiencies in tissue culture red raspberry system through biodegradable plastic mulches. American Society for Horticultural Science (ASHS). Washington, D.C.
- Zhang, H. (presenter), C. Miles, S. Ghimire, C. Benedict, I. Zasada, and L.W. DeVetter. 2018. Promoting productivity and efficiencies in summer planted Tissue culture floricane raspberry using biodegradable plastic mulches. Poster presentation. ASHS. Washington, D.C.
- Zhang, H. (presenter), C. Miles, S. Ghimire, C. Benedict, I. Zasada, and L.W. DeVetter. 2018. Biodegradable plastic mulches in floricane red raspberry. Biodegradable mulches SCIR meeting. Spokane, WA.
- Zhang, H., C. Miles, S. Ghimire, C. Benedict, I. Zasada, and L.W. DeVetter. 2018. Application of biodegradable plastic mulches in floricane red raspberry planted as tissue culture transplants. Poster presentation. North American Blackberry & Raspberry Association. Ventura, CA.

C. Regional

- DeVetter, L.W (presenter), H. Zhang, C. Miles, S. Ghimire, C. Benedict, and I. Zasada. 2018. Plastic biodegradable mulches for improved establishment in caneberry. Southeast Regional Fruit & Vegetable Conference. Savannah, GA. Invited Presentation

D. State

- Zhang, H. (presenter), C. Miles, S. Ghimire, C. Benedict, I. Zasada, and L.W. DeVetter. 2018. Increasing raspberry productivity with plastic mulches. Washington Small Fruit Conference. Lynden, WA.
- DeVetter, L.W (presenter), H. Zhang, C. Miles, S. Ghimire, C. Benedict, and I. Zasada. 2018. Application of biodegradable plastic mulches in red raspberry. WSU Pomology Class. Mount Vernon, WA.
- DeVetter, L.W (presenter), H. Zhang, C. Miles, S. Ghimire, C. Benedict, and I. Zasada. 2018. Application of biodegradable plastic mulches in red raspberry. WSU Agricultural and Food System 201 Class (Systems skills development for agricultural & food systems). Mount Vernon, WA.
- DeVetter, L.W. (presenter), H. Zhang, C. Miles, S. Ghimire, C. Benedict, and I. Zasada. 2018. Application of biodegradable plastic mulches in red raspberry. Orchard Vineyard Supply Lynden Growers Meeting. Lynden, WA. Invited Presentation

E. Local

- Zhang, H. (presenter), C. Miles, S. Ghimire, C. Benedict, I. Zasada, and L.W. DeVetter. 2018. Application of biodegradable plastic mulches on tissue culture red raspberry. WSU NWREC Field Day. Mount Vernon, WA.
- Zhang, H. (presenter), C. Miles, S. Ghimire, C. Benedict, I. Zasada, and L.W. DeVetter (co-presenter). 2018. Application of biodegradable plastic mulches on tissue culture red raspberry. Anacortes Science Cafe. Anacortes, WA. Invited Presentation
- Zhang, H. (presenter), C. Miles, S. Ghimire, C. Benedict, I. Zasada, and L.W. DeVetter. 2018. Application of biodegradable plastic mulches on tissue culture red raspberry. Seattle Tree Fruit Society. Seattle, WA. Invited Presentation
- Zhang, H. (presenter), C. Miles, S. Ghimire, C. Benedict, I. Zasada, and L.W. DeVetter. 2018. Application of biodegradable plastic mulches on tissue culture red raspberry. Burlington-Edison High School. Burlington, WA. Invited Presentation

Publications/Outputs:
Scientific articles:

- Zhang, H., C. Miles, S. Ghimire, C. Benedict, I. Zasada, and L.W. DeVetter. 2018. Polyethylene and biodegradable plastic mulches improve growth, yield, and weed management in floricane red raspberry. Scientia Horticulturae. *Submitted*.

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- Miles, C. (presenter), H. Zhang, S. Ghimire, C. Benedict, I. Zasada, and L.W. DeVetter. 2018. Application of biodegradable mulch in red raspberry production. Ontario Fruit and Vegetable Conference, Niagara Falls, Canada.

B. National

- Zhang, H. (presenter), C. Miles, S. Ghimire, C. Benedict, I. Zasada, and L.W. DeVetter. 2018. Promoting productivity and on-Farm efficiencies in tissue culture red raspberry system through biodegradable plastic mulches. American Society for Horticultural Science (ASHS). Washington, D.C.
- Zhang, H. (presenter), C. Miles, S. Ghimire, C. Benedict, I. Zasada, and L.W. DeVetter. 2018. Promoting productivity and efficiencies in summer planted Tissue culture floricane raspberry using biodegradable plastic mulches. Poster presentation. ASHS. Washington, D.C.
- Zhang, H. (presenter), C. Miles, S. Ghimire, C. Benedict, I. Zasada, and L.W. DeVetter. 2018. Biodegradable plastic mulches in floricane red raspberry. Biodegradable mulches SCIR meeting. Spokane, WA.
- Zhang, H., C. Miles, S. Ghimire, C. Benedict, I. Zasada, and L.W. DeVetter. 2018. Application of biodegradable plastic mulches in floricane red raspberry planted as tissue culture transplants. Poster presentation. North American Blackberry & Raspberry Association. Ventura, CA.

C. Regional

- DeVetter, L.W (presenter), H. Zhang, C. Miles, S. Ghimire, C. Benedict, and I. Zasada. 2018. Plastic biodegradable mulches for improved establishment in caneberry. Southeast Regional Fruit & Vegetable Conference. Savannah, GA. Invited Presentation

D. State

- Zhang, H. (presenter), C. Miles, S. Ghimire, C. Benedict, I. Zasada, and L.W. DeVetter. 2018. Increasing raspberry productivity with plastic mulches. Washington Small Fruit Conference. Lynden, WA.
- DeVetter, L.W (presenter), H. Zhang, C. Miles, S. Ghimire, C. Benedict, and I. Zasada. 2018. Application of biodegradable plastic mulches in red raspberry. WSU Pomology Class. Mount Vernon, WA.
- DeVetter, L.W (presenter), H. Zhang, C. Miles, S. Ghimire, C. Benedict, and I. Zasada. 2018. Application of biodegradable plastic mulches in red raspberry. WSU Agricultural and Food System 201 Class (Systems skills development for agricultural & food systems). Mount Vernon, WA.
- DeVetter, L.W. (presenter), H. Zhang, C. Miles, S. Ghimire, C. Benedict, and I. Zasada. 2018. Application of biodegradable plastic mulches in red raspberry. Orchard Vineyard Supply Lynden Growers Meeting. Lynden, WA. Invited Presentation

E. Local

- Zhang, H. (presenter), C. Miles, S. Ghimire, C. Benedict, I. Zasada, and L.W. DeVetter. 2018. Application of biodegradable plastic mulches on tissue culture red raspberry. WSU NWREC Field Day. Mount Vernon, WA.
- Zhang, H. (presenter), C. Miles, S. Ghimire, C. Benedict, I. Zasada, and L.W. DeVetter (co-presenter). 2018. Application of biodegradable plastic mulches on tissue culture red raspberry. Anacortes Science Cafe. Anacortes, WA. Invited Presentation
- Zhang, H. (presenter), C. Miles, S. Ghimire, C. Benedict, I. Zasada, and L.W. DeVetter. 2018. Application of biodegradable plastic mulches on tissue culture red raspberry. Seattle Tree Fruit Society. Seattle, WA. Invited Presentation
- Zhang, H. (presenter), C. Miles, S. Ghimire, C. Benedict, I. Zasada, and L.W. DeVetter. 2018. Application of biodegradable plastic mulches on tissue culture red raspberry. Burlington-Edison High School. Burlington, WA. Invited Presentation

2019 WASHINGTON RED RASPBERRY COMMISSION
RESEARCH PROPOSAL

Project Number: New **Proposed Duration:** 2 years

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

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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**: 2019 **Terminating Year**: 2020

Total Project Request: $24,178 **Year 1**: $12,625 **Year 2**: $11,553

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 proposal we are submitting to the WRRC is new and is not funded by our WSDA grant.

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 34% compared to our non-mulched control. 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 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 'WakeField' spring-planted field (Zhang et al., 2018). 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 34% yield increase among all mulched plants compared to the non-mulched ones during the first harvest year. While research on plastic 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 with single-season mulches 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 mulch (PP; i.e. "weedmat") in establishing organic blackberry (*Rubus ursinus*) and blueberry (*Vaccinium corymbosum*), respectively. In both trials, the mulch improved weed management and crop growth compared to non-mulched plots and were considered more cost-effective than hand weeding. It is expected similar benefits will be observed in floricane raspberry planted as tissue culture transplants. However, multi-year mulches may interfere 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 the floricane raspberry system and to discern their viability in northwestern Washington.

This project will build 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 of optimal mulch products and practices for Washington red raspberry.

Relationship to WRRC Research Priorities:
This project addresses labor saving practices and weed management, which are #3 priorities.

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 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 will be established with a grower cooperator in a spring-planted field of TC raspberry in May 2019 in Lynden, WA. We propose the following activities in 2019:

1. May 2019 - Establish field experiment and apply mulch treatments. The experimental design will be a randomized complete block with four treatments replicated four times. Treatments will be: 1) Polypropylene (PP; "weedmat") from Extenday; 2) Multi-year compostable plastic mulch from BioBag; 3) PE mulch (single-season; positive control); and 4) bare ground (herbicide plus hand weeding using standard grower practices; negative control). Plot size will be a minimum of 60 ft long.
2. May 2019/2020 - Install soil temperature and moisture probes, which will record temperature and moisture conditions every 15 minutes from May to Dec. 2019 and repeated in 2020.
3. May to Dec. 2019/2020 - Monthly assessment of mulch surface degradation as percent soil exposure (PSE).
4. May to Oct. 2019/2020 - Assessment of weed number and shoot biomass in a permanent 3 ft^2 area located in the middle of each plot. This will be done once every two months in 2019 and 2020.
5. May to Oct. 2019 - Assessment of primocane number and height from 10 plants/plot. This will be done once every two months in 2019 and only once in Sept. 2020 to estimate primocane emergence and vigor.
6. Sept. 2019/2020 - Estimation of plant biomass using an unmanned aerial vehicle (UAV).
7. Oct. 2019/2020 - Visual assessment of vole activity as tunnels and holes in a permanent 30 ft^2 area in each plot. Mulches will be lifted up from the side to assess vole activity and reburied each year.
8. July 2020 - Machine harvestable yield, average berry size, fruit total soluble solids, and pH will be determined 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, and reduce labor and pesticide needs associated with weed management. 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 Small Fruit Conference in 2019 and 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, C. Benedict, and L. DeVetter. 2018. Polyethylene and biodegradable plastic mulches improve growth, yield, and weed management in floricane red raspberry. Scientia Horticulturae. *Submitted*.

Budget:

	2019	**2020**
Salaries[1/]	$6,110	$6,354
Timeslip[/2]	$960	$1,080
Operations (goods & services)[3/]	$2,450	$450
Travel[4/]	$450	$900
Equipment	$0	
Benefits[5/]	$2,655	$2,769
Total	$12,625	$11,553

1/ Scientific assistant (Sean Watkinson) at 1 month (salary at $4,051/month) and Research Associate (Ed Scheenstra) at 0.5 months (salary at $4,118) in 2019 and 2020; yearly salaries include 4% inflation.
2/Timeslip in 2019-2020 for field and lab data collection: $12/hr x 20 hr/week x 4 weeks = $960; include 4% inflation.
3/Polypropylene weedmat and experimental biodegradable weedmat at $1,000/roll x 2 rolls = $2,000 (2019 only); replacement batteries for soil temperature and moisture loggers ($300/year); sample bags and supplies for plant and soil data collection ($150/year).
4/Travel from Mount Vernon to grower-cooperator site in Lynden, WA: 84 mi RT x $0.54/mi = $45 x 10 trips = $450/year in 2019; 84 mi RT x $0.54/mi = $45 x 20 trips = $900/year in 2020 (more for harvest data collection) .
5/Benefits for Watkinson at 43.9% and Scheenstra at 38.3%; benefits for timeslip at 9.3%.

2019 WASHINGTON RED RASPBERRY COMMISSION
RESEARCH PROPOSAL

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

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

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

Co – PIs:
- Huan Zhang, PhD Graduate Student, WSU-NWREC, 16650 State Route 536, Mount Vernon, WA 98273, phone: 360-848-6129, huan.zhang@wsu.edu
- Carol Miles, Professor of Vegetable Horticulture, WSU-NWREC, 16650 State Route 536, Mount Vernon, WA 98273, phone: 360-848-6150, milesc@wsu.edu
- Inga Zasada, USDA-ARS Plant Pathologist, 3420 NW Orchard Avenue, Corvallis, OR 97330, phone: 541-738-4051, Inga.Zasada@ars.usda.gov

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

Total Project Request: $15,202 ($6,022 from WRRC + $6,458 from WSCPR + $2,722 in-kind)

Other funding sources: Yes
Agency: Washington State Commission on Pesticide Registration
Amount Requested: $6,458
Notes: We have asked WSCPR to provide a match for this project and have $2,722 as in-kind.

Description:
Washington State leads national production of processed red raspberries, producing ~78 million pounds with a value of $57 million in 2017 (USDA NASS, 2018). Weed management, especially during establishment, has become a critical issue for growers, and is a greater challenge for delicate tissue culture (TC) transplants, which have become increasingly popular within the industry. Black polyethylene (PE) mulch is used to control weeds in many annual crops, and our preliminary studies show it is also effective in perennial red raspberry. Our preliminary results show PE mulch provided effective weed control for the first year in summer-planted red raspberry, but their effect on root lesion nematode (RLN) populations and crop yield is not clear. Since PE mulch increases soil temperatures, there is concern that over time, RLN populations will increase compared to bare ground. We propose to continue our evaluation of PE mulch and bare ground (herbicide plus hand weeding) in summer-planted red raspberry and measure their

impact on: weed control, RLN populations, plant growth, and crop yield. This study was established in August 2017 on a commercial farm in Lynden, Washington, and summer 2019 will be the first harvest year.

Justification and Background:

TC raspberry plantings are increasing in Washington, largely due to new cultivars such as 'Wake^{TM}Field' and 'Wake^{TM}Haven', but also due to traditional cultivars being offered as TC transplants for improved soilborne disease management because TC transplants are produced under sterile conditions. Weed management during establishment of TC transplants is an important issue for raspberry growers. Polyethylene (PE) mulch has been used for many years to control weeds in annual crops, but there is little data regarding plastic mulch use in perennial crops, including raspberry. In a spring-planted TC raspberry study, we have shown that PE mulch can control weeds, increase primocane growth and yield, and overall improve establishment compared to bare ground plots (Zhang et al., 2018). In our preliminary research of summer-planted TC raspberry, PE mulch provided good weed control in the first year of establishment whereas there were significant weeds in the bare ground control treatment that included herbicide application and hand weeding. Because weed control was so effective in the first year of the summer-planted trial and PE mulch remained intact during winter 2017/2018, our grower collaborator has left the mulch intact for a second year.

PE mulch increases soil temperature, which benefits crop growth. However, root lesion nematode (*Pratylenchus penetrans*; RLN) hatching ability is greater when soil temperature is 68 °F compared to 50, 59 or 77 °F in several crops (Pudasaini et al., 2008). Thus, raspberry growers are concerned that increased soil temperature under PE mulch may increase the severity of RLN parasitism.

Several growers have indicated they intend to use PE mulch in their new plantings and are looking to this research for recommendations as it is the first to explore the impacts of PE mulch on weeds and RLN activity in raspberry planted as TC transplants. The study was established in summer 2017 on a commercial raspberry farm in Whatcom County, and includes two treatments: standard PE mulch (1 mil) and bare ground (BG control; standard growers' practice of herbicide application plus hand weeding). We propose to continue our evaluation of the effects of PE mulch on weed control and RLN populations in the first year of crop production in summer-planted raspberry. We propose to also measure effects on plant growth and fruit yield. Overall, this project will contribute to discovering new techniques to control weeds, elucidate impacts of PE mulch on RLN populations, and improve establishment of TC raspberry in northwest Washington.

Relationship to WRRC Research Priorities:

This project addresses the #2 priorities of alternative management systems and understanding soilborne pathogens, as well as the #3 priorities of weed management and labor-saving practices.

Objectives:

The objectives of this project are to: 1) Evaluate weed incidence in summer-planted TC raspberry established with PE mulch compared to bare ground; 2) Evaluate populations of RLN in the soil and roots of summer-planted raspberry established with PE mulch compared to bare ground; and 3) Evaluate plant growth and fruit yield of summer-planted raspberry established with PE mulch compared to bare ground.

Procedures:

Previously completed: The project is being carried out in an on-farm field trial with a grower-cooperator in Lynden, WA. The experimental design is a randomized complete block with five replicates of two treatments: standard PE mulch and bare ground (herbicide plus hand weeding; grower's standard practice). Mulch was laid by machine and TC transplants of 'Wake™Haven' were planted by hand in Aug. 2017. Plots are one row wide and 210 ft in length. RLN baseline populations were determined in all plots before mulch application. To assess impact of treatments on RLN, soil samples were collected in Oct. 2017, and soil and root samples were collected in May and Oct. 2018. Weed incidence (number, and fresh and dry weights) and primocane height and number were measured once per month from Aug. to Sept. 2017 and June to Sept. 2018.

Activities for 2019:

1. Weeds present within an area 3 ft in length in the center of each plot will be counted and weighed (weeds will be clipped at the soil surface; fresh and dry weight) once per month from May to Sept. 2019.
2. RLN population densities in soil and root samples will be determined in Apr./May and Sept./Oct. 2019. We will also collect soil and root samples from another nearby site with higher RLN population densities and planted using PE in summer 2018, which will provide additional data on the impacts of PE mulch on RLN population dynamics.
3. Soil temperature and moisture will be recorded using a data logger (Decagon Devices) that records every 15 mins from Jan. to Dec. 2019.
4. Number of emerged primocanes will be counted in the center 30 ft of each plot in June/July, after caneburning has been completed.
5. Primocane growth (number of canes/hill, and height of the tallest cane/hill) will be measured in Sept. 2019 from 10 plants per plot, based on Zhang et al. (2017).
6. Machine harvestable yield (total fruit weight per plot) will be collected in 2019 (12-18 harvests; this will be the planting's first harvest year), yield per acre will be calculated, and average berry size will be determined; we will also assess if PE has an impact on timing of harvest compared to bare ground.

Anticipated Benefits and Information Transfer:

Plastic mulches are promising tools that can enhance establishment, productivity, and efficiency of raspberry production. We expect PE mulch will manage weeds, increase plant growth and yields, and reduce labor and pesticide needs associated with weed management. Additionally, we expect the increased growth will allow plants to outcompete RLN parasitism. Project information will be presented at field days and the Small Fruit Conference in 2019 and 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 scientific publications.

References:

1. Pudasaini, M., N. Viaene, and M. Moens. 2008. Hatching of the root-lesion nematode, *Pratylenchus penetrans*, under the influence of temperature and host. Nematology 10:47-54.

2. United State Department of Agriculture National Agricultural Statistics Service (USDA NASS). 2018. USDA Noncitrus Fruits and Nuts 2017 Summary. Available from (https://usda.library.cornell.edu/) (accessed in Nov. 2018).
3. Zhang, H., C. Miles, C. Benedict, and L. DeVetter. 2018. Polyethylene and biodegradable plastic mulches improve growth, yield, and weed management in floricane red raspberry. Scientia Horticulturae. *Submitted*.

Budget:

	2019		
	WRRC	**WSCPR**	**In-Kind**
Salaries[1/]	$1,536	$4,608	$2,722
Timeslip[/2]	$1,075		
Operations (goods & services)[3/]		$900	
Travel[4/]	$950	$950	
Equipment			
Benefits[5/]	$2,461		
Total	**$6,022**	**$6,458**	**$2,722**

[1] Salary - Research associate (Ed Scheenstra) for 1 month @ $4,118/m; Scientific assistant (Sean Watkinson) for 0.5 month @ $4,051/m for 2019.
[2]Timeslip at $12.5/hr x 86 hrs.
[3] Nematode assessment from raspberry roots and soil = $600; Bags, flags, logger batteries, etc. for soil sampling and temperature monitoring = $300.
[4] Travel from Mount Vernon to grower-cooperator sites in Lynden, WA: 84 mi RT x $0.54/mi = $45 x 20 trips = $900; transport of harvester from Mount Vernon to Lynden, and return $1,000.
[5] Benefits at 38.3%, 43.9%, and 9.3% for Scheenstra, Watkinson, and timeslip, respectively; WSCPR does not allow benefits.

In-kind from grower cooperator includes production costs at $5,444/acre for 0.5 acres of experimental ground = $2,722 (Source: Galinato and DeVetter, 2016; “2015 Cost Estimates of Establishing and Producing Red Raspberries in Washington State”).

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
L.W. DeVetter, C. Miles, H. Zhang, S. Ghimire, C. Benedict, and I. Zasada	**Current:** Washington State Department of Agricultural Specialty Crop Block Grant Program	$249,959	10/1/2018-9/30/2021	35%	Promoting productivity and efficiencies in red raspberry systems through application of biodegradable plastic mulches

L.W. DeVetter, C. Miles, H. Zhang, S. Ghimire, C. Benedict, and I. Zasada	**Current:** Washington Red Raspberry Commission	$249,959	1/1/2018-12/31/2018	10%	Application of Biodegradable Mulches in Tissue Culture Red Raspberry: Impacts on Weed Control, Parasitic Nematodes, and Crop Growth
L. DeVetter, I. Zasada, C. Miles, S. Seefeldt, C. Benedict, S. Galinato, and H. Zhang	**Pending:** USDA Crop Protection and Pest Management	$324,373	1/1/2019-12/31/2021	35%	Fundamentally changing integrated pest management in raspberries to address new farmer production practices using fumigation and plastic mulches
C. Mile and H. Zhang	**Pending:** Northwest Agriculture Research Foundation	$4,441	1/1/2019-12/31/2019	10%	Pumpkin production with biodegradable mulch

DeVetter, C. Miles, H. Zhang, and I. Zasada	**Pending:** Washington State Commission on Pesticide Registration	$6,458	1/1/2019-12/31/2019	10%	Application of Polyethylene Mulch in Summer-Planted Tissue Culture Red Raspberry: Impacts on Weed Control, Parasitic Nematodes, and Crop Growth and Yield

CURRENT & PENDING SUPPORT

Name: Suzette P. Galinato

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.

Active:

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
Hayes, D. et al.	USDA SCRI CAP	$4,884,785	09/29/2014-09/28/2016 (first term); 09/29/2016-09/28/2019 (second term)	15 (average FTE per year)	Biodegradable Plastic Mulch for Sustainable Specialty Crop Production
DeVetter, L., Benedict, C. and Galinato, S.	WA Red Raspberry Commission	$89,778	2015-2020	4 (average FTE per year)	Comparison of Alternate- and Every-Year Production in Summer-Bearing Red Raspberry
Amiri, A. and Gallardo, K.	WA Tree Fruit Research Commission	$143,635	04/01/2016-12/31/2018	6 (per year)	Evaluation of Postharvest Fungicide Application Methods for Improved Fruit Quality
Louws, F. et al.	USDA SCRI CAP	$6,800,000	2016-2020	0 (Yr 1) 4 (Yr 2) 13 (Yr 3) 17 (Yr 4)	Growing New Roots: Grafting to Enhance Resiliency in U.S. Vegetable Industries
Miles, C.A., and Galinato, S.P.	WSDA SCBG	$177,808	2017-2019	8 (per year)	Cost Effective Technologies for Cider Apple Orchard Mechanization and Fruit Quality Evaluation
Jessup, E.	USDA	$266,629	2017-2018	20	Agriculture Infrastructure Prioritization Engagement Workshops

Pending:					
Jacoby, P. and Galinato, S.	Washington State Grape and Wine Research Program	$49,023	2019-2020	8	Assessment of costs and benefits of direct root-zone drip irrigation in red wine grape production: A step toward commercialization
Winkler, M., Galinato, S., Galinato, G. Neumann, R., and Mueller, A.	NSF INFEWS	$2,500,000	2019-2023	8 per year	Expansion of Livestock Production while Mitigating Water Pollution: Cost and Energy Efficient Nutrient and Carbon Recovery from Manure
Miles, C. et al.	WSARE	$74,580	2019-2021	1 per year	In-Service Training for Biodegradable Mulch
Miles, C.A. and Galinato, S.P.	USDA	$488,521	2018-2021	4 (Yr 1) 8 (Yr 2) 12.5 (Yr 3)	Grafting, biodegradable mulch and high-lignin crop rotation to control watermelon and eggplant Verticillium wilt

Current & Pending Support

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Name (List PI #1 first)	Supporting Agency and Project #	Total $ Amount	Effective and Expiration Dates	% of Time Committed	Title of Project
	Current:				
Hayes, D., et al.	USDA-NIFA-SCRI	$4,884,785	10/14-9/19	20%	Performance and adoptability of biodegradable plastic mulch for sustainable specialty crop production
Louws, F. et al.	USDA-NIFA-SCRI	$6,799,672	10/16-9/20	5%	Growing New Roots: Grafting to Enhance Resiliency in U.S. Vegetable Industries
Miles and Galinato	WSDA SCBG	$177,808	10/17-9/19	5%	Cost effective technologies for cider apple orchard mechanization and fruit quality evaluation
Walsh, D. et al.	USDA NIFA CPPM EIP	$837,000	10/17-9/20	2%	Washington state IPM extension implementation program 2017-2020
Miles and Collins	WSU ARC ERI NARF	$30,559 $ 4,569	6/18-5/19	2%	Identifying bulb fennel cultivars suitable for production in NW Washington
DeVetter et al.	WSDA SCBG	$249,960	10/18-9/21	5%	Promoting productivity and efficiencies in red raspberry systems through application of biodegradable plastic mulches
Miles et al.	WSU BIOAg	$9,924	8/18-9/19	1%	Cider sensory guide
	Pending:				
DeVetter et al.	WSDA SCBG	$249,963	10/19-9/22	5%	Novel production systems for improved production and disease management in strawberry
Grewell et al.	ND Corn Council	$120,000	5/19-4/20	1%	Multi-functional mulching system
DeVetter et al.	USDA-NIFA-SCRI	$50,000	10/19-9/20	2%	New mulch technologies and improved end-of-life management
DeVetter et al.	WSCPR WRRC	$6,458 $8,744	3/19-12/19	1%	Application of PE Mulch in summer-planted tissue culture red raspberry
Miles et al.	WSU BIOAg	$38,969	4/19-3/20	2%	Evaluating regulated deficit irrigation in cider apple orchards
Miles et al.	WSARE PDP	$74,580	10/19-9/21	2%	In-service training for biodegradable mulch

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:

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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 - 3/30/19	1%	Improving Soil Health for Whatcom County Raspberry Growers
Kruger, C., C. Benedict, M. Zhu	USDA NRCS	$500,000	09/01/15 - 03/31/19	3%	Dairy Manure-Derived Fertilizers for Use in Raspberry and Blueberry Cropping Systems:
D. Hayes, A. Wszelaki, J. DeBruyn, D. Inglis, C. Miles, J. Goldberger, T. Marsh, M. Flury, J. Cowan, M. Fly, S. Schexnayder, C. Benedict, E. Belasco, M. Velandia	USDA-NIFA	$1,912,178	10/1/14- 9/30/19	30%	Adoptability and Long-Term Effects of Biodegradable Plastic Mulches for Specialty Crop Production
Gray, S. R. Groves, A. Charowski, S. Jansky, A. Karasev, J. Kuhl, P. Nolte, N. Olsen, E. Wenninger, A. McIntosh, J. Whitworth, R. Novy, P. Hamm, S. Rondon, N. Gudmestad, D. Inglis, H. Pappu, M. Pavek, C. Benedict, N. Zidack, A. Aylokhim, D. Douches	USDA-NIFA	$7,845,443	10/1/14- 9/30/19	20%	Biological and economic impacts of emerging potato tuber necrotic viruses and the development of comprehensive and sustainable management practices.

Wasko DeVetter, L. Rudolph, R. Mazzola, M. Benedict, C.	WA Red Raspberry Commission	$7,032	1/1/15- 12/31/16	1%	Impacts of Alleyway Cover Crops on Soil Quality and Plant Competition in Established Red Raspberry
Wasko DeVetter, L. Rudolph, R. Mazzola, M. Zasada, I. Benedict, C. Jones, S.	Northwest Agricultural Research Foundation	$7,032	1/1/15- 12/31/17	1%	Impacts of Alleyway Cover Crops on Soil Quality and Plant Competition in Established Red Raspberry
Martin, B C. Benedict T. Walters	WA Blueberry Commission	$18,700	2/1/17 - 12/31/17	1%	Assessing Blueberry Virus Risks in Washington: Blueberry Fruit Drop investigations, and Surveys of Washington Blueberry Fields for Aphids and Viruses
S. Seefeldt, C. Benedict	WSDA SCBG	$120,000	9/16/18 - 9/29/21	5%	Integrated pest management of annual polygonum species in northwest Washington specialty crops: Working with plant biology
C. Benedict, 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
M. Zhu, C. Benedict	WSU BIOAg	$40,000	1/1/2018 - 12/31/18	5%	Impact of manure-derived fertilizers on bacterial community and anti-biotic resistance genes in Washington red raspberry fields.
			Total % of Active:	**68.00%**	
PENDING:					
Karkee, M., Zhang, Q., Tekada, F., DeVetter, L., Seavart, C., Benedict, C.	USDA-NIFA	$2,000,000	10/1/19 - 9/30/23	5%	Increasing Caneberry Profitability through Modified Horticultural Systems and Mechanization for Cane Pruning and Training
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
L. DeVetter, C. Miles, D. Griffin, M. Flury, S. Agehara, S. Wortman, M. Bolda and more	USDA-SCRI	$49,796		1%	Planning Grant: Implementation of New Technologies and Improved End-of-Life Management for Sustainable Use of Agricultural Plastics
C. Benedict, L. Khot, C, Gleason	WIPM	$29,938	3/1/19 - 2/28/20	10%	Non-destructive Optical Sensing for Early Detection of Soil Borne Diseases in Potatoes
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
			Total % of Pending:	**26.00%**	

CURRENT & PENDING SUPPORT

Name: Inga Zasada

Instructions:
Who completes this template: Each project director/principal investigator (PD/PI) and other senior personnel that the Request for Applications (RFA) specifies
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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:				
Moyer, Zasada, Schreiner	Washington State Grape & Wine Research	81,134	6/2015 - 5/2019	10%	Impact and management of plant-parasitic nematode in Washington vineyards
Walters et al.	Washington Red Raspberry Commission	11,508	1/2017 – 12/2018	2%	Evaluating soil fumigation alternatives in Washington raspberry fields
Dandurand et al.	NW Potato Research Consortium	118,238	7/2016 – 12/2018	5%	Eradication strategies for *Globodera pallida*: use of trap crops
Dandurand et al.	NW Potato Research Consortium	78,930	7/2016 – 12/2018	1%	Functional genomics of *Solanum sisymbriifolium* (lichi tomato) immunity for PCN eradication
Dandurand et al.	USDA-APHIS	307,237	7/2018-6/2019	5%	*Globodera* eradication
Dandurand et al.	USDA-APHIS	470,306	7/2018-6/2019	1%	*Globodera* immunity
Dandurand et al.	USDA-AFRI-Food Security	3,200,000	5/2015-4/2020	10%	Risk assessment and eradication of *Globodera* species in US potato production of potato
	Pending:				
Snelling et al.	USDA-AFRI	307,290	2018-2021	3%	Utilization of fatty ammonium salt-amylose inclusion complexes to control plant pathogens
Devetter et al.	WSCPR	6,458	1/2019-12/2019	1%	Application of polyethylene mulch in summer-planted tissue culture red raspberry: impacts
Moyer and Zasada	WSCPR	5,355	2/2019-4/2020	3%	Evaluating efficacy of post-plant nematicides in Washington vineyards

Washington Red Raspberry Commission
Final Report for 2018

Project No: 3455-6648

Title: Impact of Nitrogen on Nematode Parasitism of Red Raspberry

Personnel: L.W. DeVetter and I. Zasada

Reporting Period: This report presents data from 2018 and is the final year for this two-year project.

Accomplishments: The objective of this project is to explore if different nitrogen rates applied during red raspberry establishment influences plant growth, root lesion nematode (*Pratylenchus penetrans*; RLN) populations, and subsequent damage to plants. We established this experiment in 2017 at the Washington State University Northwestern Washington Research and Extension Center and collected primocane (i.e.) shoot biomass, primocane height, RLN population density, and yield data in 2017 and 2018 (yield data in 2018 only). Treatments included: 1) 0 lbs N/A + RLN (negative control); 2) 30 lbs N/A + RLN; 3) 60 lbs N/A + RLN; 4) 60 lbs N/A – RLN, and; 5) 100 lbs N/A + RLN. The "+" and "-" indicates microplots were or were not inoculated with RLN, respectively. Fertilization occurred weekly using a solution containing urea dissolved in water. Plots were inoculated in at planting in 2017 to achieve an initial density of ~250 RLN/250 g of soil. Project results were presented at the Small Fruit Conference in 2017.

Results: Plots were successfully inoculated and RLN densities were very high in all inoculated plots by the conclusion of the project (Fig. 1). Interestingly, RLN root and soil densities numerically increased with increasing N rate and may be due to additional root biomass for nematodes to parasitize. However, these differences were not statistically significant. Primocane height was greatest in the 60 lbs N/A – RLN treatment, whereas it was lowest in the 0 lbs N/A + RLN treatment (Fig. 2). This trend occurred in 2017 and repeated in 2018. Shoot biomass and tissue N were not different by year and were combined (Table 1). Shoot biomass was greatest in the 60 lbs N/A – RLN treatment and lowest in the 0 lbs N/A + RLN treatment. The 30 and 60 lbs N/A + RLN treatments had the same shoot biomass, while the 100 lbs N/A + RLN treatment was similar to the 30 and 60 lbs N/A + RLN treatments. Regression analysis revealed RLN root and soil densities explained 22 and 11% of the variation associated with shoot biomass in 2017 (R^2=0.22 and 0.11, respectively), whereas nitrogen rate only explained ~10% of the variation (R^2=0.079). Tissue N ranged from 3.0 - 3.4% for all treatments except the 0 lbs N/A + RLN treatment (Table 1). The 0 lbs N/A + RLN treatment was within the recommended N range described by Hart et al. (2006) of 2.3 - 3.0%, whereas the other treatments were above this range. Yield data showed a similar trend as shoot biomass with the 60 lbs N/A – RLN treatment having the greatest yield (Table 1). However overall yields were reduced because of bird depredation. Fruit quality analysis is in progress.

These data indicate additional fertilizer nitrogen at the rates and application frequency applied in this experiment cannot help plants recover from high infestations of RLN. Interestingly, the N tissue standards data suggests standards may need to be raised for northwestern Washington, as the most productive plants were beyond the range recommended by Hart et al. (2006). RLN infestations can severely reduce plant establishment and growth, as demonstrated in this experiment, which underscores the importance of good pre-plant fumigation at high-risk sites. Nematicides and/or biostimulants applied at planting or post-plant may help raspberry maintain growth and productivity under different levels of RLN infestation, but warrant further study.

Publications/Outputs:

- DeVetter, L.W. and I.A. Zasada. 2017. Impact of nitrogen on nematode parasitism in red raspberry. Presentation made at the Small Fruit Conference in Lynden, WA.
- A PDF of the above presentation and a project progress report will be made available on the WSU Small Fruit Horticulture website at: http://smallfruits.wsu.edu/impact-of-nitrogen-on-nematode-parasitism-in-red-raspberry/
- A scientific publication is in progress and will be submitted to *Nematropica*

Table 1. Shoot biomass, tissue nitrogen (N), and yield determined from 'Meeker' raspberry treated with different fertilizer N rates with and without root lesion nematodes (*Pratylenchus penetrans*; RLN), 2017-2018.

	2017-2018		
Treatment	Shoot mass (g/plant)	Tissue N (%)	Yield (g/plant)
0 lbs N/A + RLN	25.5 c[z]	2.8	35.3
30 lbs N/A + RLN	97.4 b	3.4	57.7
60 lbs N/A - RLN	231.5 a	3.4	139.2
60 lbs N/A + RLN	92.3 b	3.4	49.0
100 lbs N/A + RLN	90.9 bc	3.0	57.2
P-value	<0.0001	NA	NA

[z]Means with the same letter are not different at $P = 0.05$.

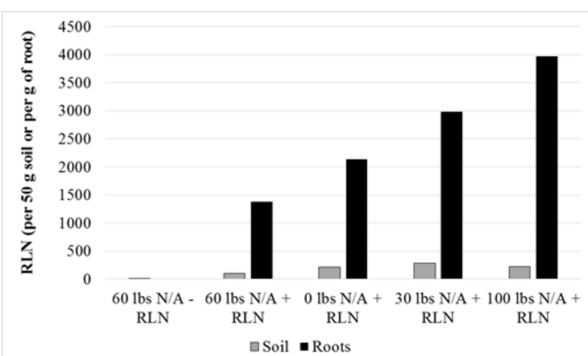


Figure 1. Root lesion nematode (*Pratylenchus penetrans*; RLN) densities in soils and 'Meeker' raspberry roots. Data are from Sept. 2018.

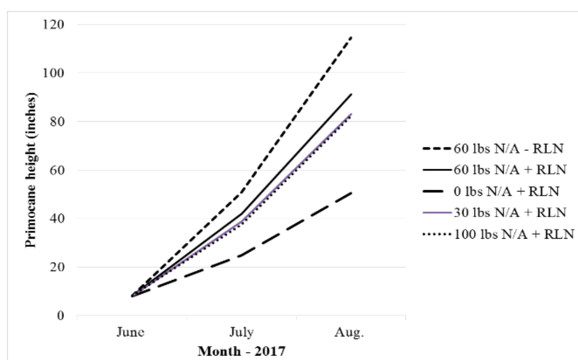


Figure 2. Cumulative primocane height of 'Meeker' raspberry treated with different nitrogen rates with and without root lesion nematodes (*Pratylenchus penetrans*; RLN).

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 Elevate, Pristine, iprodione and Switch and the level of resistance appears to have increased in the short time after he has started monitoring 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 2014 trial, but with some improvements based on 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. This project involved 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 on raspberry.

Materials and Methods (shared)

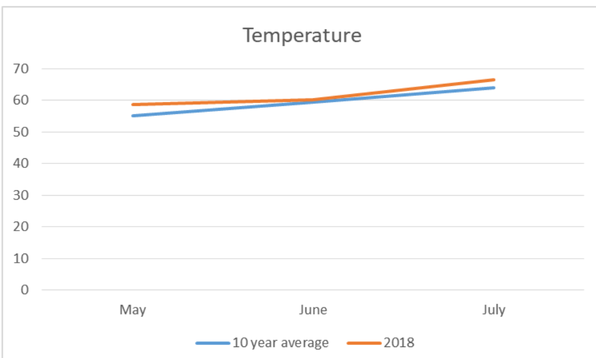
The staff at the Agriculture Development Group, Inc. started a research trial near Everson, WA in May 2018 to evaluate the effect of 30 selected treatments (efficacy trial), and in a separate trial, 14 selected programs (program trial) for the control of raspberry gray mold disease caused by *Botrytis cinerea*. The experimental design for this trial was a RCB 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.

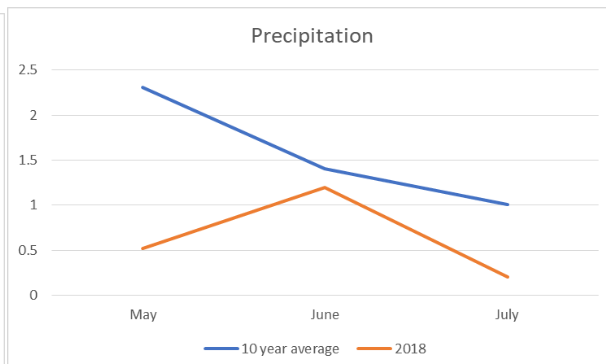
Five applications were made on May 24, June 4, June 15, June 24, and July 9. Originally the trial was scheduled for six application but the abnormally warm conditions compressed the season and the final application could not be made. The phytotoxicity of each treatment was evaluated at each application 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 on May 24 and July 12.

During the course of this trial no obvious gray mold disease symptoms were detected, due to even hotter and drier weather conditions than in 2017, a notable hot dry growing season, botrytis pressure was non-observable this year (Figure 1). In five years of doing grey mold research this is the first time not a single infected berry was detected. To compensate for the lack of disease symptoms in the field, 30 raspberries from each plot were harvested on July 12 (Photo 2) then they were transferred to incubator on July 13 for later after-harvest evaluations (Photo 3). We incubated the fruit to increase the chance of gray mold since we did not see the symptom in the field. Raspberry samples for incubation were collected and put in food service containers on July 12 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 3). The gray mold disease was evaluated on July 15, 17, and 19, respectively represented infection incidence at 2, 4, and 6 days after incubation (DAI). Berries with visible mold were removed, and remaining berries were returned to the incubator.

Yellow rust disease (*Phragmidium rubi-idaei*) was also noticed on raspberries towards the end of this trial, so an evaluation was made on August 3 (Photo 4). Rust disease was evaluated as percent of rust on each leaf. Twenty leaves were evaluated for each plot. 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.

Figure 1. Average air temperature/precipitation in May, June, and July of 2018 and history of past 10 years.





Results and Discussion

As botrytis pressure in the field was non-observable this year, we had to proceed with after-harvest incubation method for the evaluation of botrytis infection incidence level. It is interesting that botrytis inoculum was on every fruit in the field as indicated by the rapid development of the disease in humid post harvest incubation conditions. Obviously the disease simply did not develop on the fruit in the field due to the environmental conditions that were unfavorable for disease progression.

Efficacy Trial

Botrytis fungus propagated rapidly with 14.2% infection incidence by 2 DAI in untreated berries (Figure 2), then further increased to 80.8% at 4 DAI and 99.2% at 6 DAI (Figure 3 and 4). There was no statistical differences among treatments at 2 DAI but at 4 and 6 DAI. Only Omega (treatments 3) and Adepidyn (treatment 18) achieved continuous botrytis control with the lowest botrytis incidence at 2 (5% and 2.5%), 4 (36.7% and 42.5%), and 6 (75% and 85%) DAI, leading to >65%, >47%, and >14% control efficacy at according dates (Table 1; Figure 2, 3 and 4). Luna Tranquility (treatment 4) and Proline (treatment 12) showed significantly lower than untreated incidence at 4 and 6 DAI with 57.5% and 50% incidence (29 and 38% control) at 4 DAI and 79.2 and 87.5% incidence (20 and 12% control at 6 DAI), also indicating a good control potential (Figure 4 and 5). On the other hand, PhD and Captan (treatment 2 and 7) suppressed botrytis only by 2 and 4 DAI with only 7.5% and 6.7% incidence (47 and 53% control) at 2 DAI and

60.8% and 62.5% incidence (25 and 23% control) at 4 DAI, yet lost their effect at 6 DAI, indicating weaker residual effect (Figure 2 and 3).

For the yellow rust, all treatments except treatments 4, 8, 10, 18, 19, and 23 (Luna Tranquility, Elevate, Iprodione, Adepidyn, GWN-10474 low rate, and Ecoswing) showed significantly lower rust incidence than untreated check (Figure 5). Treatments 3 (Omega, 8.8%), 6 (Switch, 15%), 9 (Pristine, 8.8%), 11 (Oxidate, 11.3%), 12 (Proline, 1.3%), and 15 (Fontelis, 1.3%) showed the lowest rust incidences with >77% control, followed by treatments 2 (PhD, 22.5%), 7 (Captan, 23.8%), 13 (OSO, 23.8%), 17 (Kenja, 20%), 21 (GWN-10474 low rate, 27.5%), 22 (GWN-10474 high rate, 23.8%), 25 (SA-0650001, 22.5%), 26 (SA-0650004 low rate, 22.5%), 27 (SA-0650004 high rate, 22.5%), 28 (rotation of SA-0650001+Pristine, 25%), and 29 (rotation of SA-650004+Pristine, 28.8%) with 57% to 70% incidence control (Figure 5). Furthermore, treatment 3, 11, 12, 15 not only resulted in the lowest incidence but also exhibited minimum rust severity when the infection happened, with 82% to 100% severity control (Figure 6), suggesting they had the best overall rust control efficacy.

In summary, our data suggested the best botrytis control efficacy by Omega (treatments 3) and Adepidyn (treatment 18), and great potential by Luna Tranquility (treatment 4) and Proline (treatment 12). Rust results suggested best rust control by treatments 3 (Omega), 6 (Switch), 9 (Pristine), 11 (Oxidate), 12 (Proline), and 15 (Fontelis). It appears that Omega (treatment 3) and Proline (treatment 12) had a consistent effect with the best control on both diseases, while some other treatments showed a more selective effect, such as treatment 4 (Luna Tranquility) and 18 (Adepidyn) which did great on botrytis yet poorly on rust.

It is important to note that these applications were applied based on timings recommended for botrytis, not for rust. It is possible that improved control of rust may be possible with adjusted timings. Also, as a result of these data, Corteva is adding yellow rust to the Fontelis label.

Table 1. ANOVA mean separation table for comparison of 30 treatments for control of rust, or gray mold on raspberry at 2, 4 and 6 days after incubation.

Pest Name					Botrytis blight	Botrytis blight	Botrytis	RUST	RUST
Crop Name					Red raspberry	Red raspberry	Red raspberry	Red raspberry	Red raspberry
Description					2D after incub>	4D after incub>	6D after incub>		
Rating Type					incidence	incidence	incidence	incidence	severity
Rating Unit					%	%	%	%	%
Trt No.	Treatment Name	Rate	Rate Unit	Appl Code	1	2	3	4	5
1	Untreated Check				14.2b-f	80.8ab	99.2a	67.5a	4.7a-d
2	PhD	6.2	oz/a	ABCDE	7.5def	60.8b-e	95.8abc	22.5def	1.8b-e
3	OMEGA	1.25	pt/a	ABCDE	5.0ef	36.7f	75.0e	8.8ef	0.4e
4	Luna Tranquility	18	fl oz/a	ABCDE	17.5b-f	57.5cde	79.2de	42.5a-d	5.4abc
5	SCALA	18	fl oz/a	ABCDE	18.3b-e	69.2a-d	95.8abc	35.0b-e	0.8e
6	SWITCH	14	oz/a	ABCDE	**7.5def**	66.7a-d	95.0abc	15.0def	1.8b-e
7	CAPTAN	2.5	lb/a	ABCDE	6.7def	62.5b-e	94.2abc	23.8def	2.0a-e
8	ELEVATE	1.5	lb/a	ABCDE	23.3abc	67.5a-d	96.7ab	60.0abc	5.9a
9	PRISTINE	23	oz/a	ABCDE	19.2b-e	72.5abc	91.7abc	8.8ef	1.3de
10	IPRODIONE	2	pt/a	ABCDE	21.7a-d	69.2a-d	98.3ab	63.8ab	2.7a-e
11	Oxidate	32	fl oz/100 gal	ABCDE	14.2b-f	72.5abc	94.2abc	11.3ef	0.3e
12	PROLINE	5	fl oz/a	ABCDE	10.0c-f	50.0def	87.5bcd	1.3f	0.0e
13	OSO	3.75	fl oz/a	ABCDE	12.5b-f	65.8a-d	92.5abc	23.8def	1.5cde
14	OSO	13	fl oz/a	ABCDE	9.2c-f	67.5a-d	95.8abc	33.8cde	2.2a-e
15	Fontelis	20	fl oz/a	ABCDE	17.5b-f	63.3bcd	94.2abc	1.3f	0.3e
16	Kenja	15.5	fl oz/a	ABCDE	10.0c-f	67.5a-d	90.8abc	30.0def	3.9a-e
17	Kenja	13.5	fl oz/a	ABCDE	12.5b-f	62.5b-e	93.3abc	20.0def	0.9de
18	Adepidyn	13	fl oz/a	ABCDE	2.5f	42.5ef	85.0cde	41.3a-d	5.6ab
19	GWN-10474	21	oz/a	ABCDE	20.0b-e	77.5abc	96.7ab	43.8a-d	3.3a-e
	R-11	0.5%	v/v	ABCDE					
20	GWN-10474	28	oz/a	ABCDE	20.8bcd	77.5abc	98.3ab	32.5cde	1.7cde
	R-11	0.5%	v/v	ABCDE					
21	GWN-10474	35	oz/a	ABCDE	20.0b-e	70.8abc	90.0a-d	27.5def	3.5a-e
	R-11	0.5%	v/v	ABCDE					
22	GWN-10474	42	oz/a	ABCDE	13.3b-f	66.7a-d	92.5abc	23.8def	2.7a-e
	R-11	0.5%	v/v	ABCDE					
23	Ecoswing	2	lb/a	ABCDE	25.8ab	76.7abc	98.3ab	42.5a-d	2.5a-e
24	Serenade Optimum	20	oz/a	ABCDE	36.7a	85.0a	97.5ab	36.3b-e	1.8b-e
25	SA-0650001	55	fl oz/a	ABCDE	21.7a-d	72.5abc	95.8abc	22.5def	1.4de
	Kinetic	0.125%	v/v	ABCDE					
26	SA-0650004	28	fl oz/a	ABCDE	11.7b-f	79.2ab	99.2a	22.5def	1.8b-e
27	SA-0650004	42	fl oz/a	ABCDE	15.8b-f	65.8a-d	87.5bcd	22.5def	3.2a-e
28	SA-0650001	55	fl oz/a	ACE	19.2b-e	71.7abc	95.8abc	25.0def	2.3a-e
	Kinetic	0.125%	v/v	ACE					
	Pristine	23	oz wt/a	BD					
29	SA-0650004	28	fl oz/a	ACE	12.5b-f	72.5abc	95.8abc	28.8def	1.5cde
	Pristine	23	oz wt/a	BD					
30	SA-0670001	5	lb/a	ABCDE	14.2b-f	80.0ab	95.0abc	37.5b-e	1.3de
LSD P=.05					15.83	20.55	11.06	29.07	3.90
Standard Deviation					11.26	14.62	7.87	20.68	2.78
CV					73.33	21.6	8.45	70.91	121.33
Levene's F					1.139	0.932	1.922	0.929	1.035
Levene's Prob(F)					0.314	0.571	0.01*	0.575	0.434
Skewness					0.7395*	-0.9125*	-1.9225*	0.6456*	2.1782*
Kurtosis					-0.3583	0.8925*	3.6286*	-0.4663	5.3476*
Replicate F					4.910	1.545	1.685	2.335	2.150
Replicate Prob(F)					0.0034	0.2086	0.1761	0.0794	0.0998
Treatment F					1.567	2.124	2.055	2.515	1.296
Treatment Prob(F)					0.0575	0.0039	0.0055	0.0005	0.1790

Figure 2. Comparison of 30 treatments for control of botrytis blight in raspberry-incidence after 2 days' of incubation.

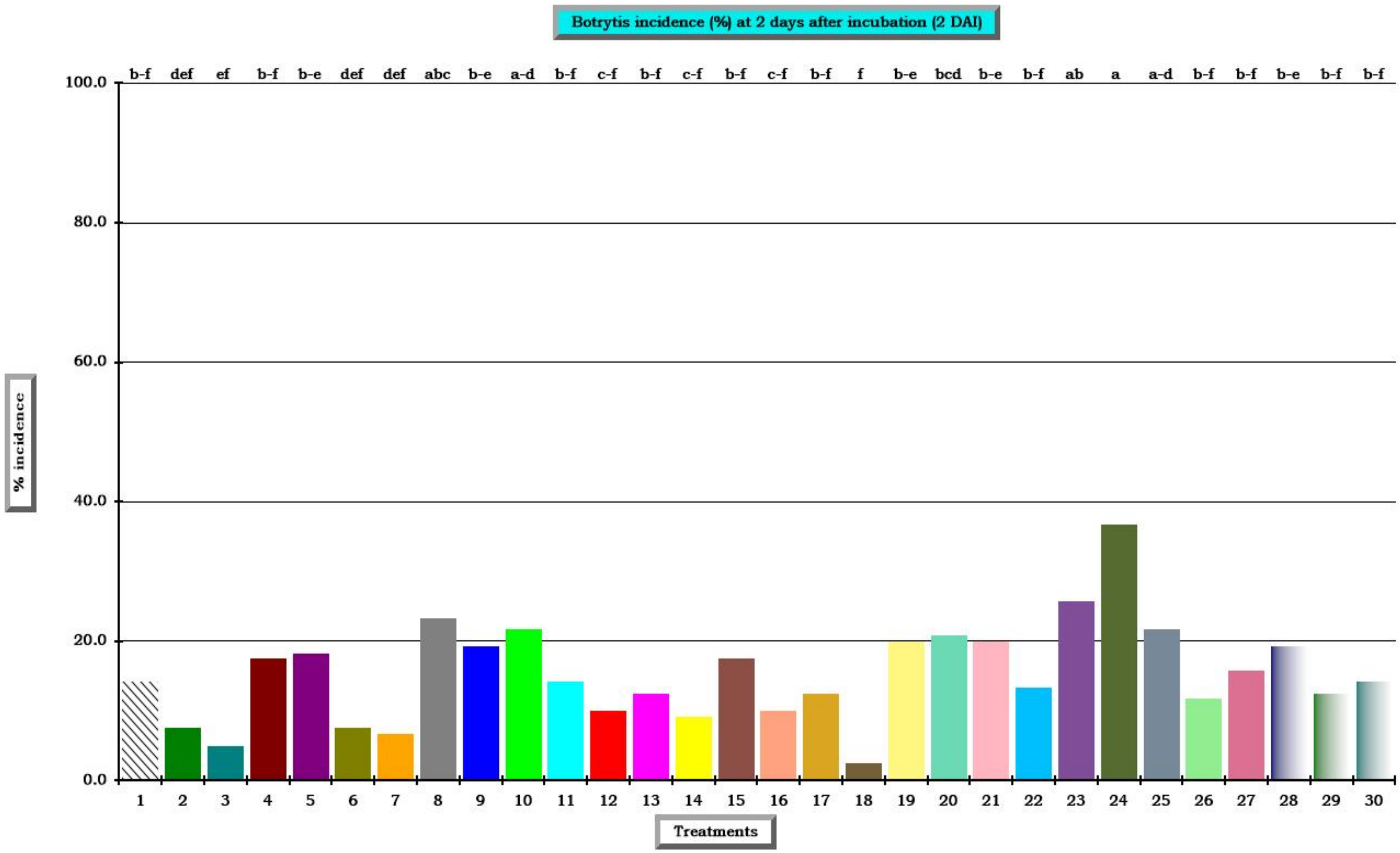


Figure 3. Comparison of 30 treatments for control of botrytis blight in raspberry-incidence after 4 days' of incubation.

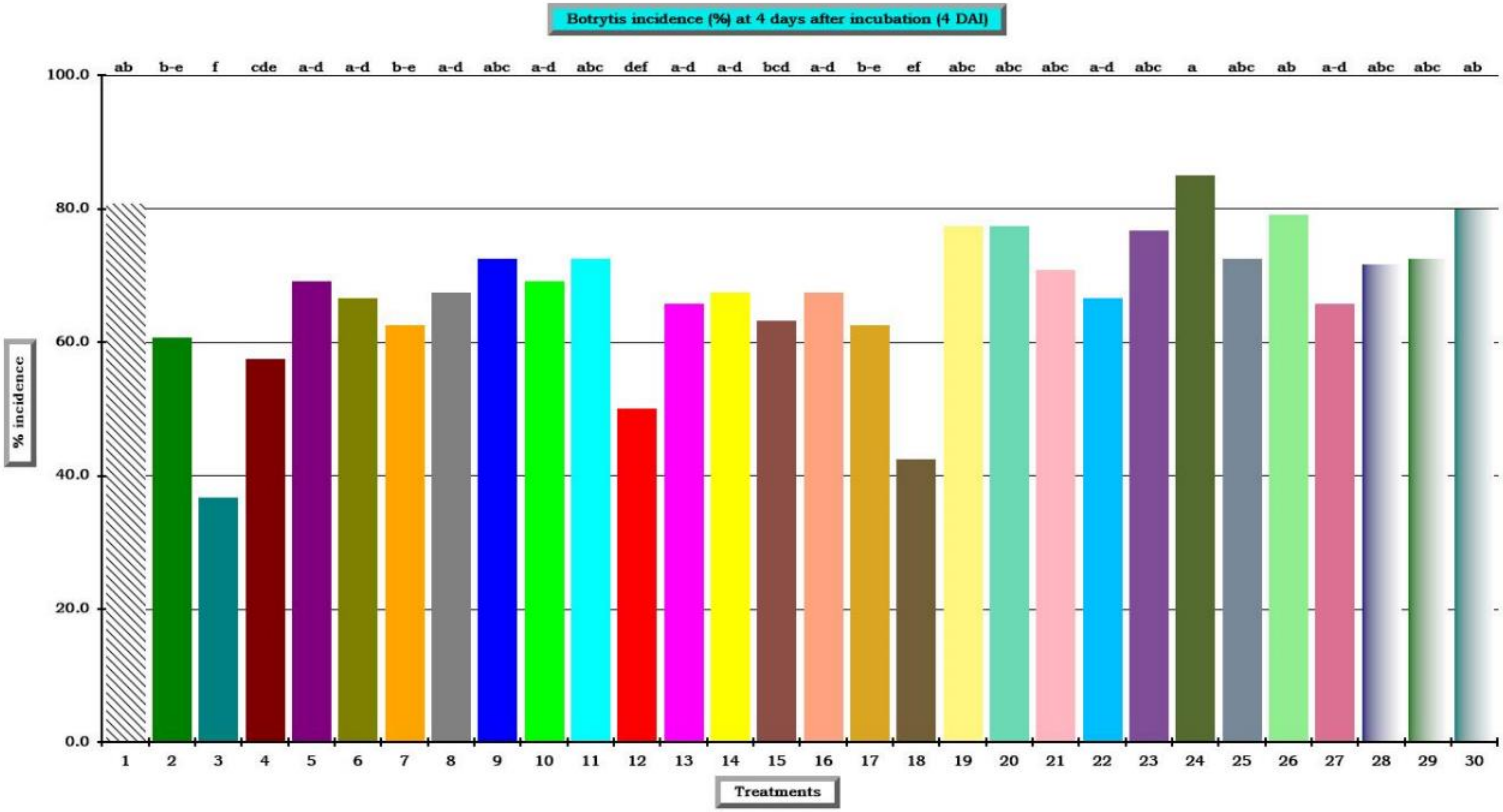
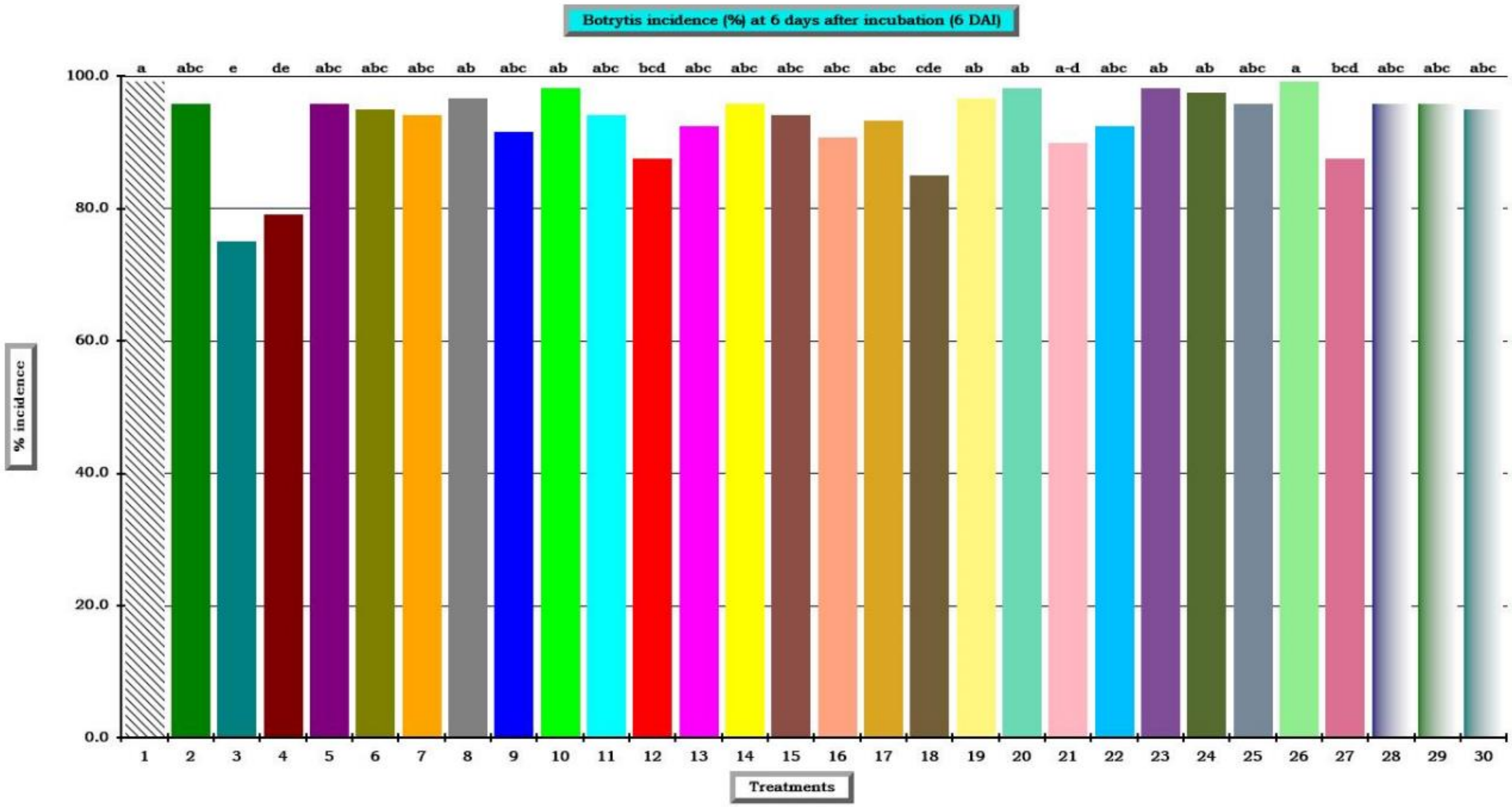


Figure 4. Comparison of 30 treatments for control of botrytis blight in raspberry-incidence after 6 days' of incubation.



Botrytis incidence (%) at 6 days after incubation (6 DAI)
a abc e de abc abc abc ab abc ab abc bcd abc abc abc abc abc cde ab ab a-d abc ab ab abc a bcd abc abc abc
100.0
80.0
60.0
40.0
20.0
0.0
% incidence
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Treatments

Figure 5. Comparison of 30 treatments for control of yellow rust in raspberry-incidence data.

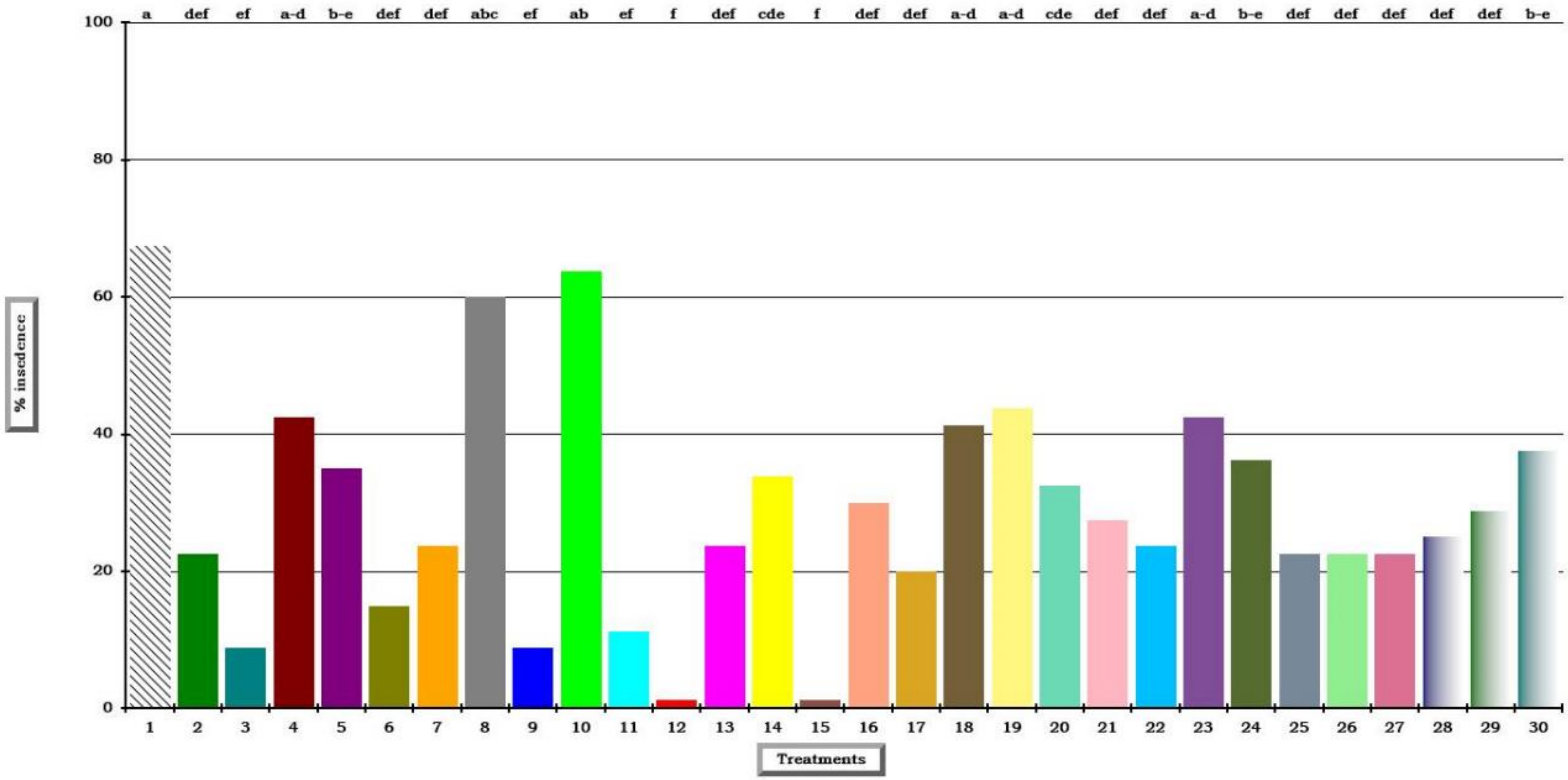
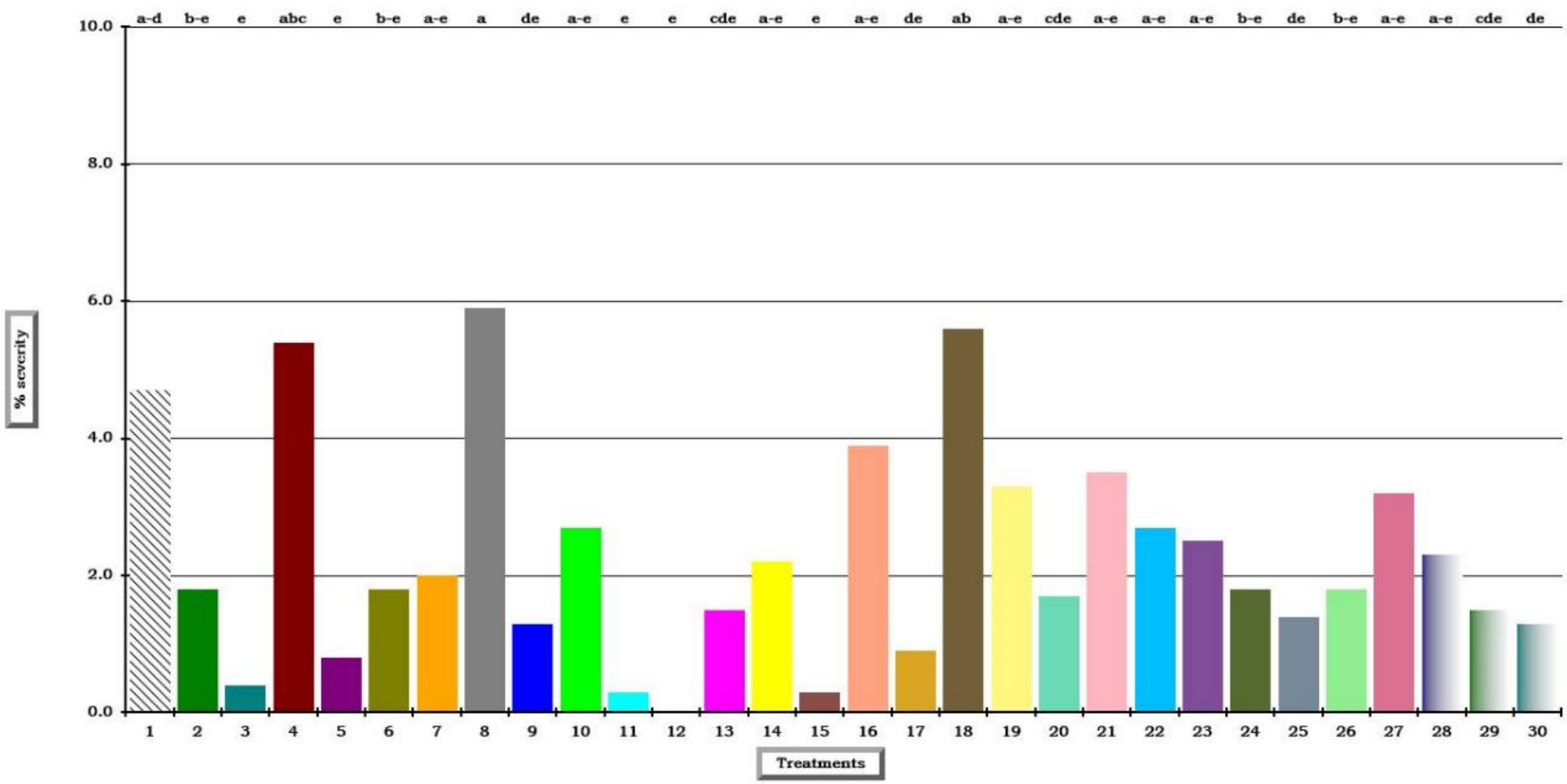


Figure 6. Comparison of 30 treatments for control of yellow rust in raspberry- severity data.



Program Trial

The Program Trial is an evaluation the ability of various botrytis programs used by the Washington raspberry industry as well as some potential new programs that are relying on newly available fungicides.

The botrytis fungus infection was already established by 2 DAI with 4% incidence in untreated check berries while program 8 (rotation of Captan, Switch, Pristine, Meteor, and PhD), 9 (rotation of Kenja, Captan, PhD, and Meteor), and 14 (repeated application of Fontelis) resulted in minimum infection (Table 2; Figure 7).

By 4 DAI, the ratio of botrytis infected berries increased to 73% in untreated check. Program 2, 3, 4, 5, 8, 9, 11, and 14 were able to significantly suppress the spreading of the infection with respectively 43%, 41%, 38%, 48%, 38%, 23%, 45%, and 52% incidence, indicating 29% or higher control efficacy. The infection reached 93% in untreated check at 6 DAI, and only programs 2 (78%), 4 (78%), and 9 (71%) still maintained statistically lower infection incidence than untreated (Table 2; Figure 7).

For the yellow rust, >61% infection incidence was observed in untreated check although the severity was much lower for all treatments (<=1%). Programs 12, 13, and 14 significantly suppressed the occurrences of rust with 5% or less incidence, followed by program 11 with 26% incidence, suggesting 57% to 100% control efficacy. Other programs had 54% or higher incidence, leading to only 11% maximum control efficacy, including few programs who even had higher than untreated rust incidence (programs 2, 4, 6, and 7) (Table 2; Figure 8). One powerful result of this trial is how effective Fontelis is in terms of controlling yellow rust.

To summary, programs 2, 4, and 9 had the best botrytis control who maintained the lowest infection incidence even at high infection stage (6 DAI). There was a potential botrytis control by programs 8 and 14 which exhibited significantly lower botrytis incidence than untreated check but only at earlier infection stage (2 and 4 DAI). Programs 10 and 12 showed the worst botrytis control with the highest incidence across 2, 4, and 6 DAI. Rust results suggested the best control achieved by programs 12, 13, and 14 with the worst control from programs 2, 6, and 7. Overall, results also indicated some selective control effect from different programs. Program 12 performed the worst for botrytis control but was one of the best for rust control, and program 2 and 4 had the best botrytis control yet performed among the worst for rust control.

Table 2. ANOVA mean separation table for comparison of 14 programs for control of rust, or gray mold on raspberry at 2, 4 and 6 days after incubation.

Pest Name					RUST	RUST	Botrytis blight	Botrytis blight	Botrytis
Crop Name					Red raspberry	Red raspberry	Red raspberry	Red raspberry	Red raspberry
Description							2D after incub>	4D after incub>	6D after incub>
Rating Type					incidence	severity	incidence	incidence	incidence
Rating Unit					%	%	%	%	%
Trt No.	Treatment Name	Rate	Rate Unit	Appl Code	1	2	3	4	5
1	Untreated Check				61.3ab	0.6abc	4.2ab	72.5a	93.3ab
2	CAPTAN	2	lb/a	A	77.5a	0.9ab	1.7ab	43.3cd	78.3bc
	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					
	SB-56 (NIS)	6	fl oz/100 gal	ABCDE					
3	CAPTAN	2.5	lb/a	A	57.5b	0.6abc	1.7ab	40.8de	81.7abc
	SWITCH	14	oz/a	A					
	CAPTAN	2.5	lb/a	B					
	PRISTINE	23	oz/a	B					
	CAPTAN	2.5	lb/a	C					
	Meteor	32	fl 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					
	SB-56 (NIS)	6	fl oz/100 gal	ABCDE					
4	CAPTAN	2.5	lb/a	A	68.8ab	1.1a	4.2ab	38.3de	78.3bc
	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					
	SB-56 (NIS)	6	fl oz/100 gal	ABCD					
5	CAPTAN	2.5	lb/a	A	58.8ab	0.5abc	1.7ab	47.5cd	87.5abc
	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					
	SB-56 (NIS)	6	fl oz/100 gal	ABCD					
6	CAPTAN	1.5	lb/a	A	77.5a	1.1a	1.7ab	58.3a-d	86.7abc
	CAPTAN	1.5	lb/a	B					
	CAPTAN	1.5	lb/a	C					
	CAPTAN	1.5	lb/a	E					
	SB-56 (NIS)	6	fl oz/100 gal	ABCD					
7	CAPTAN	1.25	lb/a	A	72.5ab	1.2a	3.3ab	52.5a-d	87.5abc
	SWITCH	14	oz/a	A					

	CAPTAN	1.25lb/a	B					
	PRISTINE	23oz/a	B					
	CAPTAN	2.5lb/a	C					
	Kenja	15.5fl oz/a	C					
	CAPTAN	1.25lb/a	D					
	SWITCH	14oz/a	D					
	PhD	6.2oz/a	E					
	Luna Tranquility	16fl oz/a	E					
	SB-56 (NIS)	6fl oz/100 gal	ABCDE					
8	CAPTAN	2lb/a	A	55.0b	0.7ab	0.0b	38.3de	89.2ab
	SWITCH	11.2oz/a	A					
	CAPTAN	2lb/a	B					
	PRISTINE	20oz/a	B					
	CAPTAN	2.5lb/a	C					
	Meteor	32fl oz/a	C					
	CAPTAN	2lb/a	D					
	SWITCH	11.2oz/a	D					
	CAPTAN	2lb/a	E					
	PhD	6.2oz/a	E					
	SB-56 (NIS)	6fl oz/100 gal	ABCDE					
9	Kenja	15.5fl oz/a	ACD	53.8b	0.4bcd	0.0b	22.5e	70.8c
	CAPTAN	2lb/a	ABCDE					
	PhD	6.2oz/a	B					
	Meteor	32fl oz/a	E					
	SB-56 (NIS)	6fl oz/100 gal	ABCDE					
10	ELEVATE	1.5lb/a	A	61.3ab	0.6abc	7.5a	62.5abc	93.3ab
	Meteor	32fl oz/a	B					
	ELEVATE	1.5lb/a	C					
	PRISTINE	20oz/a	D					
	ELEVATE	1.5lb/a	E					
	SB-56 (NIS)	6fl oz/100 gal	ABCDE					
11	Switch	14oz/a	A	26.3c	0.2cde	2.5ab	45.0cd	80.8abc
	Pristine	23oz/a	B					
	PhD	6.2oz/a	C					
	Switch	14oz/a	D					
	Pristine	23oz/a	E					
12	Fontelis	14fl oz/a	A	5.0d	0.1def	5.8ab	71.7ab	96.7a
	Switch	14oz/a	B					
	Fontelis	14fl oz/a	C					
	PhD	6.2oz/a	D					
	Fontelis	14fl oz/a	E					
13	Fontelis	24fl oz/a	A	2.5d	0.0ef	1.7ab	58.3a-d	92.5ab
	Switch	14oz/a	B					
	Fontelis	24fl oz/a	C					
	PhD	6.2oz/a	D					
	Fontelis	24fl oz/a	E					
14	Fontelis	24fl oz/a	A	0.0d	0.0f	0.8b	51.7bcd	90.0ab
	Fontelis	24fl oz/a	B					
	Fontelis	24fl oz/a	C					
	Fontelis	24fl oz/a	D					
	Fontelis	24fl oz/a	E					

Figure 7. Comparison of 14 fungicidal programs for control of botrytis blight in raspberry-incidence after 2, 4, and 6 days' of incubation.

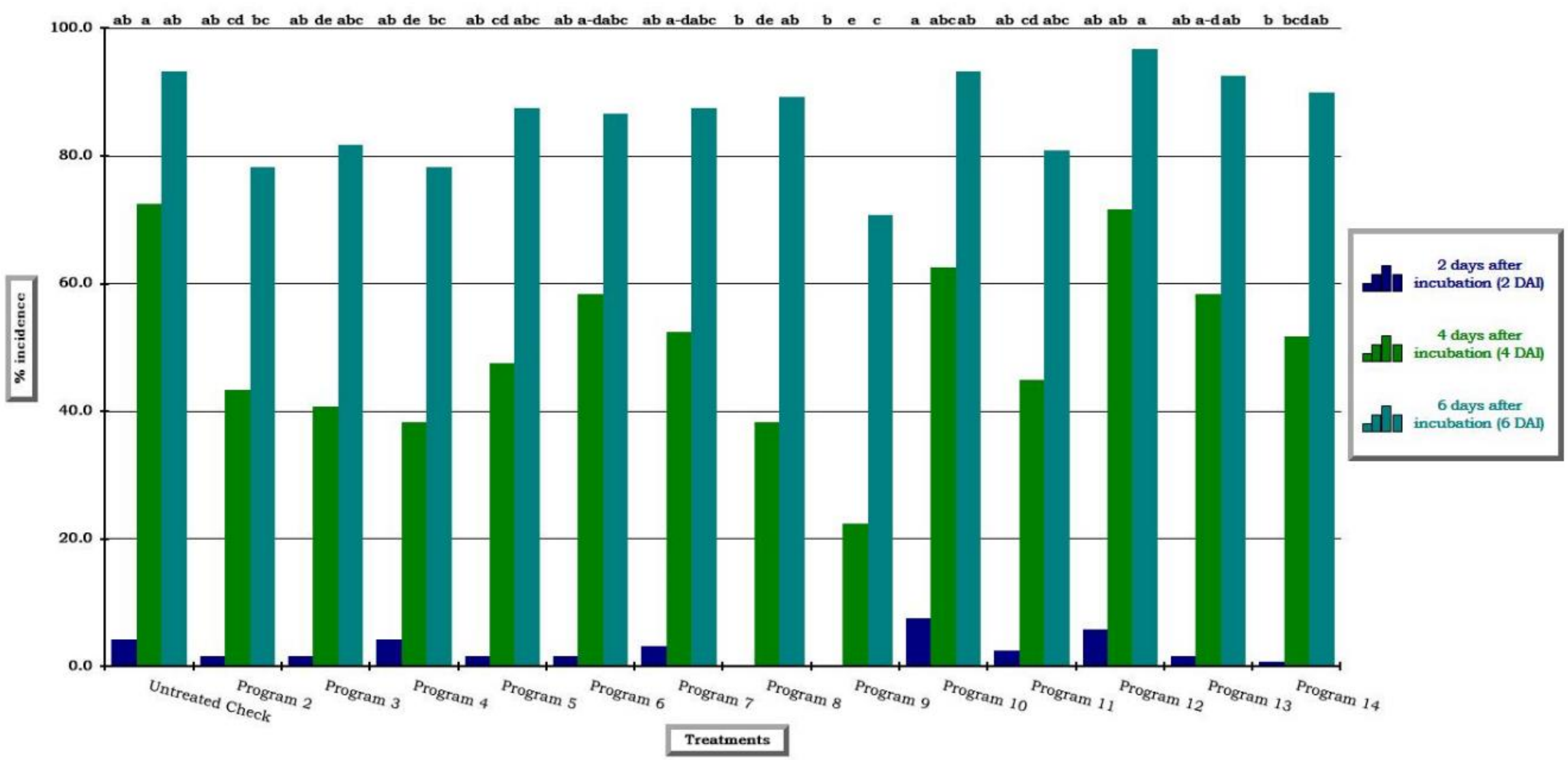


Figure 8. Comparison of 14 fungicidal programs for control of yellow rust in raspberry-incidence and severity data.

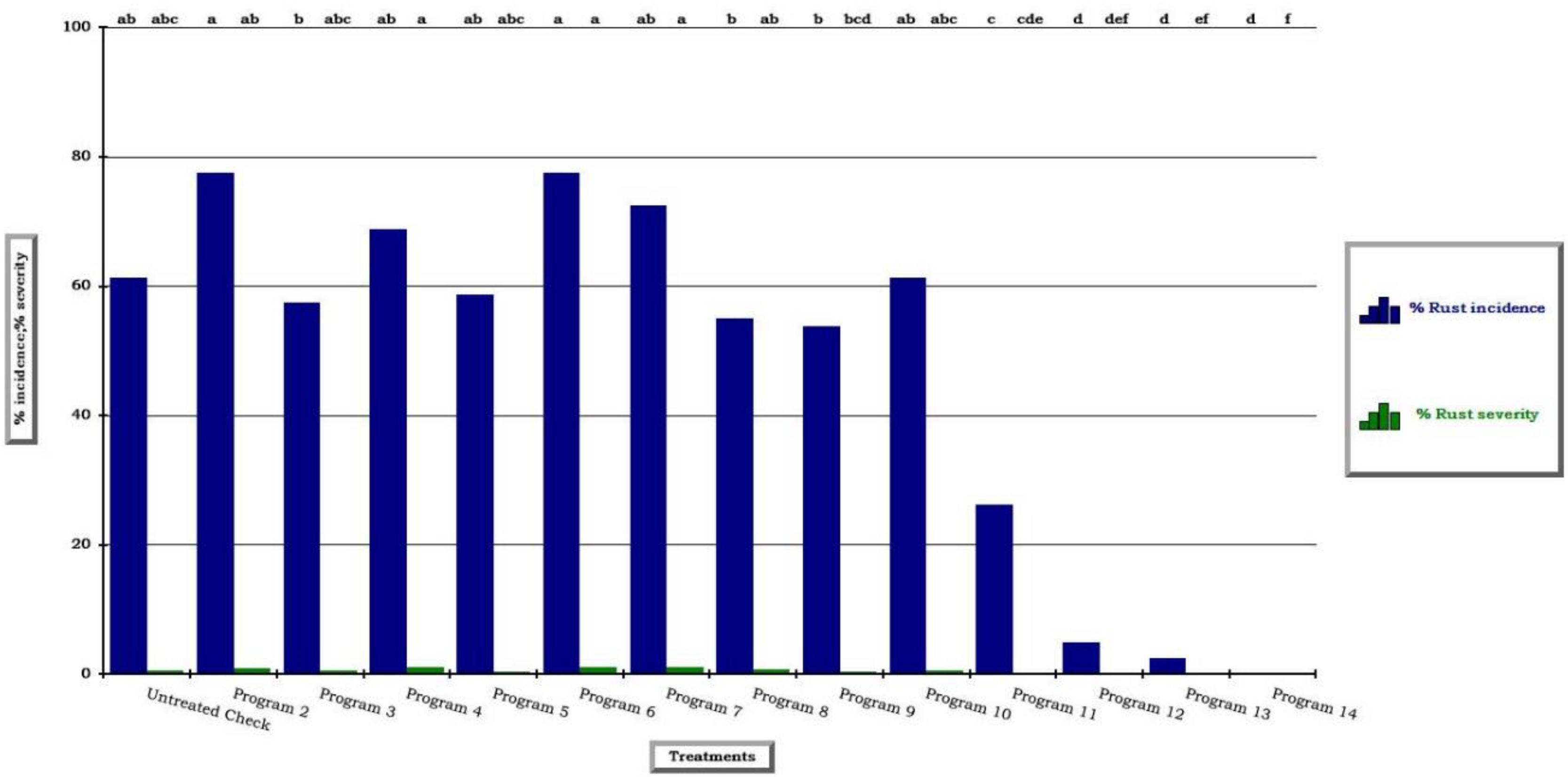


Photo 1. Application using over the row sprayer on raspberry.

Photo 2. Harvesting raspberry for incubation on July 12, 2018.

Photo 3. Representative photos of raspberry in incubator (left; July 13, 2018) and 4 days after incubation (right; July 17, 2018)

Photo 4. Evaluation of yellow rust on August 3, 2018. Left: Evaluation by Tom and Alan. Right: Yellow rust symptom on raspberry leaf. Photos were taken on August 3, 2018.

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. Tobin Peever-WSU, Tom Walters-Walters Ag Research

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 recently awarded Specialty Crop Block Grant.

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 that 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 2018 trial, but with some improvements based on 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 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 on raspberry.

Justification and Background: This project will generate conclusions on which fungicidal products are effective for controlling botrytis and which products are not. Dr. Peever 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 unusually 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 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 product 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 2019 that are similar to the trials done in 2018. 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 three trials in 2018, 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 third trial would be conducted in blackberry with similar purpose. The reason we are targeting blackberry is because it appears to have a higher likelihood of developing botrytis. Conducting this third trial in blackberry is an insurance policy to increase the likelihood that we would generate useful data for raspberry growers. 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 2019 trial. Scientists involved in 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, would make a presentation at the Small Fruit Conference, and would work closely with WSU extension, crop advisors, and members of the raspberry industry to make sure the outcome of the research was well known through the grower community.

Budget:	**2019**	**2020**	**2019**
Salaries	8,000	9,000	10,000
Operations	3,000	3,000	3,000
Travel	1,500	1,500	1,500
Benefits	1,500	1,750	2,000
Total	$14,000	$15,250	$16,500

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.

Related Information.

Results from 2018. Due to weather conditions that were highly unfavorable for botrytis, there was virtually no botrytis in the raspberry in 2017. Fruit was collected from each plot and held in an incubation chamber and evaluated for disease at 2, 4 and 6 days after harvest. Almost all fruit had botrytis spores and showed disease symptoms in between 2 and 6 days after harvest. This indicates that despite conditions not suitable for disese development in the field, botrytis is commonly and widely present.

"Fortunately", there was a yellow rust outbreak near the end of the trial that allowed for an evaluation against that disease. Both Fontelis and Oso provided significant control of the disease (yellow rust). In the blackberry trial, Kenja, Fontelis, and Luna Tranquility provided control of botrytis that was documented with resistance to boscalid. These results show that these FRAC Group 7 fungicides can control botrytis that has resistance to boscalid. Overall, these field results confirmed what was found in Tobin Peevers laboratory studies. These are highly important findings for the Washington red raspberry industry. However, it is very, very important that this industry identify new modes of action that have activity against botrytis as soon as possible, as the likelihood that resistance within the FRAC Group 7 fungicides is very high. If fungal resistance to FRAC Group 7 fungicides happens, it could result in some catastrophic losses to the raspberry industry in a high disease pressure year.

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

Project Title: Control of Cane Blight in Red Raspberries

PI: Alan Schreiber
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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: None

Description: Cane blight, *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.

Justification and Background: The Wake (Wakefield, Wakehaven)Driscoll's cultivars and Cheminus 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 several 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, the primary means of controlling the disease is expected to be fungicides. 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.) 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. 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.

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

Objectives: Develop fungicide use patterns for control of cane blight on raspberry including rate, timing and number of applications.

Procedures: A fungicide efficacy trial would be set up on a susceptible variety, 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 by product and some treatments will be a program approach that might resemble what a grower might use. The products in the trial have not been selected. The program treatments have not been selected. 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.

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 (drip)

At this time, we plan to make four applications based on what is the current accepted practice for cane blight management. The applications would be timed to coincide with botrytis applications. 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. Quilt Xcel contains propaconazole. All treatments will be rated for phytotoxicity with specific attention given to Quilt Xcel.

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.

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 to 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	7,000	7,000
Operations	1,000	1,000	1,000
Travel	500	500	500
Contract Research	4,000	4,000	4,000
Contract Research	4,000	4,000	4,000
Benefits	1,250	1,250	1,250
Total	**$17,750**	$**17,750**	**$17,750**

The funds for Contract Research are for Tom Walters for chemical application 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.

Washington Red Raspberry Commission
Progress Report for 2018 Projects

Project No: 3061-4303

Title: *Botrytis* infection and fruit rot development on red raspberry

Personnel: Tobin Peever and Olga Kozhar, Department of Plant Pathology, Washington State University

Reporting Period: January 2018 to November 2018

Accomplishments: The second year of an experiment to determine the effect of season-long fungicide sprays on the dynamics of *Botrytis* colonization of red raspberry plants at different stages of development was performed during 2018 production season. The experiment was conducted in four commercial fields of cultivar Wakefield in NW Washington. DNA fingerprinting analysis of *Botrytis* infection of flowers vs fruit was conducted as an alternate test of the hypothesis that fruit infection results exclusively from flower infection.

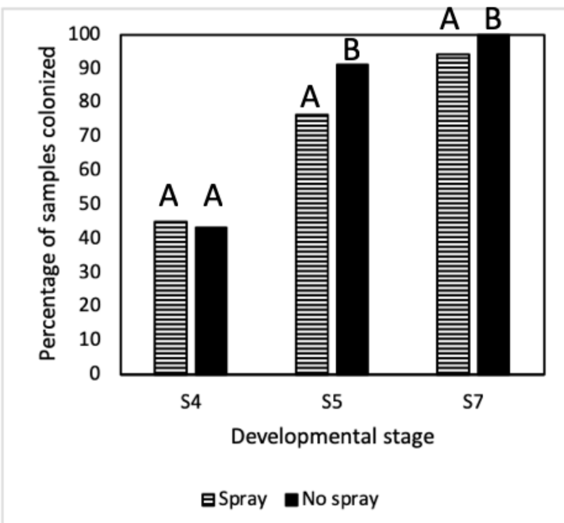

Fig. 1. Effect of fungicide applications on *B. cinerea* colonization of red raspberry flowers and fruit in 2017 and 2018

Results. Over two seasons of the experiment, colonization incidence of *B. cinerea* in early stages of flower/fruit development consistently averaged at 40% among total 800 samples of raspberry flowers (stage S4 (Fig. 1). Colonization incidence increased significantly with fruit development and maturation in all four sampled fields over two seasons. There was no difference in *B. cinerea* colonization at stage S4 between flowers sampled from sprayed by fungicides fields and fields not sprayed with fungicides (Fig.1).

B. cinerea colonization incidence of green fruit (stage S5) and ripe fruit (stage S7) was statistically significantly different between samples from sprayed and non-sprayed fields over two seasons but rates of colonization of sprayed fruit were still greater than 70% (Fig. 1). In non-sprayed fields, colonization incidence reached 100% at S5 and S7, and in sprayed fields 74% and 94% at S5 and S7, respectively (Fig. 1). Among fertilized flowers (S4) that tested positive for *B. cinerea* colonization, the carpel (female part) was the most frequently colonized organ (Fig. 2). There was no significant difference in organ colonization between S4 samples obtained from fields sprayed with fungicides and fields non-sprayed with fungicides (Fig. 2).

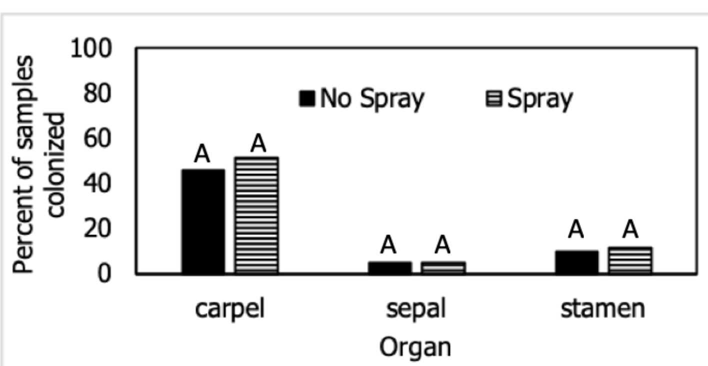

Fig. 2. Colonization of flower organs by *B. cinerea*

Among ripe fruit (S7) that tested positive for *B. cinerea* colonization, the drupelet, stamen and sepal were the most frequently colonized organs (Fig. 3a, 3b). Among samples from Field 1, 90% and 100% of ripe fruit were colonized in drupelet from sprayed and non-sprayed plots, respectively (Fig. 3a). However, among samples from Field 2, 29% and 100% of ripe fruit were colonized in drupelet from sprayed and non-sprayed plots, respectively (Fig 3b). The percentage of other organs colonized was also significantly lower in the sprayed plots of Field 2 compared to the non-sprayed plot from this field (Figs 3a, 3b).

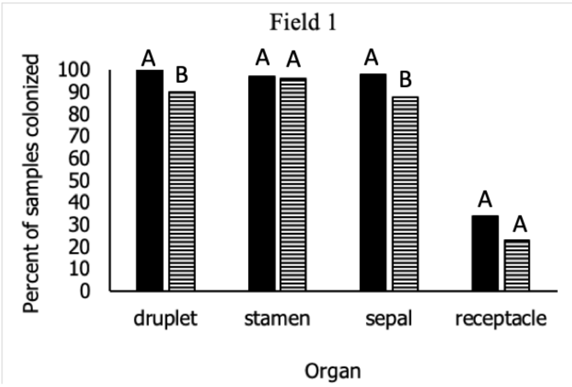

Fig. 3a. Colonization of red raspberry ripe fruit by *B. cinerea*

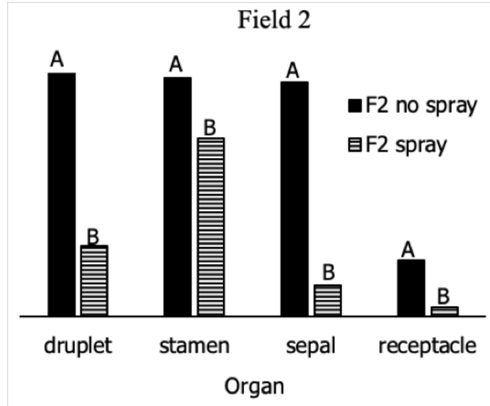

Fig. 3b. Colonization of red raspberry ripe fruit by *B. cinerea*

One possible explanation for the difference in organ colonization at the ripe fruit stage between these fields is that Field 1 had much denser canopy compared to Field 2 that may have interfered with the effective coverage of fruit by fungicides that being applied to those fields. The data obtained during two years of field experiments showed that fungicide applications did not decrease *B. cinerea* colonization of flowers, but did decrease colonization of ripe fruit.

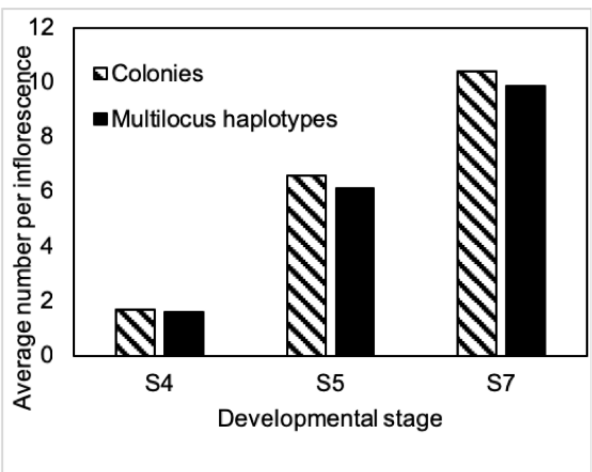

Fig. 4. Average number of *B. cinerea* colonies and DNA fingerprints per red raspberry inflorescence

DNA fingerprinting of 400 *B. cinerea* isolates sampled from three developmental stages of 20 inflorescences in 2017 showed that the number of *B. cinerea* colonies and genetic diversity increased as fruit matured (Fig.4) indicating that new pathogen isolates colonized flowers and fruit throughout the growing season. Genetic diversity also increased with 86% of isolates at stage S7 represented by a different DNA fingerprint. Among 368 fingerprints detected, only two were shared between stages S5 and S7 in the same inflorescence and no fingerprints were shared between flowers and other stages (Fig. 5). These results indicate independent infection events occurring as fruit developed and do not support the floral infection hypothesis (ie. that all gray mold infection occurs through flowers).

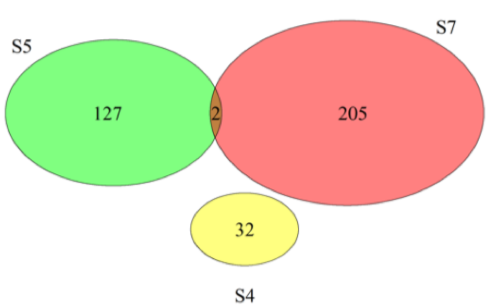

Fig. 5. Venn Diagram of the number of different fingerprints sampled from each of three stages of 20 inflorescences. Overlapping area shows the number of shared fingerprints between stages sampled from the same inflorescence

Publications O. Kozhar and T. Peever. 2018. How does *Botrytis cinerea* infect red raspberry? Phytopathology, 11: 1287-1298.

2019 WASHINGTON RED RASPBERRY COMMISSION
RESEARCH PROPOSAL

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

Project Title: Biology and control of *Botrytis* fruit rot of red raspberry in the Pacific Northwest

PIs: Tobin L. Peever and Olga Kozhar
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City/State/Zip: Pullman, WA 99164-6430

Cooperators: Enfield Farms

Year Initiated 2019 **Current Year** 2019 **Terminating Year** 2019

Total Project Request: **Year 1 $26175**

Other funding sources:

Agency Name: Washington State Department of Agriculture Specialty Crop Block Grant
Amt. Requested/Awarded: $207709 start date Nov 1, 2018

Description

The objective of this project is to improve management of *Botrytis* fruit rot of raspberry. Despite intensive fungicide application programs aimed at control of this disease in the US PNW, it is estimated that fruit losses and downgrades in fruit quality exceed 25% of the harvestable fruit due to incomplete disease control. Additionally, fungicides used for control are losing effectiveness due to the development of resistance, further limiting management options. Applications of fungicides in the PNW are currently timed on a calendar basis starting at 5-10% bloom and continuing throughout the growing season. Fungicide sprays are not applied according to infection risk largely because the life cycle of the pathogen and the infection process are so poorly understood. Specific **outcomes** of this project will include the development of a high-throughput method for monitoring of *B. cinerea* fungicide resistance in individual fields, and determining a threshold level of *Botrytis* colonization of raspberry fruit that can be tolerated in field without affecting raspberry fruit quality.

Justification and Background

Northwestern (NW) Washington is the largest producer of processed red raspberry in the United States (USDA-NASS), and *Botrytis* fruit rot, or gray mold, is a major threat to the industry. Chemical control remains the primary strategy to control gray mold affecting red raspberry and other small fruits. Fungicide applications are scheduled on a calendar basis with growers routinely starting sprays at 5-10% bloom and continuing every 7-10 days throughout the season (Pscheidt & Ocamb 2017). The biological assumption behind these spray programs is that Botrytis primarily infects raspberry flowers, stays dormant or latent in developing fruit, and emerges to cause gray mold as fruit ripens and under appropriate environmental conditions

(Dashwood & Fox 1988, Jarvis 1962). Despite such intensive fungicide application schedule, raspberry growers in NW Washington experience 20-25% annual yield losses of crop in high disease pressure years. In addition to inefficient disease management, current fungicide application programs have led to the development of extensive fungicide resistance problems with four (boscalid, fenhexamid, cyprodinil, and iprodione) of five fungicides registered to control gray mold in Washington. Previous research in our laboratory showed that resistance profiles of Botrytis pathogen populations differ significantly among fields, even between fields grown side-by-side (Peever, *unpublished*). Most fields do not have high frequencies of resistance to all four fungicides which opens the door for customized spray programs based on knowledge of the resistance profile in each field. In order to provide individual growers with relevant information on the resistance profile in each of their fields, individual fields need to be screened for resistance to each of these fungicides in a more cost-effective manner than previously. The mycelial growth assays we have used to date to estimate fungicide sensitivity of Botrytis in our laboratories are labor, time and cost-intensive. WA growers have consistently expressed a need for a more rapid and cost-effective screening method for individual fields at lower cost. We propose to develop a high-throughput method for monitoring fungicide resistance based on fungal growth which will provide growers with real-time information about fungicide resistance profiles in individual fields. This information is critical for the development of effective disease management strategies, slowing the development of fungicide resistance by the gray mold pathogen and preserving the existing arsenal of disease control products.

In order to assess fungal contamination of harvested raspberry fruit, WA raspberry growers currently use the Howard mold counting technique (Howard 1911). Howard mold counting involves enumeration of mycelial fragments in a known quantity of macerated raspberry fruit tissue under the microscope using a special counting chamber. This technique requires substantial expertise in visual identification of fungal mycelium in processed fruit. Research in our laboratory has shown that in addition to *B. cinerea*, raspberry fruit contains several other fungi in high quantities such as *Cladosporium* spp., *Phomopsis* spp., *Trichoderma* spp., and *Alternaria* spp. among others (O. Kozhar and T. Peever, *unpublished*). Because mycelium of all of these fungi look identical under the microscope, it is not possible to separate *B. cinerea* mycelium from that of other fungi. Therefore, it remains impossible to quantify *B. cinerea* colonization fruit and its effect on fruit quality using this technique. Additional techniques that are specific for *B. cinerea* and also quantitative are required to relate *B. cinerea* colonization of fruit in the field to fruit quality in the processing facility. Techniques such as quantitative isolation on Botrytis-specific agar media and quantitative PCR are needed to compare to the Howard counting method to determine the particular effect of *B. cinerea* on fruit quality.

Relationship to WRRC Research Priority(s)

This research project addresses one of the #1 priorities of the WRRC namely “*Fruit rot including pre harvest, post harvest, and/or shelf life*”.

Objectives:

1) Quantitatively relate *B. cinerea* colonization of fruit in the field to fungal contamination during processing

2) Develop a high-throughput method of monitoring of fungicide resistance to provide real-time, site-specific information to growers

Procedures

1) Quantitatively relate *B. cinerea* colonization of fruit in the field to fungal contamination during processing

In order to establish a threshold level of *B. cinerea* fruit colonization resulting in degradation of processing raspberry fruit quality, ripe raspberry fruit will be sampled from two raspberry processing facilities. Level of Botrytis colonizing the fruit will be estimated by culturing a known quantity of macerated raspberry fruit on a Botrytis-specific medium, and by using quantitative PCR. We will attempt to target the same samples that are being processed using the Howard mold count method which will allow a direct comparison between these methods and provide a quantitative estimate of the amount of *B. cinerea* mycelium present in processed raspberry in fruit tissue. This data will be related to estimates of Botrytis colonization in the field and used to establish a threshold level of *B. cinerea* mycelium in fruit related to decreases in fruit quality.

2) Develop a high-throughput method of monitoring of fungicide resistance to provide real-time, site-specific information to growers

In order to develop a high-throughput method for monitoring fungicide resistance based on fungal growth, three different assays will be evaluated. These include the microtiter method using spectrophotometry (Stammler & Spealman 2006); a loop-mediated isothermal amplification (LAMP) method (Duan et al. 2018), and a high resolution melting (HRM) analysis method (Samaras et al., 2016). We will be particularly interested in determining which of the evaluated methods will give the best results based on its specificity, time needed to perform analysis, and estimated cost of the assay per field comparing to *in vitro* plate assay that has been routinely used in our lab.

Anticipated Benefits and Information Transfer

This research addresses a critical need in the raspberry industry for improvement of Botrytis gray mold disease management in WA. Levels of Botrytis fungicide resistance differ among fields, including the fields located in closed proximity to each other. It makes it impossible to give general recommendations on fungicide use for the whole region. In order to determine what fungicides will be effective on particular field, a grower needs to know whether the resistance present on fields and to what specific chemistries of fungicides. The development of a high-throughput method for resistance detection in individual fields will give access to such data on a more cost-effective manner. Relating Botrytis colonization of raspberry fruit in the field to fungal contamination in processing facilities will allow us to determine the timing and number of fungicide applications that effectively limit internal colonization of fruit in raspberry fields and keep colonization levels below the threshold that results in a reduction in quality. Overall, improved fungicide applications programs will allow reductions in overall fungicide use, reduced selection for fungicide resistance and decreased fungicide residues in fruit.

References

Dashwood, E.P. and R.A. Fox. 1988. Infection of flowers and fruits of red raspberry by *Botrytis cinerea*. Plant Pathology 37: 423-430.

Duan, Y.B., Yang, Y., Li, M., X., Li, T., Fraaije, B.A., and Zhou, M.G.. 2018. Development and application of a simple, rapid and sensitive method for detecting moderately carbendazim-resistant isolates in *Botrytis cinerea*. Annals of applied biology. ISSN 0003-4746

Howard, B. J. 1911. Tomato ketchup under the microscope with practical suggestions to insure a cleanly product. U. S. Dept. Agr., Bureau of Chemistry, Circ. 68.

Jarvis, W.R. 1962. The infection of strawberry and raspberry fruits by Botrytis cinerea Fr. Ann. Appl. Biol. 50:569-575.

Pscheidt, J.W., and Ocamb, C.M., senior editors. 2017. Pacific Northwest Plant Disease Management Handbook [online]. Corvallis, OR: Oregon State University. http://pnwhandbooks.org/plantdisease.

Samaras, A., Madesis, P., and Karaoglanidis, G. 2016. Detection of sdhB Gene Mutations in SDHI-Resistant Isolates of *Botrytis cinerea* Using High Resolution Melting (HRM) Analysis. Frontiers in Microbiology.

Stammler, G., and Speakman, J. 2006. Microtiter method to test the sensitivity of *Botrytis cinerea* to boscalid. Journal of Phytopathology. 7-8: 508-510.

Budget

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

	2019
Salaries[1/]	8465
Time-Slip[2/]	5760
Operations (goods & services)[3/]	7000
Travel[4/]	3768
Meetings	0
Other	0
Equipment	0
Benefits[5/]	1182
Total	**26175**

Budget Justification

[1/] 0.25 FTE Salary for PhD student Olga Kozhar. Remainder paid by WSDA-SCBG grant
[2/] Time-slip employees to help with field sampling, fungal culturing, laboratory assays

[3/]Lab supplies (petri dishes, agar, chemicals) = $3500 and PCR, sequencing = $3500
[4/] Trip to field sites from Pullman to Lynden, WA is ~800 miles total, 4 trips per project from May to July equals 4 x 800 miles x $0.535/mile = ~ $1712, accommodation total for 4 trips = $800. Total for sampling trips = ~$2512. Travel for presentation of results to 2 grower meetings ~ 2*800 miles*$ 0.535 = ~$856, accommodation 2 nights per trip, 4 nights total, 4*100=$400, total ~$1256
[5/] Benefits at 12.8% for PhD student and 1.6% for student time-slip

*Budget approved by Kimberly Dudley 12/4/2018 in WSU CAHNRS Johnson Hall Business Center

Current & Pending Support

Tobin L. Peever 2018

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:				
Peever & Kozhar	WSDA-SCBG	207709	11/1/18 to 10/31/21	20	Novel Disease Control Strategies for WA Berry Growers
Peever	WA Raspberry	23808	01/01/18 to 12/31/19	10	Biology and control of *Botrytis* fruit rot of red raspberry in the Pacific Northwest
Harteveld & Peever	WA Blueberry	15474	01/01/18 to 06/30/19	10	Mummy Berry of Blueberry: Updates, Prediction Model Validation and Fungicide Resistance
Peever	WSCPR	16721	01/01/18 to 06/30/19	10	Biology and control of *Botrytis* fruit rot of red raspberry in the Pacific Northwest
	Pending:				
Peever	WA Raspberry	26175	01/01/19 to 12/31/19	15	Biology and control of *Botrytis* fruit rot of red raspberry in the Pacific Northwest (this proposal)
Peever	WA Blueberry	27759	01/01/19 to 12/31/19	15	Mummy Berry Updates, Validation of Initial Inoculum Prediction Model and Forsythia as a Prediction Tool

Washington Red Raspberry Commission
Terminal Report for 2018 Project

Title: **Characterization of pathogens that cause blossom blight, cane blight, and yellow rust of red raspberry.**

Personnel: Virginia Stockwell with Gayle McGhee and Brenda Shaffer. USDA-ARS HCRU, Corvallis, Oregon

Reporting Period: The proposed duration of the project was one year from 2/14/2018 to 2/14/2019.

Accomplishments and results:

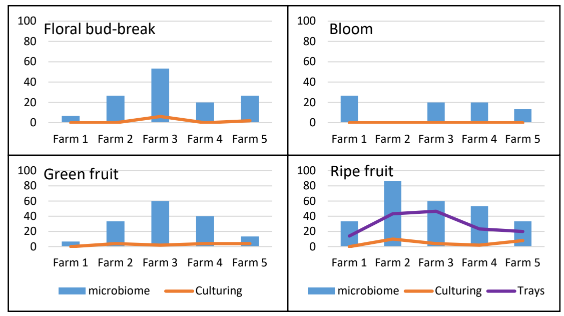
- Cane blight was sporadic in the fields that we visited, but we did find the disease in three Wakefield and two Wakehaven fields. We isolated and confirmed identity of *Paraconiothyrium fuckelii,* the causal agent of cane blight. We are conducting pathogenicity tests on raspberry maintained in a greenhouse. The primary method for management of cane blight is sanitation, the complete removal of spent floricanes and removal of damaged primocanes. Minimizing catcher-plate damage also is an important for the management of cane blight. This winter, we will test the isolates for sensitivity to fungicides, especially the QoIs (strobilurins) and thiophanate-methyl (Topsin) which were reported to be effective for cane blight management in other countries. Although fungicides cannot be applied during harvest, an effective fungicide applied post-harvest may reduce the incidence of the disease.
- Yellow rust was not observed on raspberry this year during our field visit.
- The blossom blight disease was observed primarily in Wakefield. This disease has been sporadic. We isolated a slow-growing fungus consistently from symptomatic fruit that were killed post-bloom. We isolated DNA from the fungus, using PCR we amplified a gene called ITS used to identify fungi, and sequenced the amplicon. We compared the sequence to global databases of sequences and the gene sequence indicated that the fungus may be a new species of the genera *Monilinia*. *Monilinia* is a diverse group of well-known plant pathogens, such as mummy berry, but the raspberry pathogen is very different than the mummy berry pathogen. We recently repeated the comparison of the sequence to the database and obtained a 100% match with sequence from a fungus named *Rhizoctonia rubi*.

  Rhizoctonia rubi is described in a publication by Dr. Wilbert McKeen in 1958 [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]. Dr. McKeen isolated the fungus from diseased loganberry and thimbleberry in Vancouver Island, BC. The description of the fungus agrees with the characteristics of the fungus from diseased raspberry. The symptoms of the disease shown in the paper are similar to the symptoms that we have observed on red raspberry and blackberry. He was able to show that he could repeat the symptoms by inoculating flowers with the fungus.

  From reading his research paper, we are fairly certain that the 'blossom blight' that we observed is the disease 'dry-berry.' Given our molecular evidence and the morphology of the fungus, we suspect that the fungus is not a "*Rhizoctonia*", but rather is a new species of *Monilinia*. Dr. McKeen deposited samples of his fungus in two fungal culture collections. The CBS in the Netherlands reported that his cultures are still viable. We have obtained import permits and once all of the associated paperwork clears, we will purchase McKeen's pathogen from the Netherlands collection. This will allow us to do head-to-head taxonomy and pathogenicity comparisons of his isolate and our isolates of the pathogen of raspberry.

- The red raspberry microbiome project was initiated in 2016. During that year, we collected tissues [floral buds, flowers, green fruit and ripe red raspberries] from five locations and cultured bacteria, yeasts, and fungi from the tissues. We also freeze-dried replicate samples of the tissues. In 2017, we extracted DNA, and used PCR and sequencing technologies to detect and identify the bacteria present in each of the tissue samples, a total of 384 samples. This year, we completed the sequencing to detect and identify fungi and yeasts in the floral buds, flowers, green fruit and ripe red raspberries from the five locations.

  We are currently working on analysis of the data to examine which fungi, yeasts, or bacteria are present during different developmental stages of raspberry and potential interactions between different microorganisms. We also are comparing the results of the traditional culturing of microorganisms with the results from the molecular identification of the microorganisms in the tissues. For example, the charts to the right illustrate the increased sensitivity of the microbiome method to detect *Botrytis* in tissues at different developmental stages compared to culturing on agar media. At the ripe fruit stage, the percent of fruit with *Botrytis* is similar comparing the microbiome data and the incidence of gray mold on fruit incubated at room temperature. Direct culturing detected a lower percentage of fruit with *Botrytis*.



  In addition to detecting *Botrytis* at all stages of development from microbiome data, we detected the dry-berry pathogen at each of the farms in early to full bloom. We also detected *Phyllosticta, Paraconiothyrium, Alternaria, Cladosporium*, and *Didymella* at various time points. We did not detect other pathogenic genera such as *Septoria*, *Phytophthora*, *Verticillium*, or the yellow rust fungus on the aerial tissues. Among notable bacteria, we detected *Erwinia* at bloom and green fruit, and *Bacillus* and pseudomonads at each stage of development.

  Genera of *Botrytis* biocontrol agents, such as *Trichoderma* or *Streptomycetes* were not detected on any of the samples. Yeasts identified as *Aureobasidium pullulans*, the same species as the yeasts in the product Botector that is used for biocontrol of *Botrytis*, were detected on about 30% of the samples.

  The organisms that were detected on every tissue sample were two yeast genera, *Bullera* and *Bannoa*. *Bannoa* spp. are associated with dead leaves and do not ferment sugars. Some members of *Bullera* spp. are considered mycoparasites and may produce compounds that inhibit the growth of other fungi. The function of these prominent yeasts in the microbiome of developing fruit tissues of red raspberry is unknown.

Publications: No publications.

2019 Washington Red Raspberry Commission Research Proposal

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

Project Title: Refining the microbiome of developing red raspberry fruit tissues.

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

Year Initiated 2019 Current Year 2019 Terminating Year 2020
Total Project Request: Year 1 $ 8,350 Year 2 $ 14,302

Other funding sources: None at this time. My USDA ARS base funds will be used to cover a portion of the expenses.

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. This will be done with a traditional culturing approach and also a nonculture-based molecular method, where we isolate DNA and sequence the DNA to detect, identify, and quantify the microorganisms in each tissue—this is called a microbiome study. The second objective is to compare the dry-berry pathogen of *Rubus* described by Dr. McKeen in 1959 (4) and named *Rhizoctonia rubi* with the isolates we obtained from killed immature raspberry fruits (we called it blossom blight) and identified as a *Monilinia* spp. Disease management approaches would differ if the pathogen is a *Rhizoctonia* or a *Monilinia*.

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 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 is not known if the early detection of *Botrytis* was due to the unusual climatic conditions in 2016 and early season or if *Botrytis* often is active in fields at bud break. Repeating the microbiome study will add robustness and rigor to the findings. If *Botrytis* is again found to be active in fields at

bud break in 2019, then our research group will pursue ideas on how to improve management of overwintering inoculum sources of the pathogen, which hopefully will reduce disease pressure later in the season.

This research complements the surveys and characterization of diseases of small fruits by Dr. Sabaratnam's group in Abbotsford BC. This project also complements the research by Dr. Peever's group at Washington State University that focused on colonization of raspberry by *Botrytis*.

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, such as the dry-berry pathogen, and monitor when it is 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"

Objectives:

1) Define the microbiome of raspberry fruit from bud break to harvest.
2) Characterize and compare the 'blossom blight' pathogen from raspberry to the dry-berry pathogen from other *Rubus* spp.

Procedures:
The anticipated length of the project is two years. In the first year (2019), we will sample raspberry tissues for the microbiome project. Microorganisms would be cultured from the tissues and the molecular characterization of the microbiome would be done during the second year (2020). In the first year, we also will sample 'blossom blight/dry-berry' diseased raspberry tissues to obtain fresh isolates for characterization of the pathogen.

1) Define the microbiome of raspberry fruit from bud break to harvest. Tissues will be sampled from four commercial raspberry fields (two Meeker and two Wakefield) in the Lynden area that were sampled in 2016. Floral/fruit samples will be collected at four time points: 1) as floral buds emerge, 2) bloom, 3) green fruit, and 4) ripe fruit. Each field will have five replicate blocks of labeled plants for sampling. Twenty samples will be collected from each replicate block at each sample time. At harvest, an additional 50 fruits will be collected from each block and incubated in moist chambers at room temperature to determine gray mold incidence. This project likely will require five trips to Lynden to sample fields from floral bud emergence in Meeker to Wakefield harvest.

Isolation of microorganisms. Suspensions of crushed tissues will be spread onto potato dextrose agar and tryptic soy agar for isolation of fungi, yeast, and bacteria. Colonies will be enumerated and identified by morphology and molecular methods. Select individual isolates will be stored at -80°C for future studies.

Molecular characterization of microorganisms (microbiome). Samples will be frozen at -80°C, freeze dried, and then stored at -80°C until we extract total DNA from each of the tissues. In 2020, 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.

2) Characterize and compare the 'blossom blight' pathogen from raspberry to the dry-berry pathogen from other *Rubus* spp. We will sample 'blossom blight/dry-berry' diseased raspberry tissues in Lynden to obtain fresh isolates. We will obtain the dry-berry pathogen (*R. rubi*) deposited by Dr. McKeen into a Culture Collection in the Netherlands (4). They have confirmed that the isolate is viable. We will sequence select genes for molecular comparisons and compare various morphological characteristics and pathogenicity.

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 will provide information on the effect of weather on the microbiome and pathogen emergence. The dry-berry study will clarify the pathogen identity and potential management approaches. 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	2020 (estimated)
Salaries[1/]	$ 3,960	$ 4,320
Operations (goods & services) [2/]	$ 3,500	$ 9,000
Travel[3/]	$ 500	$ 550
Meetings	$ 0	$ 0
Other	$ 0	$ 0
Equipment	$ 0	$ 0
Benefits[4/]	$ 390	$ 432
Total	**$ 8,350**	**$ 14,302**

Budget Justification

[1/] Undergraduate student for 360 hours (12 weeks, 30 hours/week, at $11.00 per hour). Student will assist with media production and sample processing, and storage of isolates.

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

[3/] Stockwell, 5 trips Corvallis to Lynden field plots each year; Hotel @$100/night (year 1) to $110/night (year 2).

[4/]Benefits are for undergraduate student worker.

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	OR Blueberry Commission	$9,851	4/1/2018 to 3/30/2019	20%	Studies on *Botrytis cinerea*, silver leaf and other stem diseases in Oregon blueberry fields.
Stockwell	WRRC	$8,000	2/14/2018 2/15/2019	15%	Fungicide Sensitivity of Blossom and Cane Disease pathogens of Red Raspberry
Stockwell	OR Strawberry Commission	$ 5,965	5/1/2018 4/30/2019	15%	Fungicide Resistance of *Botrytis* from Oregon Strawberry Fields
Stockwell	OR Raspberry & Blackberry Commission	$6,851	4/1/2018 to 3/31/2018	15%	Fungicide Resistance Profiles of *Botrytis* Isolates Collected from Raspberry and Blackberry in Oregon.
Yang and Stockwell	OR Blueberry Commission	$10,468	3/2018 to 3/2019	15%	The Epidemiology of Crown Gall on Blueberry - A Reemerging Disease in The Pacific Northwest
	Pending:				
Stockwell	WRRC	$ 8,350	2/14/2019 2/15/2020	25%	Refining the microbiome of developing red raspberry fruit tissues (this proposal)

SOILS

Project No: WRRC 2018 Contract 4

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

Personnel: PI Thomas Walters, Walters Ag Research. Co-PIs Lisa DeVetter, WSU; Inga Zasada and Jerry Weiland, USDA-ARS.

Reporting Period: 1/1/2018 through 12/31/2018

Accomplishments:

- Documented improved weed and nematode control with tarping and deeper shanks in bed fumigation with Telone C-35 and Strike 60.
- Showed that a Vapam crop termination treatment had similar nematode reduction to herbicide treatment.
- Confirmed that shallow-applied Vapam effectively controlled nematodes with or without deep Strike 60 application in a sandy soil.

Results: *Bed fumigation trial.* A field was identified with a history of Phytophthora root rot and heavy root lesion nematode 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) 10/15/17. Fumigation shanks were kept at standard depth 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 immediately after fumigation. 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. Post-fumigation nematode numbers were zero, as expected. Preliminary results indicate that none of the treatments significantly reduced detection of *Fusarium*, *Pythium*, *Verticillium*, or *Phytophthora*. However, there were some trends that indicated that deep injections or tarped applications of either fumigant have potential to be more effective than the nontarped application (Figure 1). Weed control in April 2018 was best in tarped plots, and in plots where shanks were deeper. Similarly, nematode control in October 2018 was better in these plots (Figures 2 and 3). There were more primocanes per hill in tarped plots, as well (Figure 4).

Crop termination trial: Vapam (74 gpa) was applied to the old raspberry via drip tape 8/25/17. Foliar symptoms were visible within 5 days. Symptoms were most pronounced when plants were also sprayed with Crossbow and Roundup (Figure 5). Root and soil *P. penetrans* numbers appeared lower in plots treated with both Vapam and herbicide (Table 1). The field was fumigated by Trident in 2018. Nematode numbers were not dramatically reduced by crop termination; herbicide treatment reduced the numbers by a similar amount (Figure 6).

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 36" deep in the silt loam soil, but only found them to a 12" depth in the sandy soil (Figure 7). 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 8), but no nematodes at all in silt loam plots (data not shown). In Sept 2018, substantial numbers of *P. penetrans* were found in soil and roots of UTC plots, but very few in fumigated plots (Figure 9). 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.

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

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

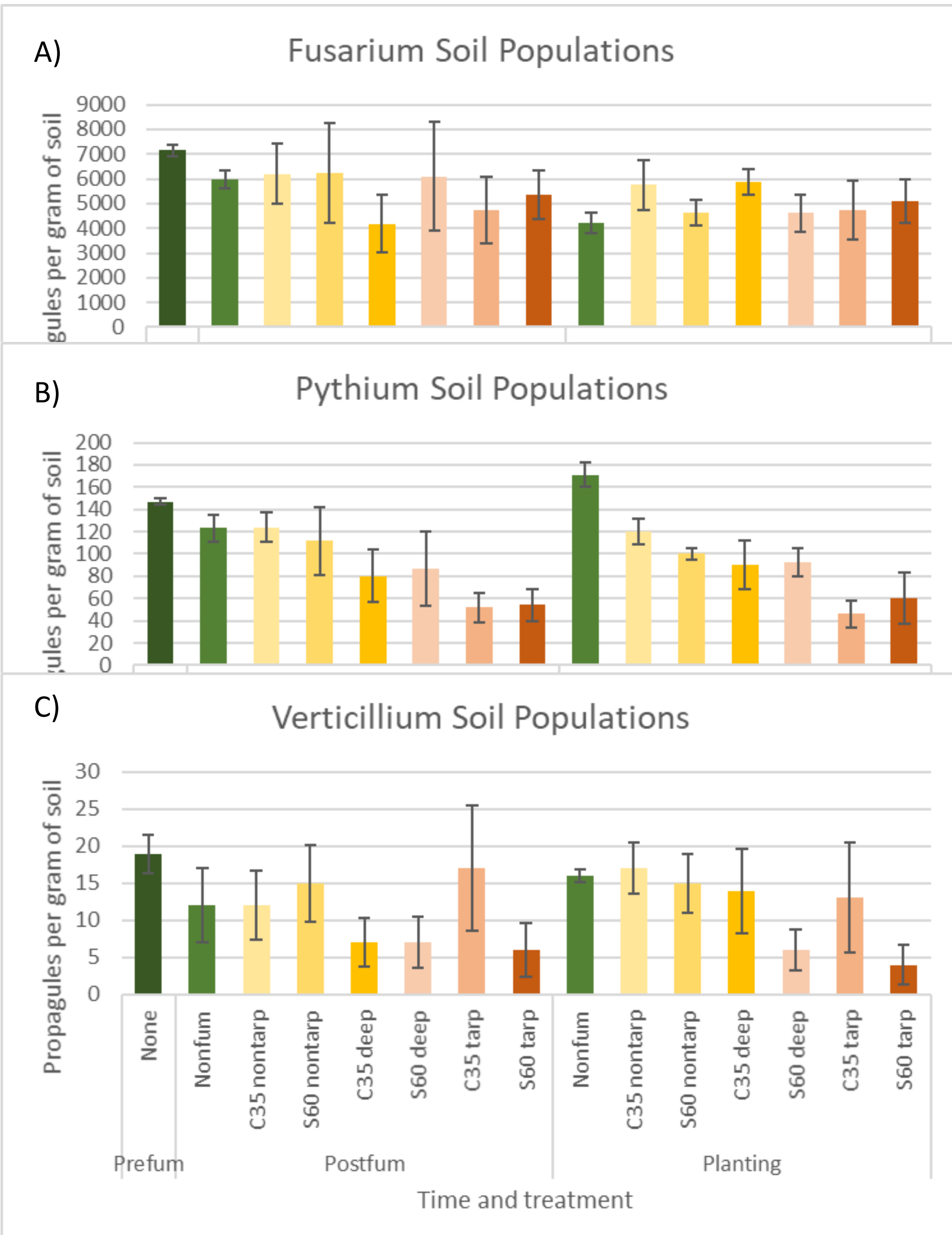


Figure 1. A) *Fusarium*, B) *Pythium*, and C) *Verticillium* populations in bed fumigation trials pre-fumigation, post-fumigation and at planting time (April 2018)

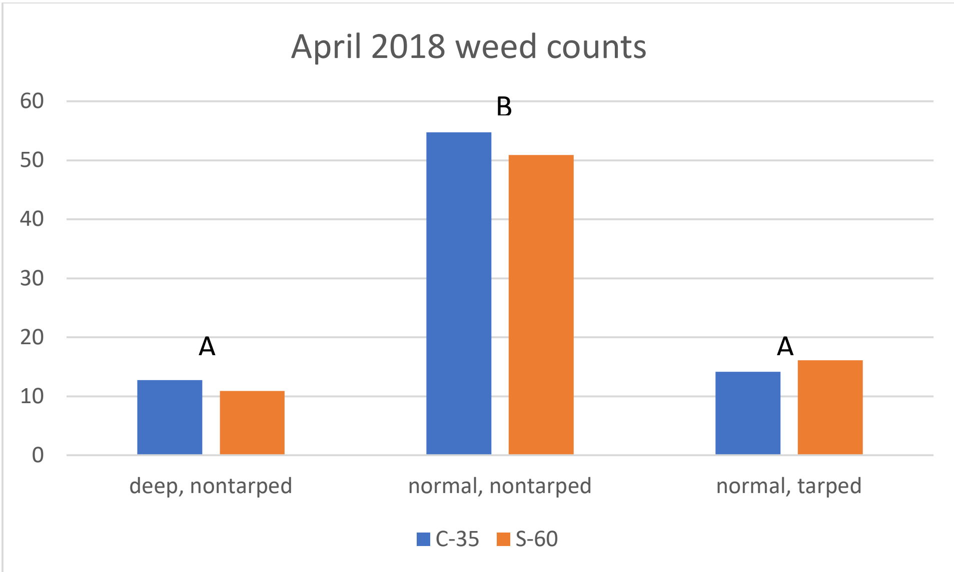


Figure 2. Weed counts in bed fumigation trials April 2018, six months after fumigation.

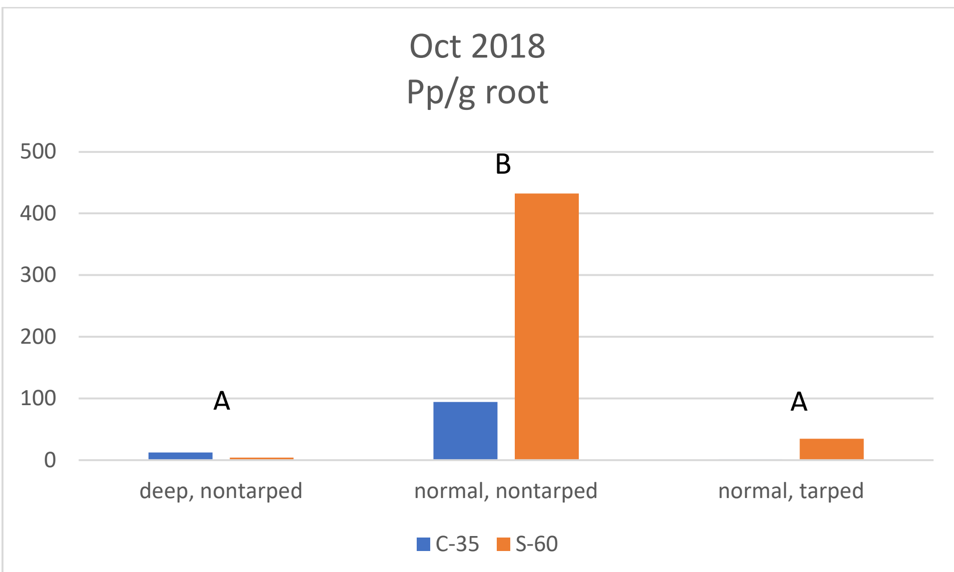


Figure 3. *P. penetrans* per g root in bed fumigation trials October 2018, 12 months after fumigation.

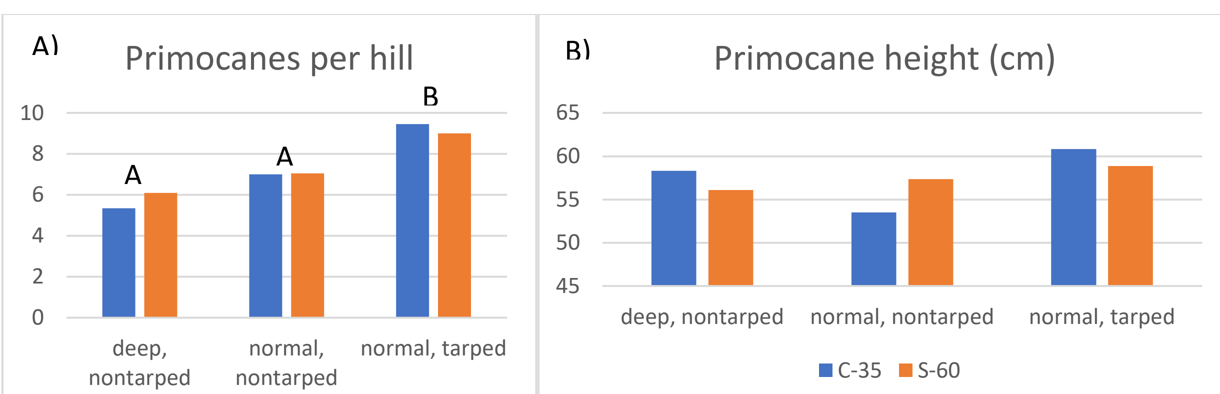


Figure 4. A) Primocanes per hill, and B) Primocane height in bed fumigation trials October 2018, 12 months after fumigation

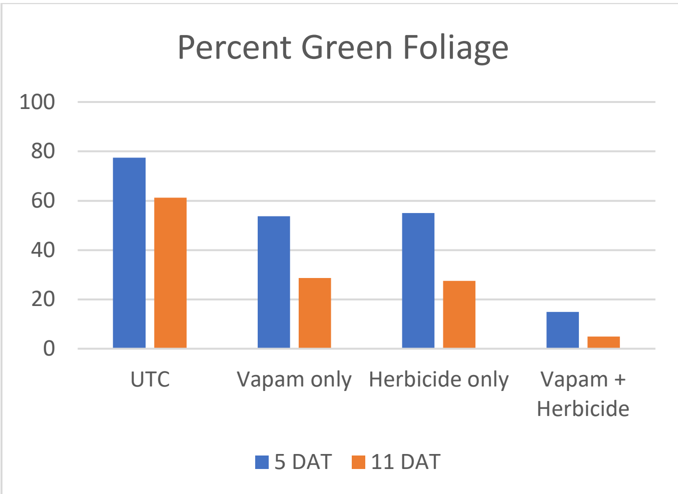


Figure 5. Percent green foliage in crop termination plots treated with Vapam, Herbicide or both 5 and 11 days after Vapam treatment (DAT).

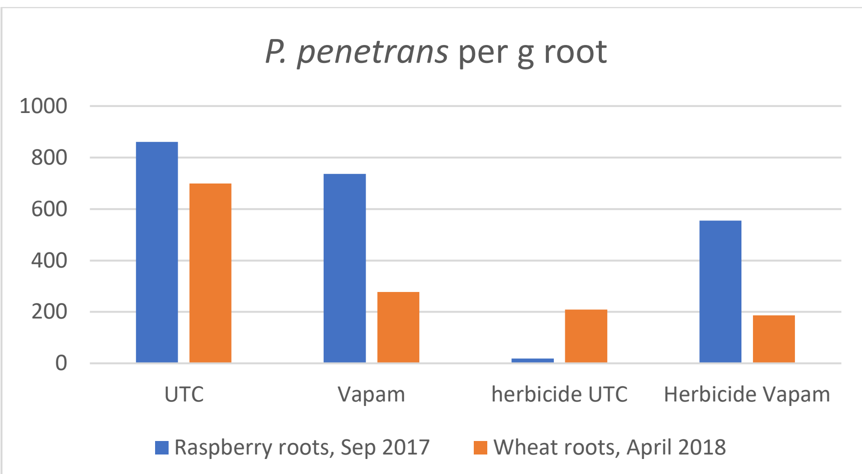


Figure 6. *P. penetrans* per g root in old raspberry crop one month after treatment (blue bars), and in wheat cover crop 8 months after treatment (orange bars).

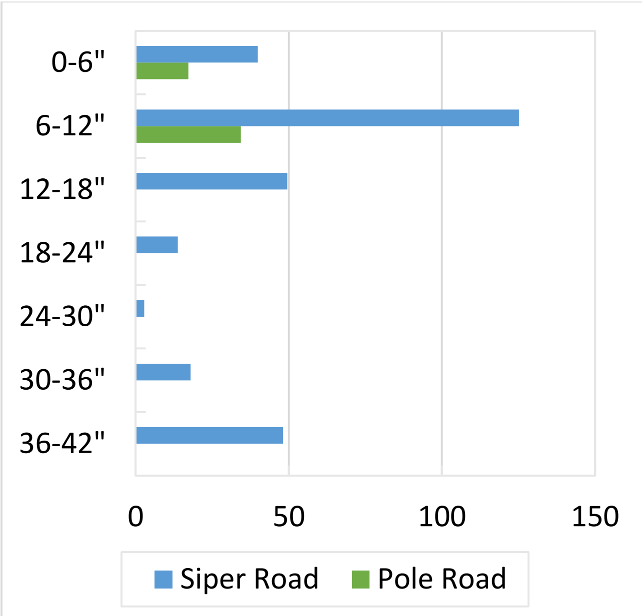


Figure 7. Prefumigation *P. penetrans* per 50 g soil in silt loam (Siper Road) and sandy loam (Pole Road) soils

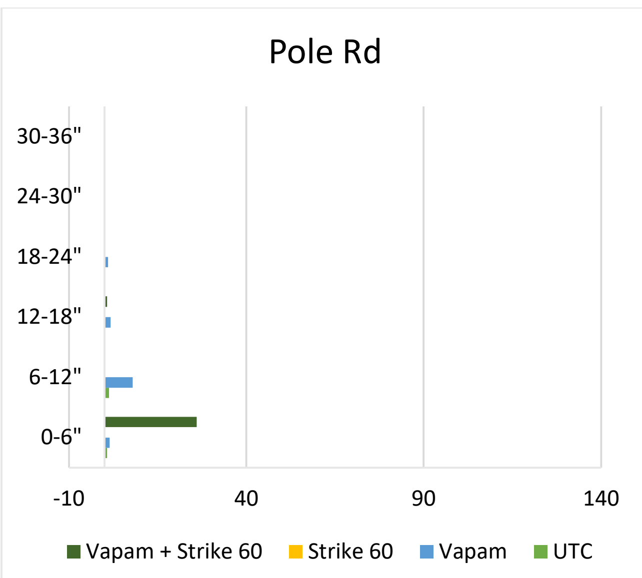


Figure 8. *P. penetrans* per 50 g soil 10 months after fumigation in a sandy loam (Pole Road) soil. No *P. penetrans* were found at the silt loam (Siper Road) location.

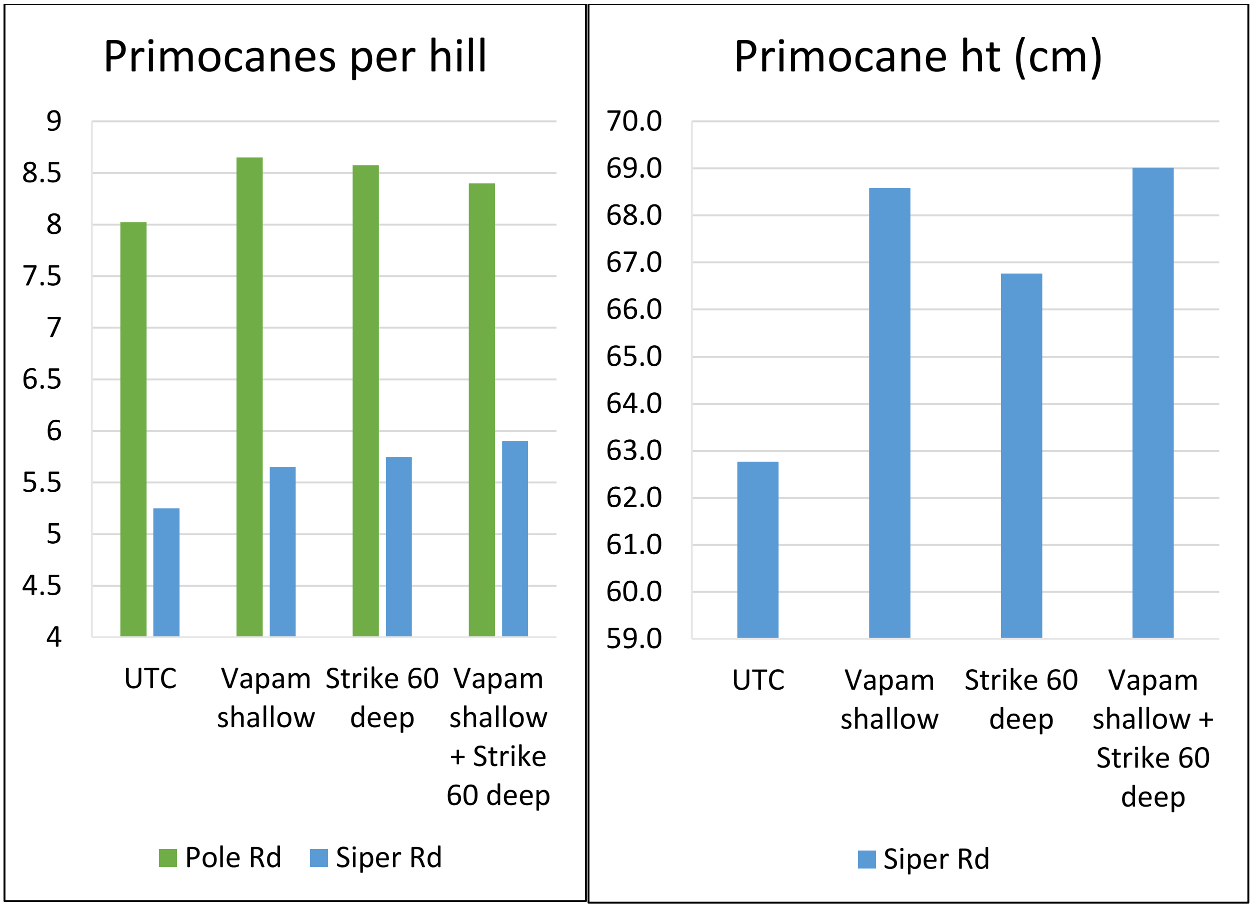


Figure 9. Plant Vigor (Primocanes per hill and primocane height) at Pole Road and at Siper Road

Publications: none yet.

2018 WASHINGTON RED RASPBERRY COMMISSION RESEARCH PROPOSAL

Continuing Project Proposal **Proposed Duration** 3 years (this is year 3)

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

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Co-PI: Lisa DeVetter
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Co-PI: Jerry Weiland
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Cooperators: Mike Conway and Tim Purcell, Trident Ag Products;
Chris Benedict, WSU Whatcom County Extension

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

Total Project Request: Year 1 $13,407 Year 2 $14,207 **Year 3 $14,857**

Other funding sources: No other cash sources. Trident provided deep-shanked fumigant and services for bed fume and Vapam cap trials; Raven industries provided TIF fumigation tarp for bed fumigation trial. Maberry Packing provided Vapam and services for Vapam cap trials. WFC provided Vapam for crop termination trial.

Description: This project addresses the need for affordable and effective preplant soil fumigation in an increasingly challenging regulatory environment.

Our objective is to evaluate the effectiveness of a Vapam cap and a post-harvest termination treatment in reducing nematode and disease carryover in fields of different soil types. We will evaluate this through soil and root nematode assays, and plant growth and disease (root rot) evaluation. We will also evaluate bed-applied fumigants.

The major outcome of this work will be improved grower understanding of how these practices will best work for them. It's already pretty clear that Vapam caps can be effective, but it would help to know which soil types and conditions are the best for this treatment. Crop termination with Vapam or other products may improve nematode control in and near the root zone, where numbers should be greatest.

Justification and Background

Fumigators must cope with buffer zone and other regulatory limitations. Most raspberry growers have a custom applicator fumigate their fields in blocks with combinations of 1,3-D (Telone) and chloropicrin, and most growers report clear benefits from this practice. However, some plant parasitic nematodes and diseases escape current fumigation procedures, and growers often find there are some nematode, disease and weed problems in newly fumigated fields (Walters et al., 2017). For example, we recently documented substantial numbers of *P. penetrans* on post-fumigation, preplant cover crops in Washington raspberry fields (up to 5100 *P. penetrans*/g root, as presented in 2015 Progress report). These problems can reduce the growth and first-season yields of newly developing plants, and can develop into chronic problems throughout the lifespan of the planting.

Telone prices are currently stable and supplies are adequate, but both have been volatile in the past . When the Telone price is high price and supplies are low, growers tend to use products containing less Telone and more chloropicrin. This is risky (chloropicrin is not an effective nematicide), and it makes fumigation more difficult (buffers depend upon the chloropicrin content of the fumigant). Regulations on the use of both fumigants are likely to become more restrictive in the future. Although there is no crisis with Telone or chlorpicrin today, we feel this is the time to prepare for a day when we may have less to use.

Raspberry growers often terminate the old crop with herbicides, but this practice does not greatly impact soilborne disease and nematode populations. Crop termination with a drip-applied soil fumigant has been a useful pest management tool in other systems (MacRae et al., 2010), and is used to address carryover disease and nematode problems.

Bed fumigation has been researched in Washington raspberries before; tarped bed fumigation with Telone C-35 was as effective or more effective than nontarped broadcast fumigation with the same product (Walters et al., 2017). Preliminary data with nontarped bed fumigation is promising (Walters and Zasada progress report), but more time and trials are needed to evaluate this practice. Nontarped applications of Telone C-35 can fail to control fungi and *Phytophthora rubi*, but increasing the concentration of chloropicrin with Pic-Clor 60 (1,3-D 40%, chloropicrin 60%) and tarping has been effective against these pathogens in other crops (Weiland et al., 2016). We expect this will also be the case in raspberry.

Relationship to WRRC Research Priorities
This proposal directly addresses the WRRC's #2 priority "Soil fumigation techniques and alternatives to control soil pathogens, nematodes and weeds". This proposal evaluates existing techniques (Vapam cap and bed fumigation) and a novel supplement (crop termination with a fumigant) to address this priority.

Objectives:

- Evaluate crop termination via buried drip and caps (both with Vapam) as ways of reducing nematodes and diseases escaping preplant soil fumigation.
- Evaluate low Telone-use systems (bed fumigation with Telone C-35 and with Pic-Clor 60) using Trident Ag Product's bed fumigation system.
- Estimate the economic costs and benefits of these practices.

Procedures
Crop Termination. In 2017, we treated plots in a field with *P. penetrans*. Vapam (74 gal/A) was injected into the drip tape with enough water to wet most of the rooted zone (approximately 1 gallon/row foot). We found that the herbicide and Vapam treatments similarly defoliated plants, and that plants treated with both defoliated more rapidly. Soil and root *P. penetrans* numbers were lower in plots where both treatments were applied. In 2018, the study area was fumigated with a Telone:chloropicrin combination along with the rest of the grower's field. In 2018, we showed that the Vapam crop termination treatment had similar nematode reduction to herbicide treatment. Additional nematode samples and plant growth data will be collected from these plots in 2019.

Vapam caps. In 2017, we identified two raspberry fields with moderate to high nematode pressure but with different soil types (e.g., a sandy loam, and a heavier silt loam). Each study area included 16 plots, each 30 ft x 50 ft. There are 4 replicate blocks of 3-4 treatments:

- Untreated check
- Deep shank applied C-35, 35 gal/A
- Shallow shank applied Vapam, 74 gal/A
- Both C-35 (deep) and Vapam (shallow)

Before treatment, plots were cored to a 36" depth to determine vertical nematode distribution. *P. penetrans* were found in the sandy loam soil to 12" depth, and in the silt loam soil to 36" depth. In 2018, we showed that shallow-applied Vapam effectively controlled nematodes in the sandy loam soil, with or without deep-shanked Strike 60 application. We also saw slightly better growth in fumigated plots. No nematodes were recovered from the silt loam fumigation site in 2018. In 2019, we will continue to monitor nematode populations, and will collect some first -year yield data. Yield data collection is costly and time-consuming, so we will focus on mid-season evaluations, when differences tend to be greatest.

Bed fumigation. In 2017, plots were established in a field with *Phytophthora* pressure and bed fumigated by Trident. In 2018, we found that tarping and deeper shanks improved weed and nematode control. We will continue to sample this trial in 2019 to confirm these results, and will evaluate yield during the middle of the harvest season. The finding that deeper shanks markedly improved nematode and weed control was unexpected, so we will cooperate with Trident to repeat this comparison in other fields.

Anticipated Benefits and Information Transfer

We know from other high value production systems that soil plays an important role in fumigant efficacy. This information is not available for soil types in northern WA. We will develop fumigation recommendations specific to the soil types present in NW raspberry fields. It is also necessary to apply and evaluate alternative fumigation application methods that have proven to be successful in other high value crop production systems to the raspberry production system. Our research will determine whether crop termination with a drip applied fumigant improves nematode and disease management above and beyond broadcast fumigation alone.

References:

MacRae, A., Noling, J., and Snodgrass, C. 2010. Maximizing the efficacy of soil fumigant applications for raised-bed plasticulture systems of Florida. HS1169, Horticultural Sciences Department, Florida Cooperative Extension Service, IFAS, University of Florida.

Walters, T.W., Bolda, M., and Zasada, I.A. 2017 Alternative fumigation practices for western states raspberry. Plant Health Progress 18(2): 104-111

Weiland, J.E., Littke, W.R., Browning, J.E., Edmonds, R.L., Davis, A., Beck, B.R., and Miller, T.W. 2016. Efficacy of reduced rate fumigant alternatives and methyl bromide against soilborne pathogens and weeds in western forest nurseries. Crop Protection 85: 57-64.

Budget:

	2017 (last year)	2018 (this year)	**2019**
Salaries[1/]	$7,486	$7,486	**$7,486**
Time-Slip			**$500**
Operations (goods and Services) [2/]	$4,817	$5,617	**$5,517**
Travel[3/]	$400	$400	**$650**
Meetings			
Other: shipping			
Equipment			
Benefits[4/]	$704	$704	**$704**
Total	$13,407	$14,207	**$14,857**

Budget Justification:

[1/] Walters 0.055 FTE, benefits included: coordinate with growers, stake out plots, supervise crop termination and Vapam cap applications, coordinate C-35 applications. Sean Watkinson (technician for DeVetter), 0.042 FTE.

[2/] Walters: $400 shipping 2017 and 2018, $650 shipping 2019. Zasada: $2800 sample processing 2017, $3600 2018 and 2019. Weiland: $1667 sample processing 2017, 2018 and 2019.

[3/] Walters, 2017: 6 trips Anacortes to Lynden, 2018: 6 trips, 2019 10 trips.

[4/] Watkinson, 35.44%.

2018 WASHINGTON RED RASPBERRY COMMISSION
RESEARCH PROPOSAL

Project No: New **Proposed Duration:** 1 year

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

Principal Investigator:
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Gabriel LaHue, Assistant Professor of Soil Science
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Mailing address: WSU NWREC, 16650 SR 536, Mount Vernon, WA 98273

Co-Principal Investigators:
Chris Benedict, Agriculture Agent, Whatcom County Extension
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Mailing address: 1000 N. Forest Street, Suite 201, Bellingham, WA 98225

Lisa Wasko DeVetter, Assistant Professor of Horticulture
E-mail: lisa.devetter@wsu.edu **Phone:** (360) 848-6124
Mailing address: WSU NWREC 16650 SR 536, Mount Vernon, WA 98273

Cooperators: Matt Maberry and Chad Bajema, Curt Maberry Farm, Inc.

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

Total Project Request: **Year 1**: $7070

Other funding sources: No other funding sources have been sought to date, but results from this trial could be leveraged to apply for a WSDA Specialty Crop or Western SARE grants.

Description:
Over the past several years an increasing number of red raspberry (*Rubus idaeus*) acres in Washington use winter alleyway cover crops to increase trafficability in the spring and promote soil health, yet this system requires many tillage passes, which increase farm labor requirements and fuel costs. The objective of this study is to evaluate the performance of an alternative tillage system - replacing several tillage passes with a single spader pass - on cover crop biomass production, multiple soil health metrics, soil-water relations, and tillage-related costs. This project will provide actionable evidence of the benefits and challenges of this alternative tillage system, which will be communicated to growers through field days, the 2019 Washington Small Fruit Conference, and an extension publication.

Justification and Background:
Planting winter cover crops in alleyways between red raspberry rows can provide multiple benefits including improved water infiltration, reduced soil erosion, less weed pressure (Funt and Hall, 2013; Forge et al., 2000), better soil aggregation (Zebarth et al., 1993), organic matter inputs that feed beneficial soil organisms (Six et al., 2012), and reduced compaction (Benedict, unpublished data). Post-harvest tillage activities vary, but can include a combination of deep ripping and rototilling to alleviate soil compaction and, if a cover crop is planted, to prepare a seedbed. Additionally, spring cover crop termination can involve several implement passes to terminate and incorporate the cover crop. These activities increase labor requirements and result in significant soil disturbance, which may offset some of the benefits gained from cover crops.

High intensity soil tillage accelerates loss of soil organic matter, which is important for soil structure, nutrient retention, soil aeration, and supporting beneficial soil organisms (Gupta and Germida, 2015). Tillage itself also disturbs microbes like mycorrhizal fungi that facilitate water and nutrient uptake by plants. However, mild intensity tillage with cover crop incorporation may actually promote beneficial soil microbes by releasing carbon-rich food. Therefore, it is important to understand the potential effects of reducing tillage on soil biology, as well as soil physical (e.g. aggregates) and chemical (e.g. soil carbon) properties.

Typical tillage for spring cover crop incorporation and post-harvest alley management could be replaced by a spader, which incorporates cover crop residues in a single pass, reducing mechanical, fuel, and labor costs as well as soil disturbance. The spader also goes deeper (12 in.) than the rototiller (6 in.) and therefore could reduce subsurface compaction and eliminate the need for post-harvest deep ripping, improving water infiltration and increasing cover crop root growth. Additionally, the manufacturer (Imants BV, Reusel, Netherlands) states that the spader's physical action is “softer” on soil aggregates and microorganisms.

This study will evaluate changes in soil physical, chemical, and biological parameters, as well as the labor, fuel, and mechanical costs of each treatment. Preliminary data from 2018 showed that the spader reduced compaction compared to the rototiller, particularly between 5-14 inches deep, where the rototiller showed signs of a hardpan.

Red raspberry growers in British Columbia more commonly utilize winter cover crops in their alleyways, but there is no known previous, on-going, or planned research evaluating this type of implement in raspberry production in British Columbia, Idaho, or Oregon.

Relationship to WRRC Research Priorities:
This project is related to the following WRRC priorities:

- “Labor saving practices – ex. Pruning, AY, public/private technology partnerships, harvester automation” (Priority #1)
- “Alternative Management Systems – reduce cost of production/lb.” (Priority #2)
- “Understanding *soil ecology* and soil borne pathogens and their effects on plant health and crop yields” (Priority #2)

Objectives:
The overall objective of this project is to compare the impacts of two tillage regimes (conventional vs. spader) on 1) physical, biological, and chemical aspects of soil health, 2) cover crop growth, and 3) labor, fuel, and mechanical costs. All objectives will be addressed within this funding year.

Procedures:
This study will be conducted on tillage treatment plots established in spring 2018 at Curt Maberry Farm, Inc. The field is planted with 'Meeker' and white oats (*Avena sativa*) were seeded (70 lb/ac) as a cover crop in September 2018 and will be incorporated in March-April 2019. Plots are replicated four times per treatment. Tillage treatments are defined in Table 1.

Table 1. Tillage treatments

	Treatment 1 (Conventional)		**Treatment 2 (Spader)**	
	# passes	**Implement**	**# passes**	**Implement**
Fall	1 1 1 1	Subsoiler Rototiller Chisel plow Cultivator	1	Spader
Spring	1 1 2	Herbicide Rototiller Chisel plow	1 2	Spader Cultivator

Soil health measurements will include compaction, aggregate stability, water infiltration, active and total carbon contents, microbial biomass, and microbial community composition. Soil samples and in-field measurements will be collected from alleyways at two time points over the year: 1) 2 weeks after spring tillage for incorporation of the winter 2018-2019 cover crop, 2) 2 weeks after fall tillage and establishment of the winter 2019-2020 cover crop.

Intact soil cores will be taken from 0-18 inches in 3-inch increments for saturated hydraulic conductivity measurements, and these cores will then be dried and weighed to measure dry bulk density. Compaction will be assessed with penetrometer measurements (at 1-inch increments) in addition to bulk density, and *in situ* water infiltration will be measured with a ring infiltrometer. Soil samples for aggregate stability, active and total carbon contents, microbial biomass, and microbial community composition will be taken at depths of 0-6 and 6-12 inches. Soil aggregate stability will be assessed through wet-sieving, active carbon through permanganate oxidation (POXC), and total carbon through elemental combustion. Soil microbial biomass and community composition will be measured through phospholipid fatty acid (PLFA) analysis and will identify major microbial groups such as mycorrhizal fungi. Cover crop biomass measurements will be taken prior to termination and observations of cover crop residue incorporation will be made in spring 2019.

Assessment of financial savings will be done using a Land Use System analysis (Vosti et al., 1997), which quantifies the labor and input costs of each system, allowing for economic comparison of the treatments in place as well as other potential tillage scenarios.

Anticipated Benefits and Information Transfer:
This project will provide information on the suitability of the spader as a replacement for conventional tillage associated with cover cropping, as a means of reducing production costs (fuel, labor) and decreasing soil disturbance during alleyway tillage. Financial savings may facilitate greater adoption of alleyway cover crops, while potential improvements to soil health (aggregation, infiltration, organic matter) will contribute to the short- and long-term sustainability of raspberry systems. Results will be discussed at field days, presented at the 2019 and 2020 Washington Small Fruit Conferences, and shared in a WSU Extension publication.

References:

Forge, T.A., R.E Ingham, D. Kaufman, and J.N. Pinkerton. 2000. Population growth of Pratylenchus penetrans on winter cover crops grown in the Pacific Northwest. J. Nematol. 32(1):42-51.

Funt, R.C. and H.K. Hall. 2013. Raspberries. CAB International, Oxfordshire, UK.

Gupta, V. and J. Germida. 2015. Soil aggregation: Influence on microbial biomass and implications for biological processes. Soil Biol. Biochem. 80:A3-A9.

Vosti, S.A., J. Witcover, J. Gockowski, T.P. Tomich, C.L. Carpentier, M.D. Faminow, S. Oliviera. 1997. Socioeconomic issues linked to Best Bets. Proceedings of a Modeller's Workshop, 18-25 March 1997, Empresa Brasileira de Pesquisa Agropecuária (Embrapa)/Acre Research Station, Rio Branco, Brazil.

Zebarth, B.J., S. Freyman, C.G. Kowalenko, 1993. Effect of ground covers and tillage between raspberry rows on selected physical and chemical parameters and crop response. Can. J. Soil. Sci. 73:481-488.

Budget:

	2019
Salaries[1/]	$387
Time-slip	$2496
Operations (goods & services)[2/]	$3815
Travel	$
Meetings	$
Other	$
Equipment	$
Benefits[3/]	$372
Total	$7070

[1/]One Whatcom County Extension technician (Betsy Schacht) at 0.8% FTE.
[2/]Funds for soil health and water infiltration measurements: microbial biomass and community composition with PLFA ($1443), active C ($384), total C ($325), soil texture ($480), supplies for infiltration rings and saturated hydraulic conductivity ($1083).
[3/]36.3% benefits for Betsy Schacht and 9.3% benefits for non-student time-slip

Name: Deirdre Griffin

Instructions:

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

NAME (List.PI #1 first)	SUPPORTING AGENCY AND AGENCY ACTIVE AWARD/PENDING PROPOSAL NUMBER	TOTAL $ AMOUNT	EFFECTIVE AND EXPIRATION DATES	% OF TIME COMMITTED	TITLE OF PROJECT
PENDING					
DeVetter, L., C. Miles, D. Griffin, M, Flury, M. Bolda, S. Wortman, S. Agehara, C. Benedict, H. Liu, T. Marsh, T. Chi, S. Galinato, K. Englund, M. Perez-Garcia, G. Yorgey, J. Goldberger, and L. McGowen	USDA SCRI	$49,796	9/2019-8/2020	5%	Planning grant: Implementation of new technologies and improved end-of-life management for sustainable use of agricultural plastics
Bryla, D., T. Flemming, G. LaHue, D. Griffin, L. DeVetter, E. Smith, and J. Williamson	USDA SCRI	$1,800,000	9/2019-8/2023	10%	Investigation of the biological benefits of biostimulants and development of comprehensive management strategies for their use in blueberry
LaHue, G., D. Griffin, L.W. DeVetter, and C. Benedict	WBC	$25,334	1/2019-12/2020	10%	Valuing nitrogen release from high organic matter soils
McMoran, D., S. Seefeldt, D. Griffin	NW Potato Consortium	$17,996	3/2019-2/2020	10%	Cover crop alternatives for potato growers
Ewing, B., J. Niebler, J. Reganold, C. Kruger, L. Lewis, D. Greeno, W. Rockhill, L. Brooks, J. Santry, B. Butler, B. Gerdeman, L.W.	NSF IUSE:EHR	TBD	9/2019-8/2024	5%	Planting seeds: Developing pathways for undergraduate STEM sustainable agriculture education through early

DeVetter, D. Griffin, G. LaHue					exposure and engagement
Griffin, D., G. LaHue, C. Benedict, and L.W. DeVetter	WRRC	$7,070	1/2018-12/2019	10%	Reducing alleyway tillage to decrease costs and improve soil health

Name: Gabriel LaHue

Instructions:

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

NAME (List.PI #1 first)	SUPPORTING AGENCY AND AGENCY ACTIVE AWARD/PENDING PROPOSAL NUMBER	TOTAL $ AMOUNT	EFFECTIVE AND EXPIRATION DATES	% OF TIME COMMITTED	TITLE OF PROJECT
PENDING					
Miles, C., G. LaHue, T. Alexander, J. King, E. Scheenstra	WSU BIOAg (Submitted)	$38,969	3/2019-3/2020	10%	Evaluating regulated deficit irrigation in cider apple orchards for improved water use efficiency, reduced labor input, and improved fruit quality.
Bryla, D., T. Flemming, G. LaHue, D. Griffin, L. DeVetter, E. Smith, and J. Williamson	USDA SCRI (Submitted)	$1,800,000	9/2019-8/2023	5%	Investigation of the biological benefits of biostimulants and development of comprehensive management strategies for their use in blueberry
LaHue, G., D. Griffin, L.W. DeVetter, and C. Benedict	WBC (Submitted)	$25,334	1/2019-12/2020	30%	Valuing nitrogen release from high organic matter soils
Ewing, B., J. Niebler, J. Reganold, C. Kruger, L. Lewis, D. Greeno, W. Rockhill, L. Brooks, J. Santry, B. Butler, B. Gerdeman, L.W. DeVetter, D. Griffin, G. LaHue	NSF IUSE:HER (Submitted)	TBD	9/2019-8/2024	5%	Planting seeds: Developing pathways for undergraduate STEM sustainable agriculture education through early exposure and engagement
Griffin, D., G. LaHue, C. Benedict, and L.W. DeVetter	WRRC	$7,070	1/2018-12/2019	20%	Reducing alleyway tillage to decrease costs and improve soil health