2018 Research Proposals

and

2017 Research Reports

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

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Research Priorities 2018

#1 priorities

- Develop cultivars that are summer bearing, high yielding, winter hardy, machine-harvestable, disease resistant, virus resistant and have superior processed fruit quality
- Maximum Residue Limits (MRL) – residue decline curves, harmonization
- Fruit rot including pre harvest, post-harvest, and/or shelf life.
- Management options for control of the Spotted Wing Drosophila

#2 priorities

- Soil fumigation techniques and alternatives to control soil pathogens, nematodes, and weeds.
- 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
- Mite management
- Alternative Management Systems – AY, reduce cost of production/lb.

#3 priorities

- Labor saving practices – ex. Pruning, AY, public/private technology partnerships
- Nutrient Management – Revise OSU specs, Consider: timing, varieties, appl. techniques
- Irrigation management – application techniques including pulsing
- Viruses/crumbly fruit, pollination
- 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

PAGE	PROJECT TITLE	RESEARCHER (S)	REQUEST	Draft #1	Other $	Source	Approved
PLANT BREEDING			39.78%	0.00%			0.00%
5	Cooperative raspberry cultivar development	Finn	$12,790				
19	Red Raspberry Breeding, Genetics and Clone Evaluation	Moore	$85,000		$32,299	NWCSFR	
27	Coordinated Regional on-farm Trials	Peerbolt	$12,700		$11,500	ORBC	
33	Red Raspberry Cultivar Development	Dossett	$12,000				
ENTOMOLOGY			13.62%	0.00%			0.00%
43	Delimiting distribution of BMSB	Gerdeman	$4,260		$14,229	NARF	
48	Factors affecting spider mite outbreaks	Gerdeman	$12,662		$15,389	WSCPR	
51	Development of Biologically-based RNAi Insecticide	Choi	$10,000		$30,000	berry com.	
58	Managing SWD with Reduced Insecticide Residues	Schreiber	$15,000		$15,000	WSCPR	
71	WSU NWREC Raspberry Field Plot Report	Gerdeman					
WEEDS			1.24%	0.00%			0.00%
74	Determining whether plants should be caneburned	Miller	$3,815		$3,815	RIDC	
PHYSIOLOGY			24.32%	0.00%			0.00%
84	Mechanizing red raspberry pruning and cane tying	Karkee	$9,832				
90	Comparison of Alternate- and Every-Year Production	DeVetter	$5,110				
97	Application of Biodegradable Mulches in Tissue Culture	DeVetter	$25,066				
101	Impact of Nitrogen on Nematode Parasitism	DeVetter	$10,536				
105	Changes in Leaf and Fruit Tissue Nutrient Concentration	DeVetter	$24,327				
PATHOLOGY/VIROLOGY			19.30%	0.00%			0.00%
110	Evaluation of Raspberry Bushy Dwarf Virus strains report	Moore/Martin					
111	Fungicide Resistance in Botrytis in Caneberries	Schreiber	$15,000		$22,500	WSCPR	
126	Biology and control of *Botrytis* fruit rot	Peever	$23,808		$16,721	WSCPR	
134	Boscalid resistance mutations in *Botrytis cinerea*	Peever	$20,610		$25,302	WSCPR	
141	Characterization of pathogens	Stockwell	$5,378				
146	Development of novel disease management methods - final report	Stockwell					
SOILS			0.00%	0.00%			0.00%
149	Vapam Cap, crop termination, bed fumigation treatments - Final Report	Walters/Zasada					
	Total Production Research		**$307,895**	**$0**	**$186,755**		**$0**
	Research Related	WRRC expenses	$5,250	$5,250			$5,250
	Small Fruit Center fee		$2,500	$2,500			$2,500
	TOTAL		**$315,645**	**$7,750**			**$7,750**
	2018 Research Budget		$220,000		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 was identified in Puyallup as having good root rot tolerance and ORUS 4600-2, ORUS 4600-2, and ORUS 4692-1 have been competitive for yield in machine harvest trial in Washington and will be propagated for more extensive grower trials. All floricane trials were harvested with a Littau machine. Primocane fruiting raspberries have been released and are being adopted for commercial fresh market. We made 29 selections this year (20 floricane, 9 primocane).

Results: Forty-seven crosses were made in spring 2017 and a new seedling field (~2000 seedlings) was established. We made 29 floricane and 9 primocane selections that have cultivar potential. This year we used a Littau machine on our floricane trials and while not perfect, it did work well. We had new pest, Rose Stem Girdler that did not impact the floricane trials harvested this year but hammered the primocane trials and the trials we would have harvested next year. We will spray next year but this was a new pest for raspberry and blackberry in Oregon. Presented in Tables RY1-RY8 are the results from 2017. Machine trials have in Lynden have pointed to a couple promising selections (Table RY3). ORUS 4373-1, ORUS 4600-2, ORUS 4600-2, and ORUS 4692-1 and five primocane fruiting selections are being cleaned up and propagated for grower trial. 'Kokanee', a primocane fruiter, was released; it is a late season high quality raspberry suited for fresh market sales. Multiple selections were identified as having excellent root rot resistance in Puyallup.

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). Genetic markers are being been developed for sources of aphid resistance.

Publications:

Bassil, N.V., K.E. Hummer, and C.E. Finn. 2017. Lessons learned from DNA-based tool development and use in a genebank. Acta Hortic. 1156:25-36.

Bradish, C.M., J.M. Bushakra, M. Dossett, N.V. Bassil, C.E. Finn, and G.E. Fernandez. 2016. Genotyping and phenotyping heat tolerance in black raspberry (*Rubus occidentalis* L.) Acta Hortic. 1127:321-324.

VanBuren, R., D. Bryant, J.M. Bushakra, K.J. Vining, P.P. Edger, E.R. Rowley, H.D. Priest, T.P. Michael, E. Lyons, S.A. Filichkin, M. Dossett, C.E. Finn, N.V. Bassil and T.C. Mockler. 2016. The genome of black raspberry (*Rubus occidentalis*). The Plant J. 87:533-680 (and cover).

Appendices

Table RY1. Mean yield and berry size in 2016-17 for floricane fruiting raspberry genotypes at OSU-NWREC planted in 2014. Hand harvested in 2016 and harvested with a Littau (Stayton, OR) machine in 2017.

	Berry size (g)	Yield ($tons \cdot a^{-1}$)		
Genotype	2016-17[z]	2016	2017	2016-17
2016	4.5 a			3.84 a
2017	4.0 a			3.10 a
Replicated				
WSU 2166	5.1 a	4.11 a	3.76 a	3.94 a
Lewis	4.4 bc	4.83 a	2.77 a	3.80 a
Meeker	**3.5 d**	**3.71 a**	**3.48 a**	**3.60 a**
ORUS 4482-3	4.3 bc	3.74 a	3.09 a	3.42 a
ORUS 3713-1	3.7 d	3.21 a	3.22 a	3.22 a
ORUS 4462-2	4.0 cd	4.09 a	2.29 a	3.19 a
WSU 2188	4.7 ab	3.15 a	3.07 a	3.11 a
Nonreplicated				
WSU 2010	2.8	2.76	4.68	3.72
ORUS 3767-3	3.2	3.60	3.06	3.33
ORUS 4465-2	3.8	3.83	2.78	3.30
ORUS 4473-3	3.5	4.28	1.95	3.11
WSU 2130	3.0	2.11	3.70	2.90
WSU 2133	2.4	2.45	2.78	2.62

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

Table RY2. Mean yield and berry size in 2017 for floricane fruiting red raspberry genotypes in replicated and observation trials at OSU-NWREC planted in 2015. Harvested with a Littau (Stayton, OR) machine.

Genotype	Berry size (g)[z]		Yield ($tons \cdot a^{-1}$)
Replicated			
ORUS 4607-2	3.8	ab	5.33
ORUS 4600-2	4.0	a	4.46
ORUS 4600-3	3.6	b	4.21
Meeker	**3.7**	**ab**	**3.99**
ORUS 4603-1	3.7	ab	3.81
ORUS 4603-2	3.8	ab	3.73
Nonreplicated			
ORUS 4600-5	3.7		5.57
ORUS 4600-4	4.1		5.08
ORUS 4601-1	3.9		4.50
ORUS 4611-1	4.2		4.12
ORUS 4608-2	3.3		3.87
ORUS 4608-1	3.8		3.76
ORUS 4600-1	3.7		3.54
ORUS 4606-2	3.5		3.00
ORUS 4613-1	3.9		2.26
ORUS 4641-2	3.7		1.17

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

Table RY3. Performance of ORUS selections in machine harvest trials in Lynden, Washington at two commercial grower fields. Planted in 2015 and 2016.

Genotype	Total yield (tons/acre)			Yield as % of Meeker	Berry weight (g)	Firmness (g/mm)			Brix (%)			Acidity (%)			pH	RBDV test
	2016	2017	2016-17	2016-17	2017	2016	2017	2016-17	2016	2017	2016-17	2016	2017	2016-17	2017	2017
Grower 1 2015 planted																
Wake®field	**12.70**	**6.00**	**9.35**	**136**	**2.8**	**43.9**	**62.2**	**53.1**	**12.6**	**9.3**	**11.0**	**1.1**	**1.9**	**1.5**	**3.3**	**-ve**
ORUS 4600-3	8.00	8.10	8.05	117	2.9	36.6	52.4	44.5	11.6	11.4	11.5	1.2	1.5	1.3	3.5	+ve
Meeker	**9.40**	**4.40**	**6.90**	**100**	**2.7**	**30.4**	**39.2**	**34.8**	**11.3**	**12.2**	**11.8**	**1.2**	**1.5**	**1.3**	**3.5**	**-ve**
ORUS 4600-1	6.30	6.90	6.60	96	4.2	40.6	55.2	47.9	11.1	9.4	10.3	1.0	1.9	1.5	3.3	+ve
ORUS 4607-2	11.40	1.40	6.40	93	3.6	26.6	32.1	29.4	13.0	8.4	10.7	1.1	2.1	1.6	3.3	+ve
Cascade Harvest	**5.80**	**6.90**	**6.35**	**92**	**3.5**	**29.8**	**36.3**	**33.0**	**10.7**	**9.7**	**10.2**	**1.0**	**1.3**	**1.2**	**3.6**	**+ve**
ORUS 4603-1	8.60	3.50	6.05	88	3.1	31.3	31.9	31.6	10.6	10.1	10.4	1.0	1.6	1.3	3.5	+ve
ORUS 4462-1	6.00	6.00	6.00	87	3.3	46.4	72.4	59.4	10.8	9.1	10.0	1.0	2.1	1.6	3.4	+ve
ORUS 4284-1	0.60	2.40	1.50	22	3.3	16.0	25.9	21.0	11.5	8.3	9.9	1.0	1.5	1.2	3.6	-ve
Grower 2 2015 planted																
Cascade Harvest	**9.33**	**7.46**	**8.39**	**126**												
Meeker	**6.12**	**7.26**	**6.69**	**100**												
Willamette	**6.37**	**5.80**	**6.08**	**91**												
ORUS 4465-3	5.87	3.96	4.91	73												
ORUS 3722-1	5.27	4.17	4.72	71												
ORUS 3713-1	4.33	3.75	4.04	60												

Table RY3. (Cont.)

Genotype	Total yield (tons/acre)	Yield as % of Meeker	Berry weight (g)	Firmness (g/mm)	Brix (%)	Acidity (%)	pH	RBDV test
Grower 1 2016 planted								
Wake®field	**6.10**	**145**	**3.4**	**49.9**	**8.6**	**2.9**	**3.2**	**-ve**
ORUS 4692-1	5.20	124	-	-	10.8	-	-	-ve
Meeker	**4.20**	**100**	**2.7**	**37.9**	**10.6**	**2.0**	**3.5**	**-ve**
Cascade Harvest	**3.20**	**76**	**-**	**34.1**	**9.8**	**1.2**	**3.6**	**-ve**
ORUS 3702-3	3.00	71	4.4	22.3	10.2	1.8	3.3	-ve
ORUS 4373-1	3.00	71	4.1	37.6	9.6	1.6	3.4	-ve
ORUS 4089-2	2.60	62	3.1	32.1	9.9	1.6	3.4	-ve
ORUS 4482-3	2.40	57	4.3	36.1	8.8	2.0	3.4	-ve
ORUS 4462-2	1.40	33	4.3	30.4	8.5	1.6	3.4	-ve

Table RY4. Mean yield and berry size in 2015-2017 for primocane fruiting raspberry genotypes at OSU-NWREC planted in 2014.

Genotype	Berry size (g) 2015-17	Yield (tons·acre^{-1}) 2015	2016	2017	2015-17
2015	2.6				1.13
2016	3.1				2.80
2017	3.0				2.37
Non replicated					
Heritage	**2.1**	**1.62**	**3.72**	**3.88**	**3.07**
ORUS 4090-1	3.5	0.68	2.73	2.65	2.02
ORUS 4487-4	3.1	1.17	2.20	1.81	1.73
Vintage	**3.0**	**1.04**	**2.55**	**1.15**	**1.58**

Table RY5. Mean yield and berry size in 2016-17 for primocane fruiting red raspberry genotypes at OSU-NWREC planted in 2015.

Genotype	Berry size (g) 2016-17	Yield (tons·a^{-1}) 2016	2017	2016-17
2016	3.33			2.43
2017	2.95			2.19
Non replicated				
Heritage	**1.85**	**1.77**	**5.08**	**3.42**
ORUS 4725-1	3.65	2.79	3.25	3.02
ORUS 4622-2	3.45	3.93	1.97	2.95
Kokanee	**3.15**	**2.65**	**1.85**	**2.25**
ORUS 4716-1	3.20	3.09	1.31	2.20
ORUS 4291-1	2.95	1.96	1.33	1.64
Vintage	**3.05**	**1.99**	**1.15**	**1.57**
BP1 (Amira)	3.80	1.32	1.58	1.45

Table RY6. Mean yield and berry size in 2017 for primocane fruiting red raspberry genotypes at OSU-NWREC planted in 2016.

Genotype	Berry size (g)	Yield ($tons \cdot a^{-1}$)
Non replicated		
ORUS 4864-1	2.2	1.05
ORUS 4493-1	1.3	0.89
Vintage	**3.8**	**0.74**
ORUS 4494-3	3.2	0.60
Imara	2.2	0.47
ORUS 4873-1	1.8	0.38
ORUS 4872-1	1.2	0.31
ORUS 4858-3	2.9	0.23
Kweli	1.7	0.15

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

Table RY7. Ripening season for floricane fruiting red raspberry genotypes at OSU-NWREC. Planted in 2014 or 2015 and harvested 2016 and/or 2017.

Genotype	Year planted	Harvest season 5%	50%	95%	No. years in mean	Rep/ Obsv
ORUS 3767-3	2014	31-May	14-Jun	28-Jun	1	Obsv.
ORUS 4465-2	2014	31-May	14-Jun	28-Jun	1	Obsv.
WSU 2075	2014	31-May	14-Jun	28-Jun	1	Obsv.
WSU 2200	2014	31-May	14-Jun	28-Jun	1	Obsv.
WSU 2205	2014	31-May	14-Jun	28-Jun	1	Obsv.
ORUS 4473-2	2014	7-Jun	14-Jun	28-Jun	1	Obsv.
WSU 2068	2014	7-Jun	14-Jun	28-Jun	1	Obsv.
WSU 2130	2014	7-Jun	14-Jun	28-Jun	1	Obsv.
WSU 2166	2014	7-Jun	14-Jun	28-Jun	1	Rep
ORUS 4462-1	2014	7-Jun	14-Jun	5-Jul	1	Obsv.
WSU 2133	2014	7-Jun	14-Jun	5-Jul	1	Obsv.
ORUS 3722-1	2013	4-Jun	18-Jun	25-Jun	2	Rep
ORUS 3702-3	2013	4-Jun	18-Jun	29-Jun	2	Rep
WSU 2010	2013	4-Jun	18-Jun	29-Jun	2	Obsv.
ORUS 4465-1	2013	8-Jun	18-Jun	25-Jun	2	Obsv.
ORUS 4371-3	2013	8-Jun	18-Jun	29-Jun	2	Obsv.
WSU 1914	2013	11-Jun	18-Jun	2-Jul	2	Obsv.
WSU 2010	2014	7-Jun	21-Jun	28-Jun	1	Obsv.
Meeker	**2014**	**7-Jun**	**21-Jun**	**5-Jul**	**1**	**Rep**
ORUS 3713-1	2014	7-Jun	21-Jun	5-Jul	1	Rep
ORUS 4465-3	2014	7-Jun	21-Jun	5-Jul	1	Rep
ORUS 4473-3	2014	7-Jun	21-Jun	5-Jul	1	Obsv.
WSU 1985	2014	7-Jun	21-Jun	5-Jul	1	Obsv.
WSU 2122	2014	7-Jun	21-Jun	12-Jul	1	Rep
ORUS 3959-3	2014	14-Jun	21-Jun	5-Jul	1	Obsv.
WSU 2188	2014	14-Jun	21-Jun	5-Jul	1	Rep
Meeker	**2013**	**8-Jun**	**22-Jun**	**2-Jul**	**2**	**Rep**
ORUS 4371-4	2013	8-Jun	22-Jun	10-Jul	2	Rep
ORUS 4380-3	2013	15-Jun	22-Jun	29-Jun	2	Obsv.
ORUS 4462-2	2014	14-Jun	24-Jun	12-Jul	1	Rep
ORUS 4373-1	2013	8-Jun	25-Jun	10-Jul	2	Rep
ORUS 4463-1	2014	12-Jun	28-Jun	12-Jul	1	Obsv.
Lewis	**2014**	**14-Jun**	**28-Jun**	**12-Jun**	**1**	**Rep**
ORUS 4482-3	2014	14-Jun	28-Jun	12-Jul	1	Rep
WSU 1956	2014	14-Jun	28-Jun	19-Jul	1	Obsv.
WSU 1980	2014	14-Jun	28-Jun	19-Jul	1	Rep
WSU 2029	2013	2-Jul	13-Jul	24-Jul	2	Obsv.

Table RY8. Ripening season for primocane fruiting red raspberry genotypes at OSU-NWREC. Planted in 2014, 2015, or 2016 and harvested 2015-17.

Genotype	Year planted	Harvest season 5%	50%	95%	No. years in mean	Rep/ Obsv
ORUS 4291-1	2015	29-Jul	8-Aug	22-Aug	2	Obsv.
ORUS 4493-1	2016	1-Aug	15-Aug	22-Aug	1	Obsv.
ORUS 4864-1	2016	1-Aug	15-Aug	29-Aug	1	Obsv.
ORUS 4873-1	2016	1-Aug	15-Aug	29-Aug	1	Obsv.
BP-1 (Amira)	2015	29-Jul	15-Aug	26-Aug	2	Obsv.
ORUS 4725-1	2015	29-Jul	15-Aug	29-Aug	2	Obsv.
ORUS 4622-2	2015	1-Aug	15-Aug	26-Aug	2	Obsv.
ORUS 4858-3	2016	15-Aug	22-Aug	22-Aug	1	Obsv.
ORUS 4872-1	2016	15-Aug	22-Aug	29-Aug	1	Obsv.
Vintage	**2016**	**15-Aug**	**22-Aug**	**29-Aug**	**1**	**Obsv.**
Vintage	**2015**	**8-Aug**	**22-Aug**	**2-Sep**	**2**	**Rep**
Kokanee	**2015**	**12-Aug**	**22-Aug**	**12-Sep**	**2**	**Rep**
ORUS 4716-2	2015	15-Aug	22-Aug	5-Sep	2	Obsv.
Vintage	**2014**	**4-Aug**	**23-Aug**	**10-Sep**	**3**	**Rep**
Heritage	**2014**	**9-Aug**	**25-Aug**	**10-Sep**	**3**	**Rep**
Heritage	**2015**	**15-Aug**	**26-Aug**	**5-Sep**	**2**	**Rep**
ORUS 4494-3	2016	15-Aug	29-Aug	5-Sep	1	Obsv.
Imara	2016	22-Aug	29-Aug	5-Sep	1	Obsv.
ORUS 4090-1	2014	16-Aug	1-Sep	15-Sep	3	Obsv.
Kweli	2016	29-Aug	5-Sep	5-Sep	1	Obsv.
ORUS 4487-4	2014	21-Aug	6-Sep	15-Sep	3	Obsv.

Project Title: Cooperative raspberry cultivar development program

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Cooperators: Pat Moore, WSU
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Year Initiated __2013___ **Current Year** 2018-2019__ **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)	$9,290
Operations (goods & services)	1,000
Travel[1]	1,500
Other: "Land use charge" ($3,500/acre)	1,000
Total	**$12,790**

[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	$18,920	7/2017-6/2018	2	Cooperative Breeding Program-Blueberries
Finn, C.E.	Oregon Blueberry Commission	$11,738	7/2017-6/2018	4	Developing PNW Cultivars That May Resist Blueberry Shock Virus
Strik, B.C. and C.E. Finn	Oregon Raspberry and Blackberry Commission	$39,600	7/2017-6/2018	4	Production System/Physiology Research and Cooperative Breeding Program-Raspberries and Blackberries
C.E. Finn	Oregon Strawberry Commission	$8,509	7/2017-6/2018	2	Breeding day-neutral strawberries in Corvallis, OR
Strik, B.C. and C.E. Finn	Oregon Strawberry Commission	$16,500	7/2017-6/2018	4	Cooperative Breeding Program - Strawberries
Bassil, N.V., J.M. Bushakra, C.E. Finn, and M. Dossett	OSU ARF	12,500	2/2016-1/2018	1	Assessment of aphid resistance in black raspberry and development of trait-associated molecular markers for breeding improvement
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	$16,060	7/2017-6/2018	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	7/2017-6/2018	2	Cooperative raspberry cultivar development program.
Finn, C.E.	Washington Strawberry Commission	$3,500	7/2017-6/2018	2	USDA-ARS Cooperative Strawberry Breeding Program

Byrne, D, et al.	USDA NIFA Specialty Crop Research Initiative	$50,000	10/2017-9/2018	1	Development and validation of genetic/genomic/analytical tools for polyploid crop plants - Planning Grant
Name(List PI #1 first)					
Pending:					
Finn, C.E.	Washington Red Raspberry Commission	$11,861	7/2018-6/2019	2	Cooperative raspberry cultivar development program.
Strik, BC, and Finn, C.E.	Oregon Blueberry Commission	$18,520	7/2018-6/2019	2	Cooperative Blueberry Breeding Program - Cultivar and Selection Evaluation, NWREC
Finn, C.E.	Oregon Blueberry Commission	$11,966	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	$12,790	7/2018-6/2019	2	Cooperative raspberry cultivar development program.
Finn, C.E.	Washington Strawberry Commission	$9,886	7/2018-6/2019	2	USDA-ARS Cooperative Strawberry Breeding Program

Project: 13C-3755-5641
Title: Red Raspberry Breeding, Genetics and Clone Evaluation
Personnel: Patrick P. Moore, Scientist, Washington State University Puyallup Research and Extension Center
Wendy Hoashi-Erhardt, Scientific Assistant, WSU Puyallup

Reporting Period: 2017
Accomplishments:
OBJECTIVES:
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.

Potential release. WSU 2166 has been recommended for release by the Cultivar Release Committee and is waiting for the recommendation by the Agriculture Research Center. 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.

Crosses/selections. Fifty-eight crosses were made in 2017 for floricane breeding with emphasis on parents that are machine harvestable and root rot resistant. Forty of the 58 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. An additional 12 crosses were made for primocane breeding. Twenty-two selections were made in 2017 from seedlings planted 2014 and 2015.

Selection Trial Puyallup. The 2014 and 2015 replicated plantings at Puyallup were hand harvested in 2017. In the 2014 selection trial, 'Cascade Harvest' had the highest two year total yield (**Table 1**) followed by WSU 2001, WSU 2188 and WSU 2200. WSU 2166, which performed very well in machine harvesting trials and grower trials, had the lowest yield in the selection trial although there were few statistically significant differences. It appears that this selection did not establish very well at this location and produced few canes. The yield per cane did not differ from the highest yielding selections. WSU 2001 and 2088 had the highest yields in 2017 in the 2015 planting with very good firmness (**Table 2**). The 2015 and 2016 plantings will be harvested in 2018.

Machine Harvesting Trials. A new machine harvesting trial was planted in Lynden with 40 WSU selections, 8 BC selections, 6 ORUS selections and 'Cascade Harvest', 'Meeker' and 'Willamette' for reference. This planting will be harvested in 2019 and 2020.
The 2014 and 2015 planted machine harvesting trials were harvested in 2017. Yield was determined for each harvest date for the 2014 planting and total yield calculated (Table 3). Two year yield for WSU 2166 was greater than that of 'Willamette' and 'Meeker'. WSU 2166 had a production curve almost identical to 'Willamette' (Figure 1)..

Grower trials
Four WSU selections were planted in Grower Trials in 2014 (WSU 1980, WSU 2122, WSU 2166 and WSU 2188). All of these selections appeared very promising in small plots in previous Machine Harvesting Trials in grower fields in the Lynden area. In the 2014 Grower Trials, one

grower field has a history of very high levels of root rot and WSU 1980 and WSU 2122 did not perform well on this site. WSU 2188 had significant root rot damage. WSU 2166 did not show any damage in 2014-16 and slight damage in 2017. Three selections were planted in Grower Trials in 2017 and three additional selections will be planted in Grower Trials in 2018.

Publications/Presentations
Machine Harvesting Field Day Lynden, WA July 19, 2017

Summary
This project will develop new raspberry cultivars using conventional breeding methods. Controlled pollinations will be made, seedlings grown, selections made among the seedlings and these selections evaluated. The primary goal of the program is to develop new summer fruiting red raspberry cultivars with improved yields and fruit quality, and resistance to root rot. Selections adapted to machine harvesting or fresh marketing will be identified and tested further. The most promising selections will be tested in grower trials and evaluated for possible release.

Several raspberry selections tested in machine harvesting trials appear very promising: machine harvest well, productive, with good fruit integrity, good flavor and some with probable root rot tolerance. WSU 2166 has been recommended for release by the Cultivar Release Committee and is waiting for the recommendation by the Agriculture Research Center. The proposed name is 'Cascade Premier'.

Table 1. 2016-17 harvest of 2014 planted raspberries, Puyallup, WA

	Yield (t/a)			Fruit weight (g)		Fruit firmness (g)		Fruit rot (%)		Midpoint of Harvest	
	2016	2017	Total	2016	2017	2016	2017	2016	2017	2016	2017
C Harvest	11.0 a	7.0 ab	18.0 a	4.16 ab	3.54 bc	90 a-c	106 d-f	9.8 a-c	14.5 ab	6/23 d-f	7/11 b-d
WSU 2001	7.8 a-c	8.1 a	15.8 ab	3.86 a-c	3.84 ab	87 a-d	147 a-e	14.3 a	12.7 a-c	6/30 a	7/17 a
WSU 2188	8.1 ab	7.2 ab	15.3 a-c	4.41 a	4.05 a	102 a	168 a-c	7.8 bc	5.7 de	6/27 a-d	7/13 ab
WSU 2200	6.8 a-c	8.1 a	14.8 a-c	2.49 f	2.57 e	59 e	94 f	6.4 bc	6.3 de	6/22 ef	7/8 d-f
Willamette	7.8 a-c	6.3 ab	14.2 a-d	3.06 d-f	3.37 bc	74 b-e	122 c-f	7.2 bc	6.6 de	6/19 fg	7/5 f
WSU 1985	6.7 a-c	6.8 ab	13.5 a-d	3.43 b-d	3.80 ab	64 de	180 ab	9.2 a-c	6.5 de	6/27 a-c	7/13 ab
Meeker	6.8 a-c	6.5 ab	13.4 a-d	3.10 de	3.19 cd	74 c-e	107 d-f	11.4 ab	10.6 a-d	6/28 ab	7/9 b-f
WSU 2122	6.9 a-c	5.7 ab	12.6 a-d	3.64 bc	3.18 cd	88 a-d	158 a-d	12.0 ab	9.7 b-e	6/26 b-e	7/12 bc
WSU 0836	5.4 bc	7.0 ab	12.4 b-d	2.92 ef	2.71 de	63 de	95 ef	12.4 ab	16.0 a	6/17 g	7/7 ef
WSU 2133	4.4 bc	7.6 a	12.0 b-d	2.93 ef	2.53 e	60 e	95 ef	6.3 bc	4.8 e	6/23 c-f	7/10 b-e
WSU 2205	6.2 bc	5.8 ab	12.0 b-d	3.16 de	3.26 c	74 b-e	110 d-f	4.2 c	5.2 de	6/17 g	7/7 ef
WSU 2082	4.0 bc	6.1 ab	10.1 cd	4.27 a	4.16 a	100 ab	195 a	9.4 a-c	8.0 c-e	6/23 c-f	7/13 ab
WSU 2166	3.7 c	5.1 b	8.7 d	4.30 a	3.84 ab	101 a	137 b-f	4.4 c	5.4 de	6/19 fg	7/8 c-f
	6.6	6.7	13.3	3.5	3.4	80	132	8.8	8.6	6/23	7/10

Table2. 2017 harvest of 2015 planted raspberries, Puyallup, WA

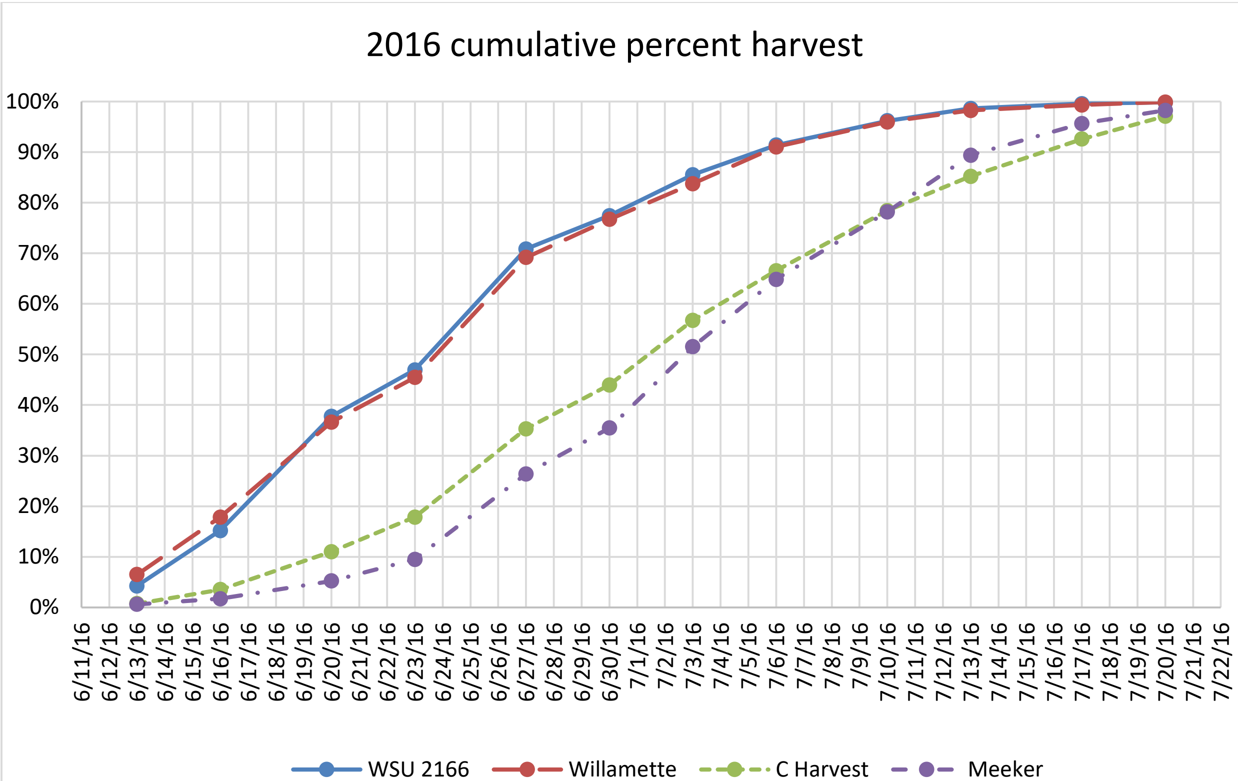
	Yield (t/a)		Fruit weight (g)		Fruit firmness (g)		Fruit Rot (%)		Midpoint of Harvest	
WSU 2001	10.0	a	3.44	a	132	b	7.9	b	7/16	a
WSU 2088	9.1	ab	3.37	a	182	a	4.3	b	7/15	a
WSU 2133	7.3	bc	2.27	c	73	d	5.7	b	7/11	b
C. Harvest	7.2	bc	3.69	a	109	bc	14.6	a	7/10	b
Meeker	7.1	bc	2.88	b	86	cd	7.2	b	7/10	b
WSU 2299	7.1	bc	2.33	c	60	d	9.7	ab	7/8	b
Willamette	5.6	c	3.33	ab	112	bc	7.9	b	7/5	c
	7.6		3.04		107		8.2		7/10	

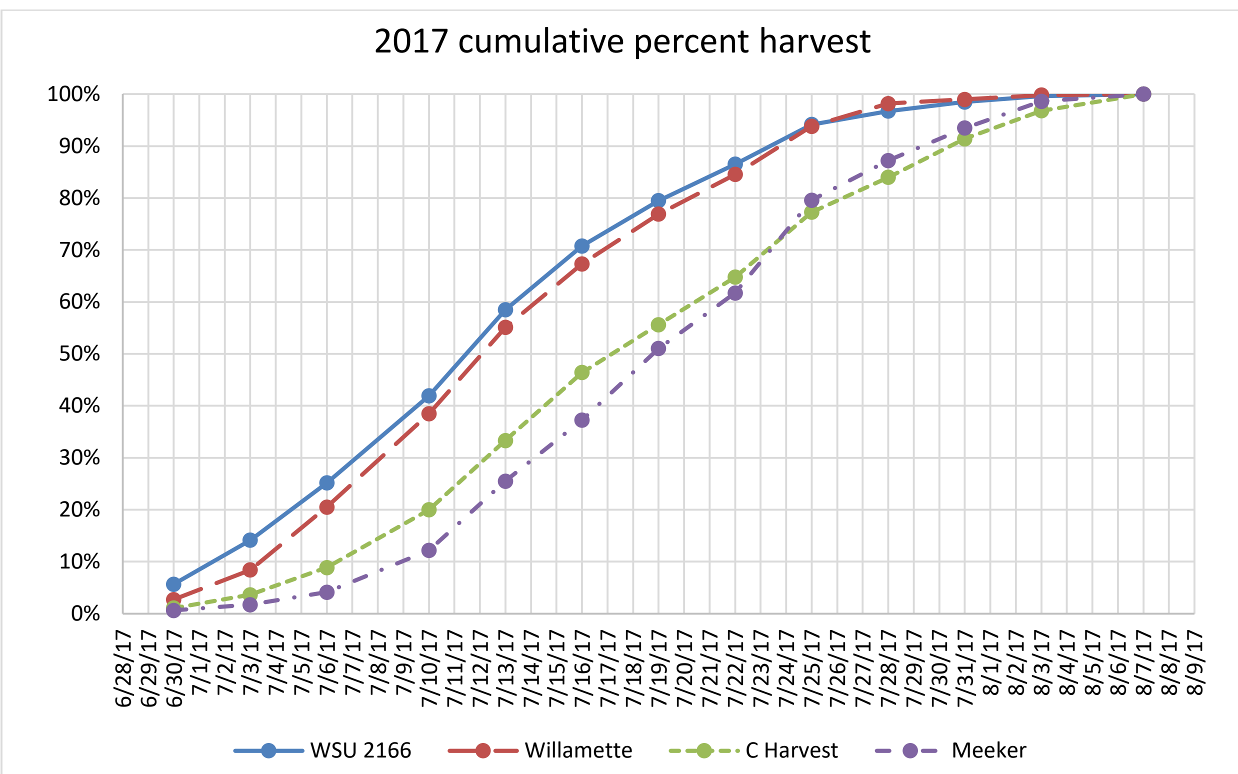
Table 3. Yield of machine harvested raspberries, 2014 planting, Lynden, WA

plot #	clone	2016 lb/plot	2017 lb/plot	2016-17 Total lb/plot
1.30	WSU 2087	90.4	68.0	158.4
1.16	**C Harvest**	**85.7**	**68.5**	**154.2**
1.14	WSU 2001	82.6	58.7	141.4
1.06	WSU 2188	75.9	54.9	130.8
1.01	WSU 2425	67.0	62.2	129.1
1.39	WSU 2088	65.0	63.7	128.6
1.17	**WSU 2166**	**73.9**	**53.7**	**127.6**
1.31	WSU 2385	71.1	55.1	126.2
1.19	WSU 2441	73.8	50.4	124.2
1.36	**Meeker**	**56.2**	**66.7**	**122.9**
1.15	WSU 2402	62.5	58.6	121.1
1.03	WSU 2133	69.8	48.6	118.3
1.28	WSU 2431	66.6	51.6	118.2
1.11	WSU 2205	62.5	54.2	116.7
1.40	**Willamette**	**58.5**	**53.3**	**111.7**
1.18	WSU 1985	79.0	30.9	109.9
1.27	WSU 2123	72.6	36.9	109.5
	Average	71.4	55.1	126.4

Planting included 40 WSU selections and 3 cultivars. After the 2016 harvest, 26 WSU selections were discarded because of low yield or fruit quality.

Figure 1. Cumulative percent yield of 2014 planted raspberries, Lynden WA.





PROJECT: 13C-3755-5641
TITLE: Red Raspberry Breeding, Genetics and Clone Evaluation
CURRENT YEAR: 2017

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 2017** **Proposed Duration:** continuing
Project Request: $85,000 for 2018-2019

Other funding sources: USDA/ARS Northwest Center for Small Fruits Research
Amount Awarded $32,419 for 2016-2017 for both raspberry and strawberry breeding

ORBC
Amount Awarded $4,500 for 2016-2017 "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 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 'Willamette' and '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 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, RBDV resistance, yield and flavor.
2. Seed from crosses made in 2016 will be sown in 2016-2017. The goal will be to plant 108 plants in the field for each cross.
3. Selections will be made among the seedlings planted in 2015. 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% or less 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 2014 and 2015 will be harvested in 2017. 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 and RBDV resistance (if potentially resistant based on parentage).
9. The replicated plantings established in 2014 and 2015 at WSU Puyallup will be hand harvested for yield, fruit weight, fruit rot and fruit firmness.
10. Selections identified in machine harvest trials and other evaluations as having potential for release as a new cultivar will be propagated for grower trials in plantings sufficient to evaluate for suitability for IQF use.

ANTICIPATED BENEFITS AND INFORMATION TRANSFER:

This program will develop new raspberry cultivars that are more productive or more pest resistant. The emphasis of the program is on 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. 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		**2018-19**
00 Salaries		**$38,648**
Scientific Assistant (0.30 FTE)		
Ag Res Tech 2 (0.60 FTE)		
01 Timeslip Labor		**4,000**
03 Service and Supplies		**17,792[1]**
Machine Harvest Trials	13,000	
Land use fees	2,500	
Supplies	2,292	
04 Travel		**1,500[2]**
07 Benefits		**23,060**
SA, ART2	22,681	
Timeslip	379	
Total		**$85,000**

[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 2015 - Honcoop Farms	$3,000
Machine harvesting trial established in 2016 - Honcoop Farms	$3,000
Maintenance of test plantings	
Machine harvesting trial established in 2017 - Honcoop Farms	$3,000
Establishment and maintenance of new test planting	
Machine harvesting trial to be established in 2018	
Will work with the WRRC to identify a suitable grower for the 2018 machine harvesting trial	$4,000

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

C***urrent 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	2017-18	5%	Small Fruit Breeding in the Pacific Northwest

Moore, P.P. and Hoashi-Erhardt	Washington Red Raspberry Commission	$70,000	2017-18	10%	Red Raspberry Breeding, Genetics and Clone Evaluation
Moore, P.P. and Hoashi-Erhardt	Oregon Raspberry and Blackberry Commission	$4,500	2017-18	2%	Genetic Improvement of Raspberry
Moore, P.P. and Hoashi-Erhardt	Oregon Strawberry Commission	$5,000	2017-18	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

Pending Support

Name (List PI #1 first)	Supporting Agency and Project #	Total $ Amount	Effective and Expiration Dates	% of time committed	Title of Project
B Strik, L.W. DeVetter, C. Finn, D. Bryla, Y. Zhao and G Fernandez	USDA SCRI	$5.500,000	2018-22	10%	Expanding the berry crops industry across multiple climactic conditions through breeding and modification of horticultural systems

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: 2017

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 now on order for planting in Spring of 2018 (1,000 of each)

- 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.

2018 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—Seventh year

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 Plants/Enfield Farms, Lynden, WA

Year Initiated 2012 Current Year 2017 Terminating Year 2018

Total Project Request: $12,700

Other funding sources:
Agency Name: Oregon Raspberry and Blackberry Commission
Amt. Requested/Awarded: $11,500
Notes: This is a similar project that will allow us to test caneberries in Oregon.

Description: Maintain a 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 five 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. In 2017, the project's sixth year, an improved advanced planning system was developed to correct logistical problems and ensure cooperating growers of getting the plant material at the optimal time and in the right amounts. Also implemented in 2017 is a system for advanced planning for selecting advanced selections for future trials 2-4 years in advance. The focus for 2018 will be improving site-visit evaluation methods and standardizing information dissemination protocols.

Justification and Background:
The northwest raspberry 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 red raspberry 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 2018 of 3-4 WSU 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 (processed, but could include some fresh selections).
- Minimum of 3 grower sites per selection per year.
- Site guidelines would be representative of the major northwest growing regions including:
    - At least two sites in Northern Washington and one in SW Washington or Oregon.
- 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.

2018 procedures

- Establish new 2018 plantings following procedures similar to those used in previous years.
- 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'.

References: none.

Budget:

	2018
Salaries[1/]	$6,000
Travel[2/]	$2,200
Outreach[3/]	$1,500
Other (Propagator payments**)**[4/]	$3,000
Total	**$12,700**

Budget Justification
[1/]Specify type of position and FTE. Administrator of project at 10% FTE

[2/]Provide brief justification for travel requested. Travel and related expenses to meet with growers and propagators, deliver plants, check plantings, attend meetings and workshops.

[3/]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/]These funds will be paid out by the Commission from invoices from the propagators. 3,000 plants are presently on order from Northwest Plants.

Washington Red Raspberry Commission
Progress Report Format for 2017 Projects

Project No:

Title: Red Raspberry Cultivar Development

Personnel:

Michael Dossett, BC Berry Cultivar Development Inc.
C/O Agriculture and Agri-Food Canada
Agassiz Research and Development Centre,
PO Box 1000, 6947 #7 Hwy.
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Reporting Period: 2017

Accomplishments:

- In 2017, we established ~3500 new seedlings in the field, made 41 new final selections and made additional 50 tentative selections on seedlings that were too small to fully evaluate.

- Over 200 BC and WSU selections were evaluated in the 2014 machine-harvest trial at Clearbrook. A subset of 47 of the BC selections were also evaluated in the WRRC sponsored trial at Willeys Lake. Data for the BC selections in the Willeys Lake plots are in Table 1, whereas data for the BC plots in 2017 are in Table 2 (combined years still being analyzed). Overall, yield on the BC selections was disappointing compared to some of the WSU selections, particularly in 2017 when many of the higher-yielding selections dropped off. BC 9-22-11 and BC 9-11-55 were particularly interesting for combination of yield and machine-harvestability, though there is some concern about firmness in these two selections. Several of the selections noted for harvesting well were established in additional trial plots in 2017 for another look down the road.

- An additional 61 BC selections were evaluated for the first time in the 2015 machine-harvest trial at Clearbrook. Three selections look the most promising from this trial. BC 10-71-27, had yields that were only equivalent to Meeker but fruit that picked exceptionally well and was done very early (essentially finished by July 24). BC 10-84-9 had large dark berries, excellent vigor and picked OK and yield that was significantly greater than Meeker or Chemainus (7.3 t/a, 5g). The only question/concern about this selection at this point in time was a significant number of somewhat overripe berries in the tray. This may be due to our 3-4 day alternating picking schedule or releasing ~1 day later than desired. Its sibling BC 10-84-10 also stood out for the same reasons, but with somewhat smaller fruit and a yield that was closer to Chemainus (6 t/a, 3.7 g).

- Machine-harvested a replicated seedling trial with 36 seedling families (parents were chosen based on the results of our first machine-harvested plots at Clearbrook in 2012). Data on yield components and machine-harvestability collected from these plots is causing us to change how we set up our seedling plantings and our strategies for seedling selection, giving us better direction for selecting some critical traits (particularly yield). This plot has also reaffirmed the value of using a machine harvester on seedling plots rather than waiting until the multi-plant trial plot stage.

- 52 BC and WSU selections were established in a replicated yield plot at the Clearbrook substation. These will be evaluated starting in 2019.

Results:

Table 1: Yield of best selections at Maberry Packing (Ferndale Washington) planted in 2014 and evaluated from 2016-2017.

Genotype	2016 T/A	2017 T/A	2016 + 2017
WSU 2087	9.8	7.4	17.2
Cascade Harvest	9.3	7.5	16.8
WSU 2001	9.0	6.4	15.4
BC 10-100-108	7.7	7.2	14.9
WSU 2188	8.3	6.0	14.2
WSU 2425	7.3	6.8	14.1
WSU 2088	7.1	6.9	14.0
BC 9-11-55	8.0	6.0	14.0
WSU 2166	8.0	5.8	13.9
WSU 2385	7.7	6.0	13.7
WSU 2441	8.0	5.5	13.5
BC 9-22-11	7.1	6.4	13.5
Meeker	6.1	7.3	13.4
WSU 2402	6.8	6.4	13.2
WSU 2133	7.6	5.3	12.9
WSU 2431	7.3	5.6	12.9
WSU 2205	6.8	5.9	12.7
Willamette	6.4	5.8	12.2
BC 10-5-26	6.6	5.4	12.0
WSU 1985	8.6	3.4	12.0
BC 9-11-42	5.5	5.9	11.4
BC 9-10-132	6.1	5.2	11.3
BC 9-37-31	6.1	5.1	11.2
WSU 2123	6.8	4.0	10.8
BC 9-4-87	6.3	4.4	10.7
BC 10-59-86	6.0	4.5	10.5
Plus 37 additional BC selections…			

Table 2: Summary data from the 2014-planted MH trial at the Clearbrook substation.

Genotype	Yield per plot (kg)	Average Size (g)	5% Harvest	50% Harvest	95% Harvest
10-76-43	11.41	3.3	July-02-17	July-14-17	July-25-17
WSU 2069	10.48	2.5	June-29-17	July-12-17	July-25-17
9-19-55	10.33	2.5	July-08-17	July-18-17	July-28-17
10-75-128	9.90	2.8	July-01-17	July-13-17	July-24-17
WSU 2010	9.59	2.1	July-01-17	July-13-17	July-25-17
10-99-88	9.53	2.8	June-29-17	July-12-17	July-26-17
Rudi	9.39	2.7	June-30-17	July-11-17	July-23-17
10-59-58	9.35	3.0	July-01-17	July-13-17	July-25-17
10-99-106	9.13	2.4	June-29-17	July-12-17	July-25-17
8-9-58	9.11	3.9	July-04-17	July-15-17	July-25-17
9-12-8	8.74	3.4	July-07-17	July-18-17	July-29-17
9-4-87	8.61	3.3	July-06-17	July-17-17	July-28-17
9-38-28	8.58	2.3	July-04-17	July-16-17	July-27-17
8-1-22	8.53	2.7	July-06-17	July-17-17	July-28-17
10-101-61	8.48	2.3	June-30-17	July-13-17	July-25-17
9-16-64	8.48	2.4	July-02-17	July-13-17	July-25-17
10-57-66	8.37	2.4	June-30-17	July-12-17	July-24-17
WSU 2188	8.33	3.1	July-07-17	July-18-17	July-28-17
WSU 2166	8.26	3.0	June-28-17	July-11-17	July-24-17
9-15-127	8.18	2.0	July-02-17	July-14-17	July-26-17
10-93-25	8.00	2.7	July-04-17	July-15-17	July-26-17
10-59-82	7.97	2.9	July-04-17	July-15-17	July-26-17
10-99-114	7.91	3.2	June-27-17	July-12-17	July-26-17
Saanich	7.91	2.2	July-06-17	July-17-17	July-29-17
10-99-85	7.80	2.1	July-03-17	July-15-17	July-26-17
8-3-81	7.68	3.1	July-05-17	July-17-17	July-28-17
10-13-20	7.64	2.7	July-01-17	July-13-17	July-25-17
9-22-10	7.62	2.7	July-09-17	July-20-17	July-31-17
9-37-31	7.61	2.7	July-06-17	July-17-17	July-28-17
8-12-27	7.55	2.6	July-02-17	July-13-17	July-25-17
8-9-4	7.50	3.3	July-09-17	July-19-17	July-30-17
9-15-84	7.44	2.7	July-03-17	July-15-17	July-27-17
10-100-47	7.29	3.6	July-03-17	July-15-17	July-27-17
9-27-6	7.28	2.4	July-02-17	July-14-17	July-27-17
9-10-51	7.21	3.0	July-04-17	July-16-17	July-27-17
WSU 2068	6.90	1.9	June-25-17	July-10-17	July-25-17
10-100-108	6.88	3.9	July-03-17	July-15-17	July-26-17
9-21-15	6.79	2.3	July-09-17	July-19-17	July-29-17
8-3-13	6.69	2.6	July-01-17	July-14-17	July-26-17
8-12-1	6.69	2.1	July-06-17	July-17-17	July-28-17
9-9-89	6.64	2.7	July-10-17	July-20-17	July-30-17
74 Entries removed to fit Meeker and Chemainus					
Chemainus	4.36	2.3	July-2-17	July-15-17	July-30-17
Meeker	4.14	2.5	July-07-17	July-17-17	July-28-17
Table truncated – 78 additional selections below Chemainus and Meeker					

Table 3: Yield and fruit size for 2015 MH trial at Clearbrook in its first year of evaluation. Selections mentioned above are in bold.

Genotype	Yield (t/a)	Avg. fruit weight (g)	Comments
10-73-19	10.1	3.6	Soft
10-79-33	8.1	3.2	Holds shape reasonably well, good color, OK skin strength, bland flavor.
1-9-11	7.7	3.6	Very light and soft
10-84-42	7.6	3.6	Large and chunky, doesn't pick until dead ripe, probably too light
10-83-22	7.4	6.5	Giant chunky drupelets
10-84-9	7.3	5.0	Large, conic, dark, nice - doesn't pick until dead ripe
96-2R-1	7.1	2.6	Round berry, uneven, ugly. 1/4 wild.
10-84-45	7.1	3.6	Good but different flavor, a bit soft and light.
10-73-15	6.9	3.2	Good shape and flavor, OK color, v. nice with some overripes
10-79-2	6.9	3.6	Light, soft, crumbly, eliminate
10-57-44	6.8	3.3	Very light, firm, uneven/lumpy and chunky. Use as parent if it has yield.
96-38R-31	6.7	2.8	1/4 wild, impressive, pretty fruit, but a bit on the soft side.
10-79-61	6.5	3.1	Glossy, lumpy. OK color bit soft. Not uniform.
1-11-15	6.5	3.5	Light, soft, dusty
K02-15	6.4	2.8	Beautiful dark fruit, excellent flavor, no root rot tolerance, late season
1-64-3	6.4	2.5	Light, super soft. Meeker size
93-26-25	6.3	3.9	Bit light, glossy. Very good flavor, but significant overripes
10-84-28	6.3	3.5	Bit acid, but fruit in good shape. Medium red color.
1-86-21	6.2	3.5	Beautiful! bit soft, good flavor, much better than 1-86-11. Not RR tolerant
Chemainus	6.1	2.9	
10-84-10	6.0	3.7	Impressive plant, firm berry.
10-78-40	6.0	3.4	Dark, dull, good shape but lumpy with some crumbles
3-19-5	6.0	2.5	Small and soft but with very nice flavor. Rough and crumbly
1-86-11	5.8	2.8	Glossy, but overripe and soft. Not as good as 1-86-21
10-84-47	5.7	3.1	Beautiful fruit but light and dusty, very firm, but also many overripe
10-71-22	5.6	3.9	Chunky and firm, picks well. Bit acid, if anything it picks before fully ripe.
96-22R-46	5.6	3.0	Extremely vigorous,
4-36-17	5.5	2.5	Good cohesion, but quite soft
10-84-14	5.5	3.4	Extremely healthy and vigorous and firm, clings to plant, acidic
10-52-68	5.3	2.9	Good color, but lumpy with wide opening, bit soft
10-65-1	5.3	2.8	Light, firm, picks exceptionally well, lumpy berries
10-71-23	5.3	3.2	Good color, good flavor, picks well with only a few overripe. Ok firm
10-80-100	5.2	2.6	Dark, frosty looking. Meeker size but otherwise very nice MH
10-80-9	5.1	2.3	OK firm, picks ok but light color. Uneven mix of colors in tray
96-17R-30	5.0	2.3	Discard, crumbly
96-29R-30	4.9	2.1	Nice berry. Dark, tight drupelets. Soft ¼ wild
10-84-76	4.8	3.6	Light and lots of overripes
10-57-41	4.8	3.5	Crumbly mess from RBDV
10-71-27	4.5	3.0	Early, firm, picks exceptionally well. Color? Flavor?
Meeker	4.4	2.3	
1-55-31	4.4	2.5	Soft, crumbly, eliminate
97-44-27	4.4	2.3	1/2 wild from Serbia, Late, beautiful fruit, very productive laterals
Table truncated – 19 additional selections			

Publications:

- Several manuscripts are in various stages of preparation, but nothing stemming from this project was published in 2017.

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

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 funding comes from AAFC's Growing Forward 2 Initiative in the form of a proposal with two sections, "Berry Cultivar Development" and "Berry Germplasm Development." In this initiative, industry dollars are matched 1:3 with Federal government support. Since this is an umbrella project, I have broken down portions and time commitments by commodity for illustrative purposes. Pending is a projection with the caveat that the federal program hasn't been unveiled yet, so we don't know quite what we will be dealing with yet, but we are having to replace technical support formerly provided by AAFC (see note under other funding sources in this year's application).				
	Current:				
	AAFC, WRRC, RIDC, LMHIA	$801,266	April 1, 2013 – March 31, 2018	50%	Red Raspberry Breeding for the Pacific Northwest
	AAFC, BCBC, WBC, LMHIA	$641,012	April 1, 2013 – March 31, 2018	40%	Blueberry Breeding for the Pacific Northwest
	AAFC, WSC, BCSGA, LMHIA	$160,253	April 1, 2013 – March 31, 2018	10%	Evaluating Strawberry Cultivars and Germplasm for BC and Northern Washington
Michael Dossett	**Pending:**				
	AAFC, BCBC, WBC, LMHIA	$1,265,000	April 1, 2018 – March 31, 2023	55%	Blueberry Breeding for the Pacific Northwest
	AAFC, WRRC, RIDC, LMHIA	$920,000	April 1, 2018 – March 31, 2023	40%	Red Raspberry Breeding for the Pacific Northwest
	AAFC, WSC, BCSGA, LMHIA	$115,000	April 1, 2018 – March 31, 2023	5%	Evaluating Strawberry Cultivars and Germplasm for BC and Northern Washington

2018 WASHINGTON RED RASPBERRY COMMISSION RESEARCH PROPOSAL

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

Project Title: Red Raspberry Cultivar Development

PI: Michael Dossett
Organization: BC Berry Cultivar Development Inc.
Title: Research Scientist
Phone: 604-796-6084
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Cooperators:
Pat Moore, WSU Puyallup
Chad Finn, USDA-ARS, Corvallis
Nahla Bassil, USDA-ARS, Corvallis
Tom Forge, Nematology/Plant Pathology AAFC
Beatrice Amyotte, Berry Breeder AAFC Kentville NS

Year Initiated_2016__ Current Year 2018_ Terminating Year_2018__

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

Other funding sources:
Agency Name: Raspberry Industry Development Council, Lower Mainland Horticultural Improvement Association, Agriculture and Agri-Food Canada (also pursuing funding from BC Blueberry Council, BC Strawberry Growers' Association, Washington Blueberry Commission, and Washington Strawberry Commission to support the blueberry and strawberry portions of our work).
Amt. Requested/Awarded: $~460,000 total, $184,000 raspberries (40% of effort)
Notes: We are currently in the process of putting together our plan for the next 5-year federal policy framework. Unfortunately there are still lots of unknowns with regards to how the federal program will look. We have had to increase our overall budget from the previous 5-year cycle due mostly to the loss of technical support staff from Agriculture Canada. At this time, we don't know what the matching ratios will be. For the last 5 years the matching ratio has been 25% industry, 75% federal. We are expecting it to be 30% industry, 70% federal, but have been told it may be less favorable. The other big unknown is whether we will be allowed to use leveraged money to hire the replacement for the lost technical support, or whether the industry will have to cover that cost at 100% without counting it towards any sort of match. Industry funding received will be leveraged to the extent possible and will go to pay for a portion of the breeder, a portion of a field technician, student labor, machine-harvest of trial plots, and all the supplies necessary for the program.

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 office and lab space in support of the continuation of this program, as well as 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 currently in the final year of a 5 year funding program called Growing Forward 2 and preparing for a new program that will be 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:
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

	2016	**2017**	**2018**
Salaries[1/]	$	$	$
Time-Slip	$10,000	$10,000	$10,000
Operations (goods & services)	$2,000	$2,000	$2,000
Travel[2/]	$	$	$
Meetings	$	$	$
Other	$	$	$
Equipment[3/]	$	$	$
Benefits[4/]	$	$	$
Total	**$12,000**	**$12,000**	**$12,000**

Budget Justification
The costs we are asking WRRC to support represent approximately 1/5 of the red raspberry portion of the industry contribution needed for the next cycle of funding. We have allocated this primarily to student labor for field planting, plot maintenance, and harvest, as well as some operational costs towards contracting for mechanical harvesting of plots. Hiring students for the summer period costs approximately $10,000/student. With the leveraged support, the budget we are proposing to WRRC will cover the cost of hiring a summer crew of four students (May 1 – August 30) to work on planting and maintaining plots (weeding, some pruning, trellis building and take down, etc.) before and after the fruiting period as well as harvesting/weighing fruit from the plots during the period from late June to early August. All other project costs including travel, supplies, scientist salary, overhead, etc., will be coming from dollars contributed by BC industry associations.

[1/]Specify type of position and FTE.

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

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

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

ENTOMOLOGY

WRRC Final Report 2017

Title: Survey for Egg Parasitoids of Brown Marmorated Stink Bug, *Halyomorpha halys* in Skagit and Whatcom Counties in Western Washington

Personnel:
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Reporting Period: 2017

Accomplishments: Based on funding, the proposal was revised to focus on surveying for BMSB and to delay the egg parasitoid survey until significant populations of BMSB were discovered, as recommended by Dr. Betsy Beers, WSU TFREC. We focused on surveys of BMSB in Skagit and Whatcom Counties by setting ten pheromone traps (Trece™ Pherocon® BMBS and GSB lure chips): 5 sticky traps (STK™ Dual Panel Adhesive Traps) and 5 pyramid traps from June – September 2017, per county. Each county selected 5 trapping sites based on presence of BMSB preferred host plants (holly, empress tree and hazelnut) and proximity to the I-5/industrial corridor. Traps were monitored weekly through September. Monitoring included sampling surrounding vegetation using a beating sheet, extracting suspect BMSB from traps for verification and collecting egg masses.

Skagit County - The first BMSB was trapped on 26 June near the I-5 Anderson Road exit. A season total of 58 adults and 55 nymphs and 0 egg masses were collected at 4 of the 5 trapping locations. Only the Anacortes site remained negative throughout the season. High numbers of adult and late instar BMSB nymphs were observed in holly foliage on 2 October, at the site near the Anderson Road exit, however for consistency, the graph only represents numbers directly collected from the sticky trap and beat tray sampling (Appendix, Fig. 1). The numbers reflected in this report have exploded with the 10/02 discovery.

Whatcom County – Using the same procedures as above, Whatcom County collected a total of 6 adult stink bug adults and 0 nymphs and 0 egg masses from 2 different sites. The first specimens were collected 7 July 2017. Whatcom reports sticky traps were more effective than pyramid traps. While the pyramid traps will trap both adults and immature stink bugs, it is the only trap that will capture flightless immatures, therefore there is no evidence from this trapping season that BMSB is reproducing in Whatcom County.

Results: A single generation of BMSB was observed in Skagit County in 2017 with later instar nymphs appearing in traps in early August and new adults peaking in September (Appendix, Figs.1,2,3). The adults will overwinter in protected sites and repopulate areas next summer season, 2018. In contrast, Oregon reports 2 generations are possible there if enough heating degree days occur. The following bullets are a summary of results obtained in this project:

- Skagit County has resident, reproducing populations of BMSB.
- Populations are rapidly increasing in Skagit County.
- BMSB numbers are rising but more slowly in Whatcom County.
- No evidence of reproducing populations (nymphs) were discovered in Whatcom County.

Publications and Presentations: The Skagit County Pest Board was informed of these findings 16 October. Results were presented to growers and Henry Bierlink, the Executive Director of the Washington Red Raspberry Commission, at the annual Red Raspberry Commission Research Review, 4 October.

Appendix

Seasonality of Brown Marmorated Stink Bugs trapped in Skagit County, 2017.
Totals represent 5 pyramid and 5 sticky traps, each with a pheromone.

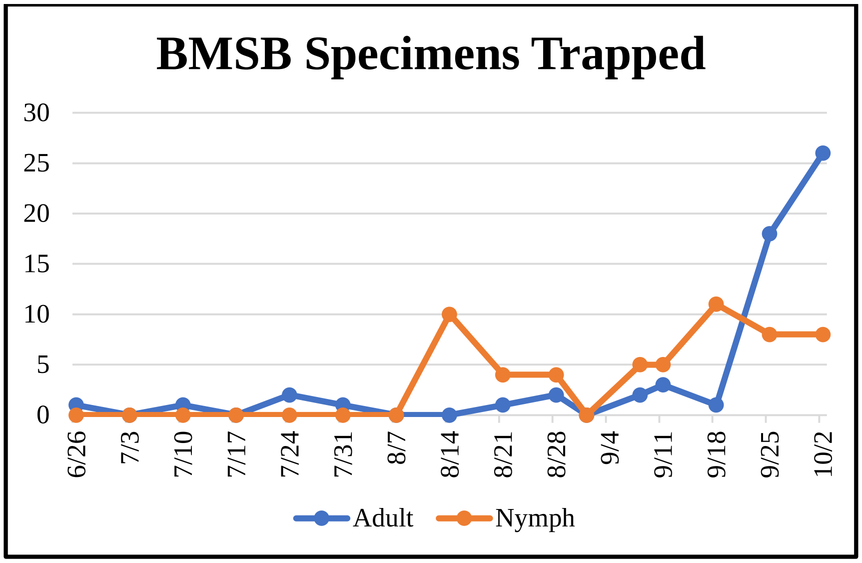

Fig. 1. 2017 BMSB totals from 5 traps located in Skagit County.
Graph courtesy of Ben Diehl, WSU Skagit County Extension.

Fig 2. BMSB nymph perfectly camouflaged against holly bark, a preferred host tree.

Fig. 3. A new adult BMSB, 2 October, still soft and not yet exhibiting its characteristic brown/gray color pattern.

2018 WRRC Proposal

Project Title: Delimiting distribution of BMSB, *Halyomorpha halys,* in Skagit and Whatcom Counties with additional survey and potential release of its egg parasitoid, *Trissolcus japonicus* as a longterm management strategy

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Collaborators:
Betsy Beers, Professor of Entomology, WSU TFREC, ebeers@wsu.edu, 509-663-8181
Josh Milne, Graduate Student, WSU IAREC, joshmilnes@gmail.com

Year Initiated: 2017 **Current Year:** 2017 **Terminating Year:** 2018
Total Project Request: $4,260
Other Funding Sources: Seeking funding from 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 have exploded in 2017 in Skagit County since its first detection in 2016 with numbers increasing in Whatcom County.

BMSB will feed and reproduce on blueberries, raspberries and blackberries (Rodriguez-Saona 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, threatening domestic trade and international exports.

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 identified in Southern Washington State, in 2015 by Betsy Beers, WSU Tree Fruit Research and Extension Center and in Walla Walla in 2017. This is significant and could be a *game-changer* for the small fruit industry but the parasitoid's distribution in the red raspberry epicenter of Western Washington remains unknown. Knowledge of the distribution of the egg parasitoid, *T. japonicus* in Western Washington may help to determine its suitability of mass releases. BMSB populations in the PNW are currently at levels most susceptible to biological control mass releases. Due diligence for natural enemy releases requires pre and post-release surveys. Therefore we propose to determine the distribution of BMSB in Skagit and Whatcom Counties, survey for *T. japonicus* and release *T. japonicus* if needed, to accelerate its establishment in NW Washington

Justification and Background: Washington produces 90% of the U.S. processed red raspberries and total production is valued at more than $90 million (2015 NAAS). Brown Marmorated Stink bug numbers have increased >200+ fold since 2016 and Whatcom County numbers are also increasing. Knowing its true distribution in these two counties will assist growers to prepare for potential infestations. Presence of *T. japonicus* will provide a longterm solution to managing BMSB.

Relationship to WRRC Research Priority: The Washington Red Raspberry Commission has recently added BMSB to tier 3 of its priority list, *Management options for control of BMSB*. There is no better longterm management solution for BMSB than biological control. The sudden increase in BMSB numbers between 2016 and 2017 suggests now is the critical window for releases of the egg parasitoid if it isn't already present.

Objective:

- This research is anticipated to determine the distribution of BMSB in Whatcom and Skagit Counties.
- Determine if *T. japonicus* is present in the region.
- Release *T. japonicus* if it is not identified in the surveys.

Procedures:

Expanded BMSB survey

BMSB surveys will be conducted from May through September of 2018. Ten locations for surveying BSMB will be based on presence of preferred host plants, particularly holly and empress tree or hazelnuts. Locations near industrial areas with high traffic routes are of particular interest. At each survey site, vegetation will be inspected weekly for presence of BMSB using a beating tray. Sticky cards with an attached *H. halys* lure (Alpha Scents, Inc, HalHal) will be set and checked weekly. Lures will be changed after 6 weeks. Sites where no stink bugs are collected after 2 weeks will be dropped and traps reset at new locations. Skagit County Extension personnel will be responsible for activities in Skagit County and Whatcom County Extension personnel will perform activities in their county.

Rearing BMSB for egg masses

WSU NWREC will establish a colony of BMSB to provide fresh sentinel egg masses for the survey based on USDA ARS recommendations. Reproductive pairs of BMSB will be placed into rearing containers 30 cm x 23 cm x 10 cm along with 50 ml glass containers covered with cotton to provide moisture. The bottom of the containers is lined with Kimwipes® and paper towels are inserted into each box to provide protection and a substrate for egg deposition. The containers will be exposed to 16-h photoperiod (16:8 h L:D) at 26^0C ±2 and 50-55% RH. BMSB adults will be provided organic green beans and seeds to promote egg development. Egg masses will be collected daily and stored at $10\text{-}12^0$ C to prevent further development. Two pre-cooled, non-viable BMSB egg masses on paper towel will be affixed to cards using double-sided sticky tape and provided to each county weekly for deployment during August and September.

Deployment and Collection

Each county will set out 2 sentinel egg masses weekly in August and September at locations with high numbers of BMSB to increase the likelihood of detecting parasitoids. Egg masses on cards will be stapled to the underside of leaves as high as possible with attached flagging to relocate. Egg masses will be retrieved 3 days later to prevent losses from predation and weathering and returned to WSU NWREC. Parasitoids found on the egg masses in the field will be collected using an aspirator and returned to WSU NWREC for identification.

Parasitoid Rearing and Shipment

Parasitized egg masses will be held for emergence in crispers stacked on shelves and exposed to 16-h photoperiod (16:8 h L:D) at 26^0C ±2 and 50-55% RH. Recovered wasps will be shipped to Josh Milnes, at WSU IAREC in Prosser, WA for identification. Betsy Beers will serve as an expert resource.

Anticipated Benefits and Information Transfer:

This research is anticipated to clarify the presence and distribution of BMSB and its egg parasitoids in Skagit and Whatcom Counties in Northwest Washington. Following a 2-month survey for egg parasitoids, *T. japonicus* will be released if absent from surveys. 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 WSU NWREC Entomology webpage, http://mtvernon.wsu.edu/ENTOMOLOGY/main/index.html, 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.

BMSB Proposed Budget 2018

Salaries and Wages:	
1 month @ 50% for Plant Technician I (WSU NWREC)	$1,252.40
Non-student time-slip employee $13/hr for 30 hrs/4 weeks	$1,560
Benefits:	
1 month employee benefits for Plant Technician 1 @ 96.84%	$1,213
Non-student time-slip employee @ 9.5%	$148.20
Goods & Services	
Operations	
Travel - WSU NWREC 160 miles @ $0.54/mile	$86.40
Total	**$4,260**

References:

N. Wiman, J. Parker, V. Walton, C. Rodriguez-Saona, Z. Milburn, B. Smith, B. Strik, D. Bryla, C. Finn. 2015. Characterizing damage of brown marmorated stink bug in OR and NJ blueberries. http://www.stopbmsb.org/stopBMSB/assets/File/Research/BMSB-SAP-Dec-2013/Small-Fruit-Rodriguez-Saona.pdf

2018 WRRC Proposal

Project Title: Factors affecting spider mite outbreaks in PNW red raspberry

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Year Initiated: 2017 **Current Year:** 2017 **Terminating Year:** 2018
Total Project Request: $12,662
Other Funding Sources: Seeking funding from WSCPR

Year Initiated: 2016 **Current Year:** 2016-2017 **Terminating Year:** 2017

Description:
Washington produces approximately 75% of the total US production of frozen red raspberries, almost entirely (95%) from Whatcom and Skagit Counties. Whatcom County Washington is home to the majority of red raspberry producers in the PNW (93 of 122 berry farms) and 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. Prices have fluctuated due to volume, with $89 million reported for 2015, a 51% increase over 2014.

It has been 8 years since spotted wing drosophila, *Drosophila suzukii*, SWD, was discovered in Washington State and soon thereafter its preference for caneberries, particularly red raspberry was confirmed. Growers responded to the threat with weekly applications of insecticides in order to protect their berries from infestation by this exotic direct pest. SWD are highly susceptible to synthetic pyrethroids, which have excellent "knockdown" capability and management programs quickly became heavily weighted with pyrethroids, beginning with bifenthrin (e.g. Brigade®, IRAC 3A), the industry standard clean-up spray, followed by zeta cypermethrin, Mustang® Maxx (IRAC 3A) often alternating with the organophosphate malathion (IRAC 1B) or with a neonicotinoid (IRAC 4B) by the 3rd rotation. Unfortunately, pyrethroids and neonicotinoids can stimulate oviposition in spider mites, exacerbating the problem and repetitive use, fuels concern that mite resistance could develop in red raspberries (Gerson and Cohen 1989).

Among the multiple species of spider mites that can infest red raspberry, yellow spider mites and twospotted spider mites are the dominate species. Yellow spider mites are active in cooler temperatures and prefer to move up into the trellised floricanes early in the season and can cause bronzing or leaf drop. Plants stressed from yellow mite damage can stimulate twospotted spider mite outbreaks (pers. observation). In 2017, the long-lingering wet spring gave way to drought conditions and spider mite populations surged. Responding to reports of spider mite outbreaks, we performed preliminary toxicity tests of twospotted spider mites to compare effects of bifenthrin (miticide/insecticide) against a popular miticide, Acramite® (bifenazate). Bifenthrin not only failed to cause spider mite mortality but increased egg production, while Acramite caused high mortality. Growers have indicated less expensive generic brands of bifenazate are no longer effective. This proposal will attempt to confirm these reports but for now, even if costlier, Acramite is still an effective spider mite control. What factors led to reports of miticide failures in red raspberry?

- SWD management programs heavily weighted towards pyrethroids and organophosphates.
- Pyrethroids, organophosphates and neonicotinoids can stimulate spider mite oviposition.
- Potential for spider mite resistance increases with repetitive use of insecticides.
- Drought conditions increase water stress in red raspberry, stimulating mites.

If full-blown spider mite resistance were to develop in PNW red raspberry, outbreaks would increase and shift earlier, threatening raspberry during the harvest season. With miticide seasonal usage restrictions, growers could be scrambling to control mites regardless of MRL restrictions and target export countries.

Understanding the risk factors for spider mite outbreaks in red raspberry, incorporating resistance management into the current SWD programs and performing a baseline tolerance study will provide the best insurance to avert spider mite resistance. This project proposes to perform a baseline sensitivity test to detect tolerance toward 4 red raspberry registered miticides (field rate, ½ rate and ¼ rate) with favorable MRLs: Acramite and Banter (generic) (bifenazate), Agri-Mek (abamectin) and Savey (hexythiazox).

Justification and Background:
Washington produces approximately 75% of the total US production of frozen red raspberries, almost entirely (95%) from Whatcom and Skagit Counties. Whatcom County Washington is home to the majority of red raspberry producers in the PNW (93 of 122 berry farms) and 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. Growers can't afford to lose any more revenues especially to pest damage. The 2017 spider mite outbreaks were unprecedented for Whatcom County red raspberries. Background information on tolerance levels could determine if miticide tolerance played a role in the outbreaks. It is critical to determine if current products remain efficacious. Spider mites have a history of developing resistance and gained the dubious title of the world's top resistant animal pest in 2010 (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. In some cases resistance developed after only a few applications!
Relationship to WRRC Research Priority: The Washington Red Raspberry Commission has mite management listed in the # 2 priority category but the severe outbreaks this past season coupled with our preliminary findings of tolerance to bifenthrin, suggest the mites could be rapidly moving toward resistance development and worthy of a higher priority position.

Objective:
The project addresses the following objective:

- Determine baseline sensitivity/tolerance of Whatcom County red raspberry twospotted spider mite populations to 3 popular red raspberry miticides with compatible MRLs: bifenazate (Acramite®, Banter®), abamectin (AgriMek®), and hexythiazox (Savey®).

Procedures:

Baseline sensitivity/tolerance

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 3 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 3 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 four 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.

Anticipated Benefits and Information Transfer:

This research is anticipated to determine baseline sensitivity to 3 popular raspberry miticides. This will alert growers to the extent of resistance development in their spider mite populations and allow them to adopt a resistance management plan to maintain manageable populations. 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.

Proposed Budget 2018

Salaries and Wages:	
2 month @ 65% FTE for Ag Research Tech III ($4,191)	$5,448
2 months @ 28% FTE for Plant Technician I ($2,595)	$1,453
Non-student time-slip ($13/hr @ 20 hr/week/8 weeks	$2,080
Benefits:	
2 months Ag Research Tech III @ 44.2%	$2,347
2 months Plant Technician 1 @ 96.8%	$1,406
Non-student time-slip employee @ 9.5%	$197
Goods and Services	
Petri dishes, filter paper, cotton, paper sacks, artists brushes	$100
Travel – Weekly trips to Whatcom County @ $0.54/mile	$432
Total	**$13,464**

References:

Gerson, U., and E. Cohen. 1989. Resurgences of spider mites (Acari: Tetranychidae) induced by synthetic pyrethroids. Experimental and Applied Acarology 6: 29-46.

Van Leeuwan, T.V., Dermauw, W., Tirry, L, Vontas, J., and A. Tsagkarakou. 2010. Acaricide resistance mechanisms in the twospotted spider mite *Tetranychus urticae* and other important Acari. Insect Biochemistry and Molecular Biology 40: 563-571.

Washington Red Raspberry Commission
Continuing Progress Report for 2017 Project

Project No: WRRC2017-001

Title: Non-toxic RNAi-based biopesticide to control spotted wing drosophila

Principle Investigators: Man-Yeon Choi, USDA-ARS Horticultural Crops Research Unit, Corvallis, OR, Phone office 541-738-4026, e-mail mychoi@ars.usda.gov

Collaborators: Dr. Jana Lee – Research Entomologist, Dr. Robert R. Martin – Research Plant Pathologist, USDA-ARS Horticultural Crops Research Laboratory, Corvallis, OR,

Reporting Period: FY2017 (1 of 3 years)

Accomplishments:

- Selected and sequenced > 30 genes from SWD for RNAi targets
- Constructed, and designed dsRNA (double-stranded RNA, RNAi material) for all targets
- Established SWD specific nano-injection system for the initial screening
- Screened 13 potential RNAi targets from SWD

Results:

1. Identification: We identified DNA sequences for 13 candidate genes, designed and synthesized their dsRNAs. We found some genes identified in this study were very different from those sequences published on the SWD genome data, indicating a wrong annotated or uncompleted the SWD genome that should need to be confirmed actual sequences for each target genes. Eight housekeeping genes as constitutive genes are expressed in all cell types at a level that does not fluctuate with the cell cycle.

2. Initial screening: The 1st screening with 13 RNAi candidates was completed with over 2,000 nano-injections to flies. We found effective phenotypic impacts, mainly mortality, from some of the RNAi injection into SWD flies. Then, three most effective RNAi candidates have been selected for further genotypic test that is quantitative PCR (qPCR) analysis for the gene expression after RNAi injection.

3. Genotypic impact of the potential 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.

Publications:
Poster presentation: RNAi-based control for SWD titled on 'Insect pests of grapes and their management' at the USDA-ARS workshop, Portland, OR 11/28-30/2017.

2018 WASHINGTON RED RASPBERRY COMMISSION RESEARCH PROPOSAL

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

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

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Cooperators: Dr. Jana Lee, Research Entomologist; Robert R. Martin, Research Pathologist, USDA-ARS, Corvallis, OR 97330

Year Initiated __2017__ **Current Year** __2018__ **Terminating Year** __2020__

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

Other funding sources: Commissions of Oregon Blueberry, Rasp-Blackberry, Washington Blueberry and Red& Raspberry, Washington and Oregon Sweet Cherry.
Current pending and support form attached

Project Description: Spotted wing drosophila (SWD) is a destructive fly pest attacking s a wide range of ripening fruits including almost all small and stone fruits. Since the first arriving in U.S. mainland 2008 the infestation of SWD is rapidly expanding across United States. The estimated economic impact from crop yield loss, drop in market value, and higher management cost is hundreds of millions of dollars in the U.S. alone, and increasing every year. Current control methods depend on chemical insecticides carrying many negative effects. Therefore, novel approaches such as non-toxic insecticides or biologically-based environmentally friendly alternatives are requested by growers.
RNA interference (RNAi) for insect control represents a new direction and promising tool for insect pest management. One of the key advantages of RNAi technology is its high degree of species-specificity for the target pests; this is a unique point compared other conventional insecticides. To develop RNAi application there are several major challenges that must be overcome. Our previous RNAi studies on SWD that addressed these technical problems, and it now can bridge a gap to develop a novel RNAi-based SWD control option. This technology enables us to develop biologically-based control alternatives for SWD to protect the small fruit industries.

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 Commission Research Priorities: *Management options for control of the Spotted Wing Drosophila* which is related in WRRC'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)
2. Construct, design and biosynthesis dsRNAs for target genes (Yrs. 1 & 2)
3. Screen for efficacy using bioassay to measure RNAi impacts on SWD (Yrs. 2& 3)
   3-1. Inject dsRNA into adult flies and monitor RNAi impacts (Yrs. 2& 3)
   3-2. Feed dsRNA to larvae and adults, and evaluate RNAi impacts (Yr. 3)

Procedures

PI has expertise on insect RNAi and published research results in several peer-reviewed papers 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 submitted for patent applications and awarded an RNAi patent 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.

<u>List of Accomplishments</u>

1st year: Identify partial and/or full sequences for more target genes, and obtain actual DNA data.

2nd year: Design templates for dsRNA synthesis, synthesis dsRNAs for all target genes and evaluate each dsRNA amount and purity.

3rd year: Determine negative phenotype and/or genotype impacts on SWD, obtain narrowed down SWD RNAi targets for further evaluation.

Anticipated Benefits and Information Transfer: 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 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., 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. 2013. Formicidae (Ant) control using double-stranded RNA constructs, Patent No US 8575328.

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

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Budget

This project is being submitted to OBC, WBC, ORBC and WRRC ($10,000 each) for FY18-19. USDA-ARS base funds in Dr. Choi's programs will be used to fund additional technical support and supplies for the project.

	2018	2019
Salaries[1/]	$24,500	$25,200
Time-Slip	$0	$0
Supplies & Services	$10,000	$9,200
Travel[2/]	$1,200	$1,200
Meetings	$0	$0
Other	$0	$0
Equipment[3/]	$0	$0
Benefits[4/]	$4,300	$4,400
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 (50%) - Fringe benefits are actual cost (~ $715 per month).

Total Budget for Project 2018 $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,	$20,000	01/01/2017 - 12/31/2017	5	Development of biologically-based RNAi Insecticide to control spotted wing drosophila
Choi	WBC & WRRC	$10,000	01/01/2017 - 12/31/2017	3	Development of biologically-based RNAi Insecticide to control spotted wing drosophila
Choi/Martin	OR Association of Nursery	$14,700	06/01/2017- 05/31/2018	3	Genomic sequencing of gray garden slug: A molecular foundation for slug research
Choi/Martin/ Rao	ARF	$12,500	01/01/2017- 12/31/2018	2	Genome sequencing to develop RNAi strategy for slug management in the Willamette Valley
Choi/Lee	WA Tree Fruit Research	$43,880	01/01/2017- 12/31/2017	8	Non-toxic RNAi-based biopesticide to control spotted wing drosophila
Choi/Martin	OR Seed Council	$20,000	01/01/2017- 12/31/2017	3	Screening of target genes to develop an RNAi-based biopesticide to control gray garden slug (*Deroceras reticulatum)*

	Pending:				
Jurenka/Choi ($120K subcontract)	USDA-NIFA	$500,000	01/01/2018-12/31/2020	10	Identify oxidase and acetyltransferase in pheromone biosynthesis
Choi	OBC, ORBC, WBC, WRRC	$40,000	01/01/2018-12/31/2018	8	Development of biologically-based RNAi Insecticide to control spotted wing drosophila
Choi/Martin	OR Association of Nursery	$20,000	06/01/2018-05/31/2019	5	Identify biological targets to develop slug management for nursery crops
Choi/Lee	WA Tree Fruit Research	$48,260	01/01/2018-12/31/2018	8	Non-toxic RNAi-based biopesticide to control spotted wing drosophila

Managing SWD in Red Raspberry with Reduced Insecticide Residues

Alan Schreiber, Agriculture Development Group, Inc., Eltopia, WA

Tom Walters, Walters Ag Research, Anacortes, WA

The goal of this project was 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 were front loaded with “harder” conventional insecticides and switched 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.

During the summer of 2017, the staff of the Agriculture Development Group, Inc. initiated a research trial investigating the efficacy of multiple organic and conventional insecticides in different rotation combinations for the control of spotted wing drosophila (SWD) in raspberry. The objective of the trial is to develop new types of SWD management programs that would in insecticide residues that would be acceptable for foreign export markets. Export markets have residue limits called maximum residue limits (MRLs). Functionally there are two kinds of MRLs those that are similar or moderately lower than those of the U.S. and those that are nonexistent or so low that it effectively precludes use of a product.

Materials and Methods

The experimental design for this trial was a RCB with 4 replications and plot sizes of 10ft x 20ft. Applications for this trial were made with an over the row sprayer calibrated to apply treatment sprays at 25 gallons per acre. Applications were initiated at first appearance of SWD on August 3.

This trial had a complicated rotation schedule of different products at different timing for treatment 1 through treatment 7, while treatment 8 and 9 only had two applications (see ANOVA table below for the treatment details). Applications were made on August 3, 10, 17, 21, 25, and 30 (ABCDEF). Amount of SWD larva in 100 berries was evaluated on August 15, 20, 25, 28, and September 5, which were 5, 3, 4, 3, and 6 days after B, C, D, E, and F applications (DAB, DAC, DAD, DAE and DAF), respectively. DAB means days after the B application so 7 DAB would mean seven days after the B application.

ANOVA Table

					Number of SWD per 100 fruit											
		Days After First and Last Application			12 5		17 3		22 4		25 3		33 6			
Trt No.	Treatment	Rate of Application		No. of Applic.	15-Aug		20-Aug		25-Aug		28-Aug		5-Sep		Total	Ave.
1	control				1.5	a	0	a	5	a	0.5	a	3.5	a	8	a
2	Delegate	420	g/ha	A	0.3	a	0	a	0	a	0	a	0.3	a	0.5	a
	Malathion	20	fl oz/a	B												
	Bifenture 10DF	6.4	oz/a	C												
	Malathion	20	fl oz/a	D												
	Mustang Max	4	fl oz/a	E												
	Grandevo	3	lb/a	F												
3	Danitol	1	pt/a	A	0	a	0	a	0	a	0	a	0.3	a	0.3	a
	Malathion	20	fl oz/a	B												
	Mustang Max	4	fl oz/a	C												
	Grandevo	3	lb/a	D												
	Jet Ag	1.25	% v/v	D												
	Venerate	6	qt/a	E												
	Jet Ag	1.25	% v/v	E												
	Grandevo	3	lb/a	F												
	Jet Ag	1.25	% v/v	F												
4	Danitol	1	pt/a	A	0.8	a	0.3	a	0	a	0	a	1.5	a	2.5	a
	Malathion	20	fl oz/a	B												
	Mustang Max	4	fl oz/a	C												
	Venerate	6	qt/a	D												
	Jet Ag	1.25	% v/v	D												
	Grandevo	3	lb/a	E												
	Jet Ag	1.25	% v/v	E												
	Venerate	6	qt/a	F												
	Jet Ag	1.25	% v/v	F												
5	Delegate	420	g/ha	A	0.5	a	0	a	1.5	a	0.8	a	0	a	2	a
	Malathion	20	fl oz/a	B												
	Bifenture 10DF	6.4	oz/a	C												
	Grandevo	3	lb/a	D												
	Jet Ag	1.25	% v/v	D												
	Venerate	6	qt/a	E												
	Jet Ag	1.25	% v/v	E												
	Grandevo	3	lb/a	F												
	Jet Ag	1.25	% v/v	F												
6	Delegate	420	g/ha	A	1	a	0	a	5	a	0.3	a	3	a	6.8	a
	Malathion	20	fl oz/a	B												
	Bifenture 10DF	6.4	oz/a	C												
	Venerate	6	qt/a	D												
	Jet Ag	1.25	% v/v	D												
	Grandevo	3	lb/a	E												
	Jet Ag	1.25	% v/v	E												
	Venerate	6	qt/a	F												
	Jet Ag	1.25	% v/v	F												
7	Delegate	420	g/ha	A	0.3	a	1	a	0	a	0.3	a	1	a	2.5	a
	Malathion	20	fl oz/a	B												
	Bifenture 10DF	6.4	oz/a	C												
	Success	6	fl oz/a	D												
	Jet Ag	1.25	% v/v	D												
	Grandevo	3	lb/a	E												
	Jet Ag	1.25	% v/v	E												
	Success	6	fl oz/a	F												
	Jet Ag	1.25	% v/v	F												
8	KFD-318-01	8.5	fl oz/a	AB	0	a	0	a	2	a	0	a	0.8	a	1.8	a
9	Bifenture 10DF	6.4	oz/a	AB	1.5	a	0	a	1	a	0	a	3	a	5	a

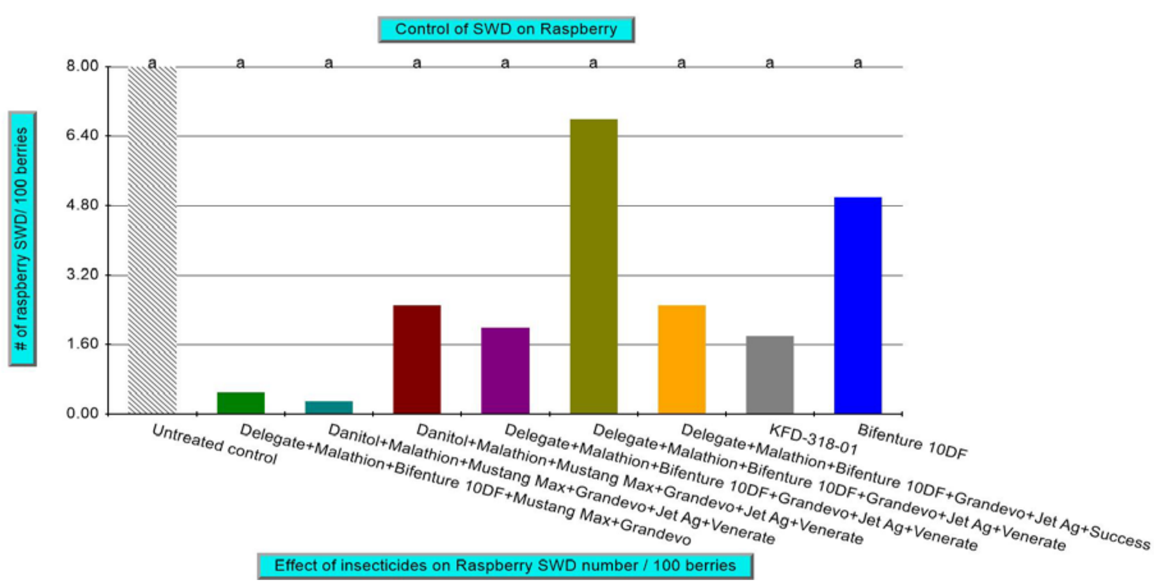
Results and Discussion

The most critical information is the ANOVA table particularly the data column to the far right headed by the column "Total Ave.". This column shows the total average number of SWD found per 100 fruit over the course of the trial. All insecticidal treatments resulted in less SWD larva than untreated control with treatment 2 and 3 resulted in relatively better control than others with 67% to 233% lower larva counts across the rating dates, and 4 to 25-fold lower study total counts. Treatment 2 is a program most similar to a standard conventional program.

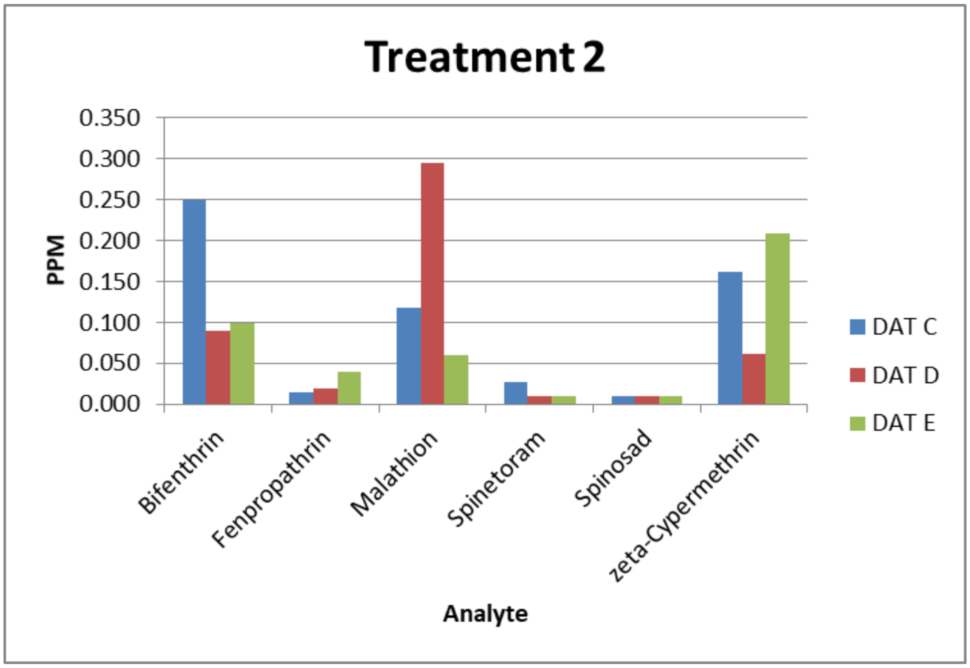
Treatment 4, 5, and 7 performed very similar to treatment 2 and 3 with slightly higher amount of SWD larva, yet somehow treatment 6 did not show a control efficacy as good as other treatments. It is interesting to see that the only differences between treatment 5 and 6 was the sequence and amount of rotations of Grandevo and Venerate, indicating a potential better control efficacy from Grandevo than Venerate. Similar potential can be observed when comparing treatment 3 and 4, while 3 is better than 4, and the only differences were again the different sequences and amount of rotations of Grandevo and Venerate. Additionally, although treatments KFD-318-01 and Bifenture 10 DF only had two applications, they showed 77.5% and 37.5% reduction of total SWD, respectively, compared to the untreated control.

Of similar importance is that virtually all of the treatments using the tolerance exempt products resulted in residues that would allow the fruit to enter several major export markets. However, the fruit would still be violative of MRLs for countries with no or very low MRLs for some products. Markets such as Hong Kong and the EU would still be out of reach of exporters with these SWD programs. Markets such as Japan, Canada and South Korea would accept this fruit.

Graph 1. Effect of insecticides on total number of raspberry SWD per 100 berries.



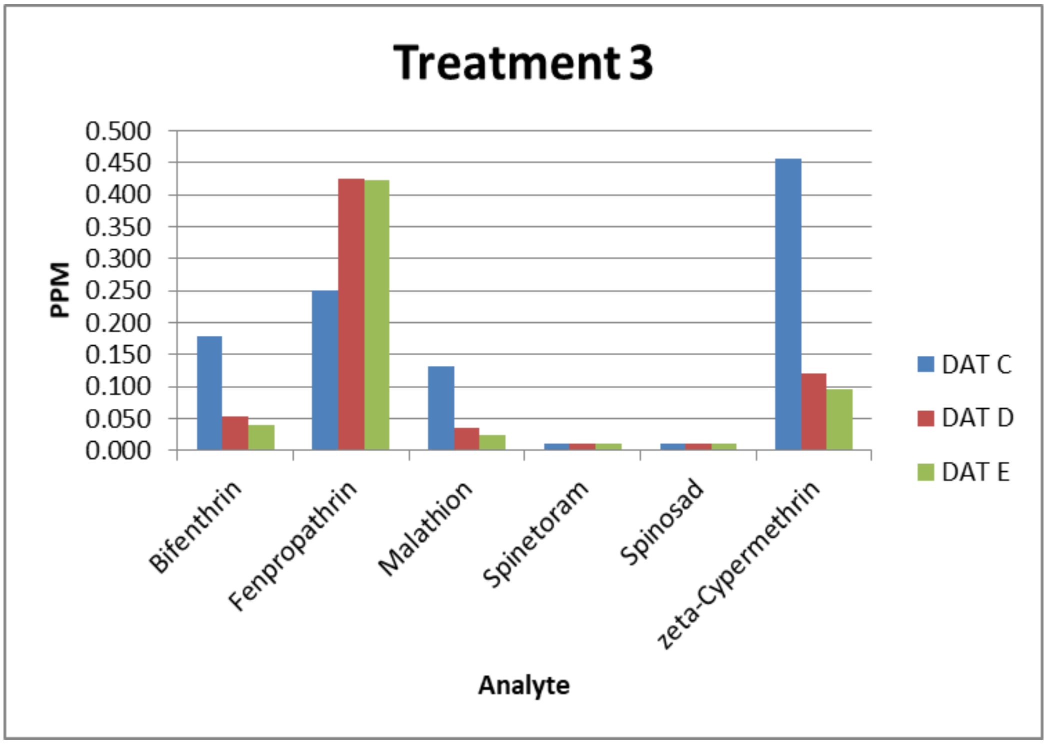
Graph 2. Treatment 2 program (0.5% of fruit infested with SWD).



Delegate	420	g/ha	A
Malathion	20	fl oz/a	B
Bifenture 10DF	6.4	oz/a	C
Malathion	20	fl oz/a	D
Mustang Max	4	fl oz/a	E
Grandevo	3	lb/a	F

This program is close to a regular conventional program currently used by the raspberry industry and would meet MRLs for the US, Philippines, Korea, and Japan, but the Europe, Canada, Taiwan, Hong Kong, Australia, and China markets are out of reach of Washington exporters.

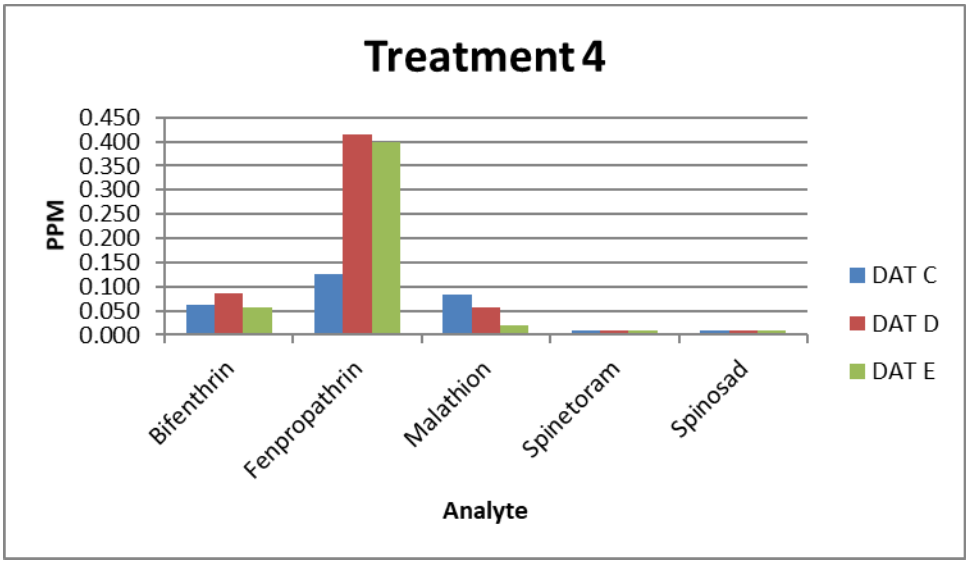
Graph 3. Treatment 3 program (0.25% of fruit infested with SWD).



Danitol	1	pt/a	A
Malathion	20	fl oz/a	B
Mustang Max	4	fl oz/a	C
Grandevo	3	lb/a	D
Jet Ag	1.25	% v/v	D
Venerate	6	qt/a	E
Jet Ag	1.25	% v/v	E
Grandevo	3	lb/a	F
Jet Ag	1.25	% v/v	F

This program would meet MRLs for the US, Philippines, Korea, and Japan, but the Europe, Canada, Taiwan, Hong Kong, Australia, and China markets are out.

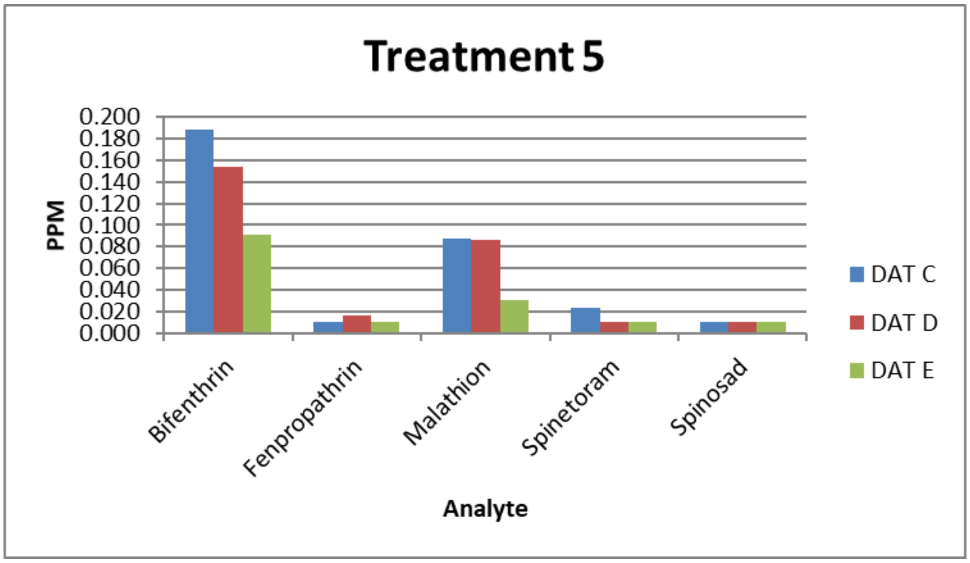
Graph 4. Treatment 4 program (2.5% of fruit infested with SWD).



Danitol	1	pt/a	A
Malathion	20	fl oz/a	B
Mustang Max	4	fl oz/a	C
Venerate	6	qt/a	D
Jet Ag	1.25	% v/v	D
Grandevo	3	lb/a	E
Jet Ag	1.25	% v/v	E
Venerate	6	qt/a	F
Jet Ag	1.25	% v/v	F

This program would meet MRLs for the US, Philippines, Korea, Canada, Sand Japan, but the Europe Taiwan, Hong Kong, Australia, and China markets are out.

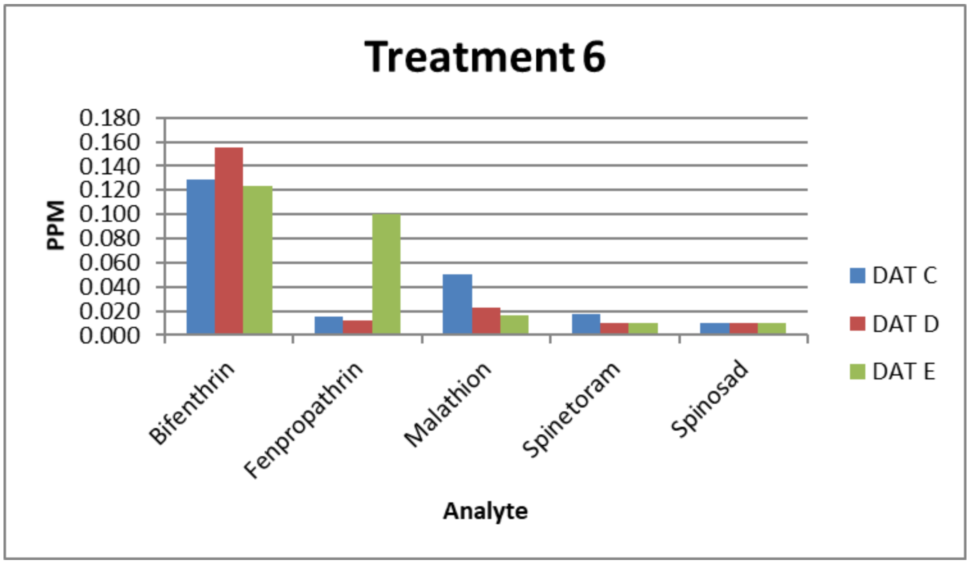
Graph 6. Treatment 5 program (2.0% of fruit infested with SWD).



Delegate	420	g/ha	A
Malathion	20	fl oz/a	B
Bifenture 10DF	6.4	oz/a	C
Grandevo	3	lb/a	D
Jet Ag	1.25	% v/v	D
Venerate	6	qt/a	E
Jet Ag	1.25	% v/v	E
Grandevo	3	lb/a	F
Jet Ag	1.25	% v/v	F

This program would meet MRLs for the US, Philippines, Korea, Canada, and Japan, but the Europe, Taiwan, Hong Kong, Australia, and China markets are out.

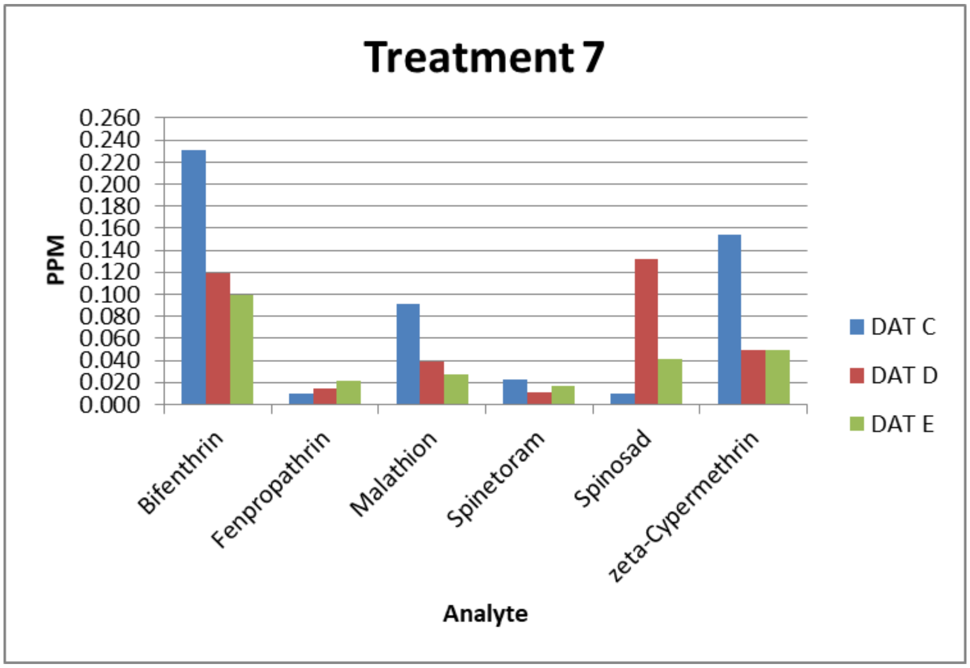
Graph 7. Treatment 6 program (6.8% of fruit infested with SWD).



Delegate	420	g/ha	A
Malathion	20	fl oz/a	B
Bifenture 10DF	6.4	oz/a	C
Venerate	6	qt/a	D
Jet Ag	1.25	% v/v	D
Grandevo	3	lb/a	E
Jet Ag	1.25	% v/v	E
Venerate	6	qt/a	F
Jet Ag	1.25	% v/v	F

This program would meet MRLs for the US, Philippines, Korea, Canada, and Japan, but the Europe, Taiwan, Hong Kong, Australia, and China markets are out.

Graph 4. Treatment 7 program (2.5% of fruit infested with SWD).



Delegate	420	g/ha	A
Malathion	20	fl oz/a	B
Bifenture 10DF	6.4	oz/a	C
Success	6	fl oz/a	D
Jet Ag	1.25	% v/v	D
Grandevo	3	lb/a	E
Jet Ag	1.25	% v/v	E
Success	6	fl oz/a	F
Jet Ag	1.25	% v/v	F

This program would meet MRLs for the US, Philippines, Korea, and Japan, but the Europe, Canada, Taiwan, Hong Kong, Australia, and China markets are out.

Based on this first year's effort, we believe that with additional work we can improve efficacy and further reduce residue levels. Additionally, we would like to attempt a program that would result in no detectable residues that would permit entry into any market in the world.

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

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

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

Cooperators: Tom Walters-Walters Ag Research

Year Initiated: 2017 **Current Year:** 2018 **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 $15,000 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.

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.

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, Berendsun 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

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 $3,000 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.

WRRC Final Report 2017

Title: WSU NWREC Raspberry Field Plot for Invasive Pests and Foliar/fruit Disease Management Trials

Personnel:
Beverly S. Gerdeman, WSU Assistant Research Professor Entomology bgerdeman@wsu.edu 360-848-6145
Lisa Devetter, WSU Assistant Professor Small Fruit Horticulture lisa.devetter@wsu.edu 360-848-6124
WSU NWREC, 16650 State Route 536, Mount Vernon, WA 98273

Reporting Period: 2017

Accomplishments: Olson Field West (Fig. 1) on the WSU NWREC campus was selected for the location of the red raspberry experimental field plot. The soil is field silt loam (USDA 1980) and well suited for red raspberry. Irrigation water is easily accessible and applied weekly. Locating it near the late season red raspberry varietal trial increases the potential for a SWD infestation for experiments. Julie Enfield, NW Plant Co, Ferndale, WA, graciously waived the annual license fee for ‘Wakefield’ plugs for the life of the planting. Bed preparation for the red raspberry experimental field plot began in early May 2017 (Appendix, Fig.2) with planting following on 11 May. Approximately 900’ of ‘Meeker’ and 900’ of ‘Wakefield’ (393 tissue culture plugs for each cultivar) were transplanted into biodegradable mulch at the recommended 27.5” spacing on 6 and a partial 7th row set on 10’ centers, for a combined total of 0.4 acres. (Appendix, Fig. 2). Plots were fertigated weekly with 46-0-0 from 23 May – 31 July. Plants are exhibiting vigorous growth (Appendix, Fig. 3). Posts are anticipated to be set prior to spring 2018. First year trials will occur when an adequate volume of berries allows replication.

Publications and Presentations: Status of the experimental field was presented to growers and Henry Bierlink, the Executive Director of the Washington Red Raspberry Commission, at the annual Red Raspberry Commission Research Review, 4 October.

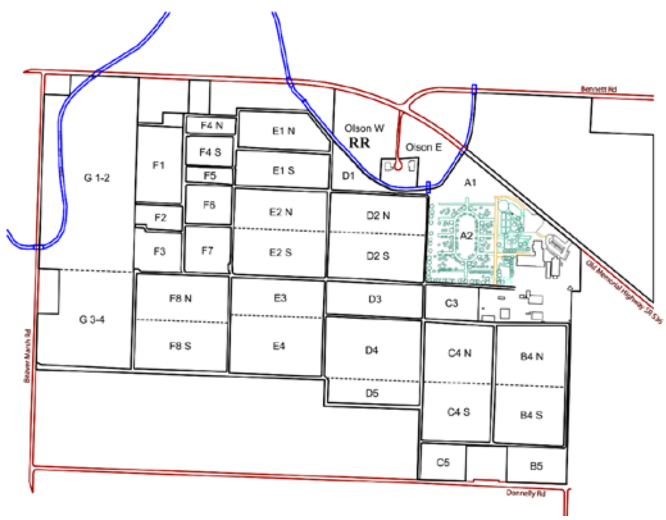


Fig. 1. WSU NWREC with red raspberry experimental field plot location marked as “RR” in Olson W.

Appendix

WSU NWREC Raspberry Field Plot for Invasive Pests
and Foliar/fruit Disease Management Trials

Fig 2. Shaping the raspberry beds and applying biodegradable mulch May 2017 WSU NWREC.

Fig. 3. Raspberry planting exhibiting vigorous growth August 2017, WSU NWREC.

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: 2016-17

Accomplishments: Two raspberry trials were conducted during 2016-17: 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 Lower Mainland Horticulture Improvement Association Short Course in Abbotsford.

Results:

Caneburning trial. The objective of this trial is to determine how raspberry vigor may influence the effects of caneburning treatments and potentially affect stand longevity. The 2017 trial was established 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:

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). Standard treatments were applied when first primocanes were 4- to 6-inches tall (April 14, 2017). 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. If the full bed had been treated at the early timing, the late treatments were applied May 19, 2017. Finally, if the full bed had been treated at the standard timing, the late treatments were applied May 25, 2017.

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). 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 eastern "low vigor" plots contained fewer floricanes than western "high vigor" plots (77 and 101 canes/25 ft, respectively) (data not shown). Floricane count did not differ going prior to application of caneburning treatments, indicating that vigor was similar among the raspberry plants in all the plots (Table 1). Berry sample weight was greater in "high vigor" plots than in "low vigor" plots (327 and 290 g/m, respectively), as was 50-berry weights (1.9 and 1.8 g/berry, respectively). Neither total sample weight nor 50-berry weights differed by treatment in either section of when analyzed regardless of vigor classification (Tables 2 and 3).

This experiment will continue into 2018. Next season's floricanes will be counted and length determined during winter 2017-18 to determine the effect of 2017 caneburning programs on raspberry growth. The plots will receive the same caneburning program in 2018, with similar berry sampling and cane counts occurring next season.

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, 'Meeker', 'Squamish', and 'Wakefield' red raspberry plugs were transplanted May 24, 2016. 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. Weed control was estimated on July 26 and September 12, 2016 and July 18 and October 16, 2017. 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. 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.

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. Cane length in 2016 was reduced by POSTR Chateau at both rates, Fierce, and Matrix in both July and September (Table 5). In 2017, herbicide treatment did not influence raspberry growth by mid-season. By October, however, raspberry growth was maximized by Chateau, Alion, Surflan, Trellis, and Sandea.

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 two-year raspberry growth response values are given, be aware that 2016 values were taken in September compared to October in 2017, and that Chateau and Fierce were applied differently in the two years, and only single-year measurements were generated for Devrinol and Alion. '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.

A final cane number and length will be determined in December, 2017, after which plots will be mowed. Plots will be treated with glyphosate in February, 2018 to control emerged weeds, and then retreated with the same herbicides prior to shoot emergence, 2018. Weed control and final growth numbers will be evaluated until July, 2018.

Table 1. Floricane counts among "low" and "high" vigor 'Meeker' raspberry prior to application of caneburning herbicides (2017).

Treatment	"Low vigor"	"High vigor"	Overall
	Flori. no./plot	Flori. no./plot	Flori. no./plot
1. No in-row treatments; late treatment with Aim to sides of the bed	76.0	100.8	88.4
2. Early treatment with Aim to full bed; no late treatment to sides of the bed	72.3	92.5	82.4
3. Standard treatment with Aim to full bed no late treatment to sides of the bed	60.8	106.5	83.6
4. Early treatment with Aim to full bed; late treatment with Aim to sides of the bed	72.8	108.5	90.6
5. Standard treatment with Aim to full bed; late treatment with Aim to sides of the bed	75.0	104.5	89.8
6. No in-row treatments; late treatment with Goal to sides of the bed	84.0	104.3	94.1
7. Early treatment with Goal to full bed; no late treatment to sides of the bed	80.3	105.0	92.6
8. Standard treatment with Goal to full bed; no late treatment to sides of the bed	85.3	99.3	92.3
9. Early treatment with Goal to full bed; late treatment with Aim to sides of the bed	83.5	98.0	90.8
10. Standard treatment with Goal to full bed; late treatment with Aim to sides of the bed	78.3	93.3	85.8
11. No caneburning (nontreated check)	82.0	100.3	91.1

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).

Treatment	“Low vigor”	“High vigor”	Overall
	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	360.0	313.3
2. Early treatment with Aim to full bed; no late treatment to sides of the bed	308.3	329.8	319.0
3. Standard treatment with Aim to full bed no late treatment to sides of the bed	282.5	302.0	292.3
4. Early treatment with Aim to full bed; late treatment with Aim to sides of the bed	281.5	323.3	302.4
5. Standard treatment with Aim to full bed; late treatment with Aim to sides of the bed	267.5	326.0	296.8
6. No in-row treatments; late treatment with Goal to sides of the bed	331.8	347.3	339.5
7. Early treatment with Goal to full bed; no late treatment to sides of the bed	303.8	324.0	313.9
8. Standard treatment with Goal to full bed; no late treatment to sides of the bed	307.5	310.3	308.9
9. Early treatment with Goal to full bed; late treatment with Aim to sides of the bed	272.3	342.0	307.1
10. Standard treatment with Goal to full bed; late treatment with Aim to sides of the bed	321.5	335.8	328.6
11. No caneburning (nontreated check)	250.5	302.0	276.3

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).

Treatment	“Low vigor”	“High vigor”	Overall
	g/berry	g/berry	g/berry
1. No in-row treatments; late treatment with Aim to sides of the bed	1.6	2.0	1.8
2. Early treatment with Aim to full bed; no late treatment to sides of the bed	1.8	1.8	1.8
3. Standard treatment with Aim to full bed no late treatment to sides of the bed	1.8	1.9	1.8
4. Early treatment with Aim to full bed; late treatment with Aim to sides of the bed	2.1	2.0	2.0
5. Standard treatment with Aim to full bed; late treatment with Aim to sides of the bed	1.7	2.0	1.8
6. No in-row treatments; late treatment with Goal to sides of the bed	1.9	1.9	1.9
7. Early treatment with Goal to full bed; no late treatment to sides of the bed	1.7	1.9	1.8
8. Standard treatment with Goal to full bed; no late treatment to sides of the bed	1.8	1.9	1.9
9. Early treatment with Goal to full bed; late treatment with Aim to sides of the bed	1.7	1.9	1.8
10. Standard treatment with Goal to full bed; late treatment with Aim to sides of the bed	1.8	2.0	1.9
11. No caneburning (nontreated check)	1.8	1.9	1.8

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 and 2017).

Treatment[a]	Rate	Mid-season[b]			Late season[c]		
		2016	2017	Avg.	2016	2017	Avg.
	product/a		%			%	
Zeus	8 fl.oz	77 bcd	0	39 b	12 de	53	33 ef
Chateau POSTR	6 oz	95 abc	---	95 ab	65 abc	---	65 a-f
Chateau, POSTR	12 oz	95 abc	---	95 ab	70 ab	---	70 a-e
Fierce, POSTR	6 oz	98 ab	---	98 a	87 a	---	87 ab
Chateau, PRETR	6 oz	---	83	83 abc	---	83	83 ab
Chateau, PRETR	12 oz	---	48	48 abc	---	87	87 ab
Fierce, PRETR	6 oz	---	60	60 abc	---	92	92 a
Devrinol	8 lb	40 e	---	40 b	37 b-d	---	37 def
Alion	5 fl.oz	---	77	77 abc	---	90	90 a
Prowl H2O	3 pt	60 de	38	49 abc	22 cde	60	41 c-f
Surflan	6 qt	92 abc	38	65 abc	48 a-d	78	63 a-f
Trellis	1.5 lb	75 cd	37	56 abc	50 a-d	60	55 a-f
Matrix	4 oz	83 abc	17	50 abc	75 ab	68	72 a-d
Sandea	2 oz	78 a-d	63	71 abc	67 ab	90	78 abc
Simazine	4 lb	100 a	0	50 abc	50 a-d	53	52 b-f

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 and May 24, 2017; herbicides (POSTR only) were applied May 18, 2016, May 23 (PRETR) and May 26 (POSTR), 2017.

[b]Mid-season weed control was estimated July 26, 2016 and July 18, 2017.

[c]Late season weed control was estimated September 12, 2016 and October 16, 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	Avg.	2016	2017	Avg.
	product/a	cm	cm	cm	cm	cm	cm
Zeus	8 fl.oz	22.1 ab	22.0	22.1 a	78.8 abc	68.8 c	
Chateau POSTR	6 oz	12.3 d	---	12.3 bc	65.2 cd	---	65.2 efg
Chateau, POSTR	12 oz	11.6 d	---	11.6 c	61.0 d	---	61.0 fg
Fierce, POSTR	6 oz	13.5 cd	---	13.5 bc	59.0 d	---	59.0 g
Chateau, PRETR	6 oz	---	26.8	26.8 a	---	133.3 a	133.3 a
Chateau, PRETR	12 oz	---	27.1	27.1 a	---	112.2 ab	112.2 ab
Fierce, PRETR	6 oz	---	24.4	25.4 a	---	89.1 bc	89.0 b-e
Devrinol	8 lb	26.0 a	---	26.0 a	81.8 abc	---	81.8 c-f
Alion	5 fl.oz	---	20.3	20.3 ab	---	102.0 abc	102.0 bc
Prowl H2O	3 pt	22.4 ab	21.1	21.9 a	84.8 ab	89.8 bc	86.9 b-f
Surflan	6 qt	21.4 ab	21.9	21.6 a	89.5 ab	96.8 abc	92.6 bcd
Trellis	1.5 lb	23.0 ab	28.6	25.4 a	89.7 ab	91.7 abc	90.6 b-e
Matrix	4 oz	17.6 bcd	21.1	19.1 abc	75.2 bcd	78.0 bc	76.4 c-f
Sandea	2 oz	22.3 ab	21.8	22.1 a	87.0 ab	102.5 abc	93.6 bcd
Simazine	4 lb	19.8 abc	24.8	21.9 a	84.1 ab	70.6 bc	78.3 c-f
Nontreated	---	26.2 a	21.7	24.3 a	95.9 a	68.3 c	84.0 c-f

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 and May 24, 2017; herbicides (POSTR only) were applied May 18, 2016, May 23 (PRETR) and May 26 (POSTR), 2017.

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

[c]Late season cane lengths were measured September 12, 2016 and October 16, 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	Avg.	2016	2017	Avg.
	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	29.1 a	121.8 a	88.4	105.1 a
Squamish	15.8 b	23.4 ab	19.6 b	64.2 c	88.8	76.5 c
Wakefield	14.8 bc	25.8 a	20.3 b	77.8 b	98.6	89.0 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 and May 24, 2017; herbicides (POSTR only) were applied May 18, 2016, May 23 (PRETR) and May 26 (POSTR), 2017.

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

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

2018 WASHINGTON RED RASPBERRY COMMISSION RESEARCH PROPOSAL

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

Project Title: Determining whether raspberry plants should be caneburned

PI: Timothy W. Miller
Organization: Washington State University
Title: Extension Weed Scientist
Phone: (360) 848-6138
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Address: 16650 State Route 536
City/State/Zip: Mount Vernon, WA 98273

Cooperators: This trial is currently being conducted at the Randy Honcoop Farm near Lynden, WA. This trial was established in 2017, and this will be the second year of this trial. It will conclude in 2018.

Year Initiated __2017__ **Current Year** __2018__ **Terminating Year** __2018__

Total Project Request: **Year 1** **__$3,815__** **Year 2** **__$0__** **Year 3** **__$0__**

Other funding sources:
Agency Name: British Columbia Raspberry Industry Development Council
Amt. Requested: **__$3,815__**
Notes: Additional support for this project includes the herbicides, which are generally provided by the manufacturer.

Description:
Caneburning is the practice of removal of the first flush of primocanes of established raspberry plants in the spring using a postemergence herbicide in effort to increase yield. Approximately 95% of raspberry growers conduct caneburning annually on at least some of their fields, so the practice is almost universally used throughout the PNW region. It is known, however, that caneburning nonvigorous raspberry plants can result in decline or death of those plants, depending on the degree of plant health at the time of application. Such compromised plants normally consist of only a few overwintering floricanes, and it may be possible to gauge their ability to respond positively to caneburning herbicide application based on floricane counts. Therefore, the objective of this proposed research is to experimentally group raspberry plants by their floricane number and correlate their growth and yield to applications of various caneburning herbicides. This should provide valuable information to raspberry producers deciding whether to caneburn their raspberries.

Justification and Background:
Two excellent herbicides are currently available for caneburning operations: Goal (oxyfluorfen)

and Aim (carfentrazone). Two other products are good candidates for future registration: Treevix (saflufenacil) and Rely (glufosinate). These may also be augmented with Gramoxone (paraquat) in mixture, and may also be used in combination or sequential with residual herbicides. All quickly remove foliage from primocanes less than about 6 inches in height, and usually result in the complete removal of treated canes (a desirable outcome). It is known that Goal delays primocane regrowth longer than does Aim, while Treevix and Rely will fall between the two extremes.

While caneburning effects on healthy raspberry plants are fairly well understood, there remains much uncertainty as to whether to apply caneburning herbicides to raspberries of lower vigor. Raspberry plants not displaying vigorous growth can be severely injured by removal of the first flush of primocanes, which is the objective of caneburning treatments. What is needed is an evaluation of raspberry plant vigor, from which the expected response from the application of various caneburning herbicides can be estimated. Low vigor plants may be those displaying symptoms of Phytophthora root rot or viruses, presence of perennial weeds such as horsetail (*Equisetum* spp.), quackgrass (*Elymus repens*), or Canada thistle (*Cirsium arvense*), or simply plants in an older raspberry block. Such nonvigorous raspberry plants normally consist of only a few overwintering floricanes, which can easily be counted following dormant-season pruning and training. It may be possible to gauge the ability of these plants to respond positively to caneburning herbicide application based on floricane counts in winter. Therefore, the objective of this proposed research is to experimentally group raspberry plants by floricane number and correlate their growth and yield to applications of various caneburning herbicides. The ultimate goal of this research is to produce guidelines for growers to use when deciding whether to caneburn their raspberries.

Relationship to WRRC Research Priority(s): #3 Priority, Cane Management (including suppression). I am unaware of any other raspberry herbicide projects currently being conducted in in Oregon, Idaho, or British Columbia.

Objectives: To determine the ability of nonvigorous raspberry plants to respond positively to application of caneburning herbicides through the use of floricane counts.

Procedures:
Existing plots from 2017 will be used again in 2018, each measuring 25 feet long and centered on a single raspberry row. Floricane length and number of "vigorous" and "nonvigorous" sections of this raspberry field will be measured in January and February. Caneburning will be accomplished when the first-emerging primocanes are about 2 inches tall (defined as "early" treatment, late March, early April), when primocanes are 4 to 6 inches tall (defined as "standard", early April), and along bed edges (defined as "late", either with earlier caneburning or not). Products to be tested in the trial will be Goal and Aim, applied at the same timings listed above; other plots in each floricane-group will not be caneburned. All plots will also receive treatment with a residual herbicide, including noncaneburned plots. Weed control and crop injury will be evaluated periodically through the growing season. Plots will be sampled for berry production to determine caneburning effects on berry yield and fruit size. At the end of the growing season, raspberry primocanes (next year's floricanes) will be counted and cane length measured.

Anticipated Benefits and Information Transfer:
If positive, data from this experiment will be used in a decision model for growers to use when determining whether to apply the caneburning herbicides Goal or Aim. Additional years of testing may be necessary for model construction and validation. The data resulting from these studies will be disseminated through extension bulletins and during grower meetings sponsored by extension faculty and the agricultural industry.

Budget:

	2018	2019	2020
Salaries[1]	$ 1,500	$ 0	$ 0
Time-Slip	$ 999	$ 0	$ 0
Operations (goods & services)	$ 250	$ 0	$ 0
Travel[2]	$ 351	$ 0	$ 0
Meetings	$ 0	$ 0	$ 0
Other	$ 0	$ 0	$ 0
Equipment	$ 0	$ 0	$ 0
Benefits[3]	$ 715	$ 0	$ 0
Total	**$ 3,815**	**$ 0**	**$ 0**

Budget Details

[1]Salary for Assistant Research Faculty Steven Seefeldt is exclusively funded through external grants.
[2]Travel is for plot establishment, maintenance, and data collection.
[3]Benefits (41.36% for Assistant Research Faculty, $620; 9.5% for time-slip help, $95; total $715).

PHYSIOLOGY

Washington Red Raspberry Commission
Progress Report for 2017 Project

Project No:

Title: Mechanizing red raspberry pruning and cane tying

Personnel: Manoj Karkee, Joan Davenport

Reporting Period: Nov 2016 – Oct 2017

Accomplishments:

In 2017, 0.5-acre plot of raspberries established in Prosser, WA in 2013 and 2014 was managed following common commercial practices. Weed control was achieved by a combination of herbicide, mowing, and hand weeding. The plot was pruned and tied after leaf fall. Irrigation was achieved with a drip system. The spray for spotted wing Drosophila (SWD) was done in the plot. A newly-designed tape tying mechanism was fabricated and assembled with a previously developed bundling mechanism for automated bundling and tying of red raspberry canes. A circular gear-teeth end-effector was used to wrap an adhesive tape around bundled canes created by a two-arm bundling mechanism (Fig. 1 - Left). Canes entered the wrapper through an opening in the wrapper (Fig. 1 - Middle). Integrated bundling and tying machine was mounted on a tractor and controlled using tractor hydraulic during field tests.

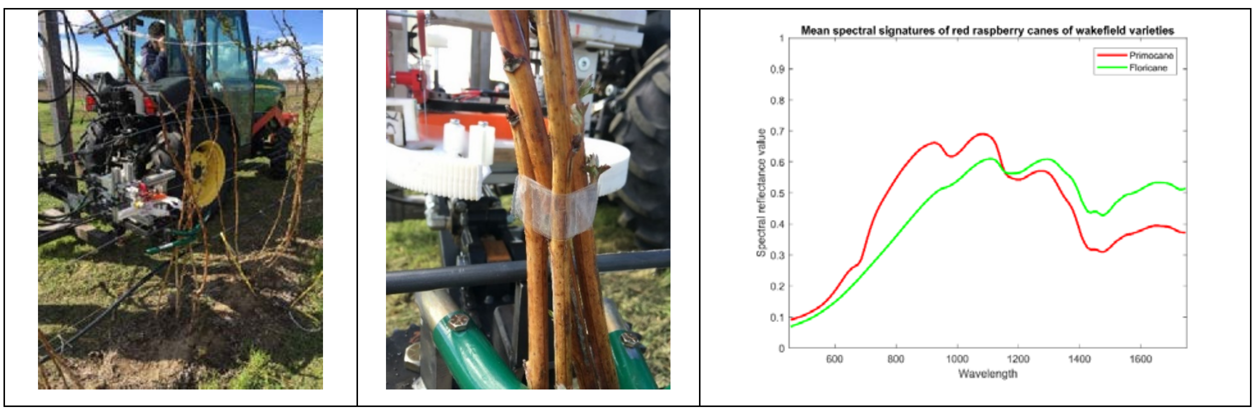

Fig. 1: Mechanization for red raspberry bundling and tying process. Left – Latest integrated machine developed for tying of red raspberry canes with an adhesive tape. Middle- Primocanes tied using the mechanism. Right – Results obtained from a spectroradiometer showing the difference in the reflectance properties of the primocanes and floricanes.

For automated pruning, the first step is to develop a sensing system that can distinguish primocanes and floricanes. In 2017, Fieldspec-4 Standard Spectroradiometer with wavelength range of 350nm to 2550nm was used for investigating the potential of spectral signature (light reflectance properties) of Chemainus, Wakefield and Meeker varieties.

Results:

The following are the key results obtained from field test of the bundling and tying mechanisms.

- Field tests showed a bundling success of 94% and overall success (bundling/tying) of 83%.
- Results are highly promising, particularly for the Chemainus and Meeker varieties; showing a varietal influence generally related to the uprightness of canes.
- Fruit yield was not affected by mechanical bundling and tying.

The key results obtained from the experiment with Fieldspec spectroradiometer are;

- The spectral data obtained from the experiment showed a substantial difference in reflectance from primocanes and floricanes (Fig. 1- Right).
- Electromagnetic wave in the range of 950-970 nm range was found to be more effective for differentiating two types of canes.

Publications:

Khanal, K., Bhusal, S., & Karkee, M. 2017. Raspberry primocanes bundling and tying mechanism. In 2017 ASABE Annual International Meeting (p. 1). American Society of Agricultural and Biological Engineers.

Karkee, M. 2016. Mechanizing red raspberry bundling and tying. *Washington Small Fruit Conference;* Dec 1, 2016; Lynden, WA.

Khanal, K., S. Bhusal and M. Karkee. 2017. Red Raspberry Cane Identification using Spectal Signature. IAREC Research Showcase, Sep 13, 2017.

Khanal, K., S. Bhusal and M. Karkee. 2017. Raspberry Primocane Tying Mechanism. *Center for Precision and Automated Agricultural Systems (CPAAS) Technology Day 2017*, July 31, 2017.

2016 WASHINGTON RED RASPBERRY COMMISSION
RESEARCH PROPOSAL

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

Project Title: Mechanizing red raspberry pruning and cane tying

PI: Manoj Karkee	**Co-PI: Gwen-Alyn Hoheisel**
Organization: WSU-CPAAS	**Organization: WSU-Extension**
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Address 2:	**Address 2:**
City/State/Zip: Prosser, WA 99350	**City/State/Zip: Prosser, WA 99350**

Cooperators: Qin Zhang, WSU-CPAAS

Year Initiated 2018 Current Year 2018 Terminating Year 2018

Total Project Request: Year 1 $9,832

Other funding sources: Two years ago, $54,188 was funded as a sub-contract to WSU from the funding that WRRC and WSU scientists received through the WA Specialty Crop Block Grant program. Part of this funding remains to be spent in 2018. An additional $9,822 is requested from WRRC to complement and continue engineering research activities under this grant.

Description:

Cane management in red raspberry production is highly labor intensive. Currently, Washington growers estimate the pruning and tying cost in red-raspberry production to be from $500 to $800 per acre. In addition, labor is at risk for chronic and acute injury. Mechanization has the potential to substantially reduce labor use from cane management. Over the last four years, we develop a systematic approach for cane management through horticultural modifications and engineering solutions. A red raspberry plot was developed with different types of red raspberries in eastern WA for their feasibility in mechanized pruning of floricanes. In addition, we have been developing mechanisms to bundle primocanes and tie them to the trellis wires. Current accomplishment from this work has been presented during annual meeting in October (Mt. Vernon, WA) and discussed in the attached progress report. In 2018, we will improve and evaluate integrated machine for cane bundling and tying. We expect that the successful completion of the proposed work will lead to a practical cane management system. In the long term, adoption of the system will improve economic sustainability of WA red raspberry production. The system will also have potential to be adapted to other crops such as blackberries.

Justification and Background:

Red raspberry is a premium crop for WA, which produces more than 85% of total US production of frozen red raspberries. This is a bi-annual crop where two-year old canes (floricanes) must be pruned out selectively every year without damaging one-year old canes (primocanes) (Fig. 1). Following pruning, a number of primocanes must be bundled and trained to trellis wires. This operation is highly labor intensive, costing about $500 - $800 per acre per year. Because labor availability is increasingly uncertain and labor costs are continually increasing (Fennimore and Doohan, 2008), an automated or mechanized solution for pruning and training is a critically important need for the WA red raspberry industry. With immigration from Mexico to the USA decreasing over time (Pew Research Center, 2012) and Congressional reform of immigration law uncertain, it is expected that labor may soon become a critical constraint on red raspberry production. Therefore, it is crucial that we begin now to develop mechanization technologies so that the technology is ready for industry adoption before its competitiveness and sustainability may be compromised. During this project we have been systematically evaluating horticultural and engineering solutions to cane training and pruning. Our goal is to develop viable, practical techniques of performing training and pruning that reduce labor from its current requirements and consequently reduce the cost of production while minimizing crop loss.

Fig. 1: Red-raspberry pruning and tying

This project will impact all red raspberry growers in WA who use the floricane production system - the entire industry relies on manual labor to prune and tie canes. This combined operation represents about 35% of the total variable costs of production (MacConnell and Kansiger, 2007). The project is expected to generate industry-applicable techniques to improve labor productivity and reduce labor demand. Success in this project will dramatically reduce labor demand and costs, amounting to as much as $400 to $500 per acre per year for cane management. These savings will lead to millions of dollars of economic benefit to WA red raspberry industry, which will substantially improve the competitiveness and long-term sustainability of the industry.

Relationship to WRRC Research Priority(s): This project directly addresses priority #3: “Labor saving practices – ex. Pruning, AY, public/private technology partnerships”

Objectives to be accomplished in 2018:
The primary goal of the proposed work is to minimize labor demand in red raspberry pruning through integrated horticultural and mechanization, or automation solutions. To achieve the overall goal, we have been particularly focusing on the following objectives over the last four years of this project.

1. Establish and maintain at Washington State University's Center for Precision Agricultural and Automation Systems (WSU-CPAAS) a block of red raspberries that will include three commercial cultivars;
2. Develop and evaluate mechanization technologies for cane management, which will include
    a. Bundling and tying mechanisms for the primocanes that will bear the following year's crop, and
    b. Sensing systems for floricane identification and a floricane pruning mechanism

Please refer to the progress report submitted along with this funding proposal for the accomplishments made in 2017. Particularly in the Year 2018, progress will be made in the following research activities.

1. Continue to manage the raspberry plot in Prosser, WA
2. Improve the cane bundling and tying mechanisms based on the findings from 2017 work
3. Evaluate the improved prototype in red-raspberry field
4. Outreach activities/ federal grant proposal development

Procedures:

Objective #1 - Horticultural Management of Red Raspberry Plot (Lead –Davenport): All cultural practices will be according to commercial standards. The following horticultural attributes will be measured: number of canes per plant; cane length at harvest; number of canes damaged by the bundling and tying mechanism (evaluated via necrosis); number of fruiting laterals per sample cane; yield; and weight of dormant-pruned spent floricanes. Graduate students supported by this project will be involved in managing the crop and collecting the horticultural attributes.

Objective #2 - Engineering Approaches (Lead – Karkee): We will complete the improvement (including speed) and evaluation of the prototype machine to bundling and tying primocanes. The prototype was evaluated in the field in 2017, which has provided important information on potential ways to improve in 2017. Faster and stronger motors will be used to increase the speed. Mechanisms will be built with higher precision to reduce the cane bundling issues. Also, stronger tapes will be used to tie the bundled canes. In addition, alternative approach will be investigated to develop a mechanism to tie commonly used ropes instead of adhesive tapes.

This year, we will also continue to investigate the method to identify and locate floricanes for automated pruning. A spectrometer and laser scanner will be used to identify and locate floricanes for pruning. We will also continue the investigation of the use of food-grade paints as well as red string-tying to provide the additional information for automated floricane detection.

Anticipated Benefits and Information Transfer:

This project will evaluate different mechanisms for training and pruning of various cultivars of red-raspberry, which will ultimately reduce the estimated $500-$800 per acre cost of these practices. Working collaborations among growers, horticulturists, and engineers will be fostered by this well-defined project. Following this, we expect smooth and effective cooperation among parties on developing federal funding proposals for mechanization projects. Results will be transferred to users at the workshops and annual berry meetings, including the Washington Small Fruit Conference. The direct participation of growers in this project will also facilitate knowledge and technology transfer to growers through peer-to-peer connections.

References:

Fennimore, S. A., and D. J. Doohan, 2008. The Challenges of Specialty Crop Weed Control, Future Directions. Weed Technology, 22: 364-372.

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.

Pew Research Center. 2012. Net Migration from Mexico Falls to Zero—and Perhaps Less. Available at: http://www.pewhispanic.org/files/2012/04/Mexican-migrants-report_final.pdf; assessed on: accessed 6 Nov, 2013.

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

	2017
Salaries	
Time-Slip	$8,000
Operations (goods & services)	
Travel	$1,000
Other/Miscellaneous	
Benefits	$832
Total	**$9,832**

Budget Justification

Wages (Sub-Total: $8,000) – Wages are required for the maintenance of, and data collection in the field plot at the hourly rates of $12.00 for field labor. Total estimated wages is $8,000.

Travel (Sub-Total: $1,000) – Each year, one graduate student will travel to Lynden, WA to conduct field experiments in collaboration with grower collaborators. A part of the travel cost will also be used in extension activities.

Benefits (Sub-Total: $832) – All values are in accordance with Washington State University's mandated rates for benefits and benefit inflation according to staff classification. It is calculated @10.4% of the wages requested.

Current & Pending Support-Karkee

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					
Slaughter (PD); Fennimore; Giles; Karkee; Siemens; Smith; Tourte; Upadhyaya; Voigioukas; Zhang	USDA-NIFA-SCRI	$2,715,901	09/14 to 08/18	10%	Crop Signaling for Automated Weed/Crop Differentiation and Mechanized Weed Control in Vegetable Crops
Karkee (PD); Whiting; Zhang	USDA-NIFA-AFRI	$495,480	12/14 to 11/18	10%	Shake and Catch Harvesting for Fresh Market Apples
Bierlink and Karkee (PD); Tarara	WSDA Special Crop Block Grant	$199,926	02/14 to 01/18	8%	Mechanizing Red Raspberry Pruning and Tying

Washington Red Raspberry Commission
Progress Report for 2017

Project number: 3455-6640

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

Personnel:

PI: Lisa Wasko DeVetter
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Title: Assistant Professor, Small Fruits
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Co-PI: Suzette Galinato
Organization: Washington State University
Title: Research Associate, Economics
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Address: 117 Hulbert Hall
City/State/Zip: Pullman/WA/99164

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

Reporting Period: This report presents data from 2017, two years after the project was initiated.

Accomplishments:

- Treatments were maintained in Mr. Jon Maberry's field in Lynden, WA.
- Both treatments produced a crop in 2017. Yield data were collected by Maberry Packing and shared with DeVetter for statistical analysis.
- DeVetter collected leaf tissue nutrient and vegetative growth data. Average internode length and node number were two new variables that were collected for assessment of primocane vegetative growth.

Results:

- The AY treatment experienced winter injury in 2016/2017 due to continued primocane growth in the fall/winter (when the plants should have been acclimating). The fertility program for the AY treatment has been adjusted to prevent injury in future years.

Table 1. Yield per row, primocane number per hill, primocane height, node number per primocane, and internode length for 'Meeker' raspberry grown in alternate- (AY) or every-year (EY; control) production systems, 2017.

	Total yield per row (lbs)	Primocane number/hill[y]	Primocane height (inches)	Node number/cane[x]	Internode length (inches)
AY	2449.0[z]	10.6	88.8	35.7	2.4
EY	2340.3	14.5	116.1	47.9	2.3
P-value[w]	NS	***	**	***	**

[z]Double-row plots replicated three times were harvested 14 times between July 2 and Aug. 2, 2017.
[y]Primocane number and height determined from 3 primocanes per hill and 7 hills per block in Aug. 2017.
[x]Node number and internode length determined from 3 primocanes per hill and 5 hills per block in Aug/Sept. 2017.
[w]NS, *, **, *** indicate nonsignificant or significant differences at $P \leq 0.05$, 0.01, or 0.0001, respectively.

- No significant differences were found in leaf tissue macro- or micro-nutrient concentrations except for iron which was 155 and 205 ppm for the AY and EY treatments, respectively (*P*-value = 0.008).

Publications:

No publications for 2017, although an enterprise budget was published by Galinato and DeVetter in 2016; this enterprise budget will be later used for future cost-benefit analyses.

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

PI: Lisa Wasko DeVetter
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Co-PIs:

- Suzette Galinato, Research Associate in Economics, Washington State University, 117 Hulbert Hall, Pullman, WA 99164, phone: 509-335-1408, sgalinato@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/Co-PI: Jonathan Maberry, Maberry Packing LLC

Year Initiated 2015 **Current Year** 2017 **Terminating Year** 2020

Total Project Request: $47,820
Year 1 $8,958 **Year 2** $8,277 **Year 3** $6,635 **Year 4** $5,110 **Year 5** $6,069 **Year 6** $12,771

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 is proposed for 2018: 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. To date, we have not observed statistically significant yield losses in our on-farm AY study in Whatcom County.

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 will establish 'Whatcom' and 'WakeHaven' 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 will be used as the experimental control. 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 the 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 2018. 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:

	2018	2019	2020
Salaries[1/]	$2,407	$3,806	$6,845
Time-Slip[2/]	$400	$416	$433
Operations (goods & services)[3/]	$1,050	$50	$1,050
Travel[4/]	$238	$238	$1,938
Meetings	$	$	$
Other	$	$	$
Equipment[4/]	$	$	$
Benefits[5/]	$1,015	$1,505	$2,505
Total	**$5,110**	**$6,069**	**$12,771**

[1/] Research Associate (co-PI Mrs. Suzette Galinato) at the WSU School of Economic Sciences [2.08% FTE in 2019 (0.25 month at $1,357); and 6.25% FTE in 2020 (0.75 month at $4,242)]; Scientific assistant in Small Fruit Horticulture program (Mr. Sean Watkinson) at 5% FTE per year ($2,407 in 2018; $2,503 in 2019, and $2,603 in 2020); yearly salaries include 4% inflation.
[2/]Timeslip in 2017-2020 for plant growth and fruit quality data collection: $10/hr x 40 hr/week x 1 week = $400; include 4% inflation.
[3/]Field supplies (e.g, sample bags, flagging tape, etc.) @ $50/year; Pix4D Software @ $1,000/year in 2018 only for drone imaging and processing; Journal publication charge @ $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 ($450 in 2019; and $1,407 in 2020); Benefits for Scientific Assistant is 40.6% ($977 in 2018; $1,016 in 2019, and $1,057 in 2020). Benefits for timeslip at 9.5% ($38, $39, and $41 for years 2018, 2019, and 2020, respectively).

Washington Red Raspberry Commission
Progress Report for 2017

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, C.A. Miles, S. Ghimire, I. Zasada, and C. Benedict. H. Zhang is the MS student funded on this project.

Reporting Period: This report presents data from 2017, when the experiment was first initiated.

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) plugs. Our main accomplishments for 2017 include: 1) Established our spring- and fall-planted trials in grower-cooperator fields in May and Aug. 2017, respectively; 2) Collected data as planned (additional data on plant moisture status, soil gravimetric water content, photosynthetic rates, mulch tensile strength, and plant and soil macro- and micro-nutrient content were also collected); and 3) Extended project information through: (a) one field day held at Enfield Farms in Sept. 2017; (b) five presentations held at regional events, (c) two published newsletter articles, and (d) three extension project fact sheets (in preparation; all available at: http://smallfruits.wsu.edu/articles-and-publications-on-bdms-in-raspberry/). Information from this study demonstrates that both biodegradable (BDM) and polyethylene plastic (PE) mulches are promising tools to manage weeds and improve TC establishment. Yield and preliminary cost/benefit data will be collected in 2018, when the spring planting produces its first crop. This project is the first to investigate BDM and PE mulch application in floricane raspberry production and is one of the few studies that evaluates plastic mulches in a perennial fruit production system. Results will contribute information about the viability of BDM and PE mulch application in perennial fruit production systems to both commercial farming operations and the scientific community.

Results: Preliminary results indicated weed incidence was reduced in mulched plots compared to the bare ground control in both trials. In the spring-planted trial, BDM degradation started on 15 Aug., but was minimal by early fall. Primocane height was greater in mulched treatments relative to the bare ground control within one month of establishment in both trials. Primocane number was also greater in mulched treatments compared to bare ground from Aug. onwards in the spring-planted trial; it is too soon after plant establishment to measure differences in primocane number in the fall-planted trial. Soil temperature under mulches was higher than bare ground from the beginning of both trials. The average soil volumetric water content in the spring-planted trial from 26 May to 30 Aug. was greatest for soil covered with PE followed by BDMs and the bare ground control. There were no root lesion nematodes (RLN) found in soil prior to treatment application at both trial sites. Samples collected in Oct. from the spring-planted trial showed average soil and root densities of RLN in BDM-treated plots were 142 and 67 RLN g/root and 100 g of soil, respectively; densities in the bare ground treatment were 44 and 5 RLN g/root and 100 g of soil, respectively. These differences were not significant. Soil densities in the fall-planted trial ranged from 0-22 RLN/50 g soil and did not differ due to treatment.

Publications/Outputs:

Newsletter articles

- DeVetter, L.W. and C. Benedict. 2017. Exploring biodegradable plastic mulches in red raspberry. Growing Produce. <http://www.growingproduce.com/fruits/berries/exploring-biodegradable-plastic-mulches-in-red-raspberry/>.
- Zhang, H., L.W. DeVetter, C. Miles, S. Ghimire, C. Benedict, and I. Zasada. 2017. Application of biodegradable plastic mulches on tissue culture red raspberry. WSU Whatcom Ag. Monthly: Volume 6 Issue 9. < http://extension.wsu.edu/wam/application-of-biodegradable-plastic-mulches-on-tissue-culture-red-raspberry/>.

Factsheets

- Zhang, H., L.W. DeVetter, C. Miles, C. Benedict, S. Ghimire, and E. Scheenstra. 2017. Application of biodegradable plastic mulches on tissue culture red raspberry. Washington State University Extension Project Factsheet.
- Zhang, H., L.W. DeVetter, C. Miles, and S. Ghimire. 2017. Dimensions and costs of biodegradable plastic mulches and polyethylene for raspberry production. Washington State University Extension Project Factsheet (in review).
- DeVetter, L.W., C. Miles, and I. Zasada. 2017. Fumigation and biodegradable plastic mulch application. Washington State University Extension Project Factsheet.

Presentations

- Zhang, H. (presenter), L.W. DeVetter, C. Miles, S. Ghimire, C. Benedict, and I. Zasada. 2017. The application of plastic biodegradable mulches on tissue culture red raspberry. Washington Small Fruit Conference. 29 Nov. 2017. Lynden, WA. Oral presentation.
- Zhang, H. (presenter) and L.W. DeVetter. 2017. Application of plastic biodegradable mulches on tissue culture red raspberry. Iowa-LEAD group of visiting agricultural professionals. 17 Nov. 2017. Mount Vernon, WA. Oral presentation.
- L.W. DeVetter (presenter), H. Zhang, C. Miles, S. Ghimire, C. Benedict, and I. Zasada. 2017. Application of biodegradable mulches in red raspberry. Orchard Vineyard Supply Workshop. 11 Nov. 2017. Lynden, WA. Oral presentation.
- Zhang, H. (presenter), L.W. DeVetter, C. Miles, S. Ghimire, C. Benedict, and I. Zasada. 2017. Application of biodegradable plastic mulches on tissue culture red raspberry. WSU NWREC presentation to a group of students from British Columbia. 30 Sept. 2017. Mount Vernon, WA. Oral presentation.
- Zhang, H. (presenter), L.W. DeVetter, C. Miles, S. Ghimire, C. Benedict, and I. Zasada. 2017. Application of biodegradable plastic mulches on tissue culture red raspberry. WSU Island County Master Garden Program. 23 Sept. 2017. Coupeville, WA. Oral presentation.
- Zhang, H. (presenter), L.W. DeVetter, C. Miles, S. Ghimire, C. Benedict, and I. Zasada. 2017. Application of biodegradable plastic mulches on tissue culture red raspberry. BDM Field Day. 11 Sept. 2017. Lynden, WA. Oral presentation.
- Zhang, H. (presenter), L.W. DeVetter, C. Miles, S. Ghimire, C. Benedict, and I. Zasada. 2017. Application of biodegradable plastic mulches on tissue culture red raspberry. 2017 WSU NWREC Summer Field Day. 11 July 2017. Mount Vernon, WA. Oral presentation.

2018 WASHINGTON RED RASPBERRY COMMISSION
RESEARCH PROPOSAL

Project Number: 3455-6642 (0640) **Proposed Duration:** 3 years

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

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Cooperators: The cooperator for the spring-planted trial wishes not to be identified. Enfield Farms is the cooperator for the fall-planted trial. Both are in Whatcom County, WA.

Year Initiated: 2017 **Current Year**: 2018 **Terminating Year**: 2019

Total Project Request: $63,931 **Year 1**: $10,457 **Year 2**: $25,066 **Year 3**: $28,408

Other funding sources: Yes, pending or in submission.
Agency: Washington State Commission of Pesticide Registration (WSCPR); Western Sustainable Agriculture Research & Extension (WSARE); and North American Raspberry & Blackberry Association (NARBA)
Amount Requested: WSCPR: $16,591 (for Year 1); WSARE: $25,000 (for Years 2-3); and NARBA: $5,000 (Year 2)
Notes: We have applied for matching funds to the WSCPR for an amount less than our request to WRRC due to the restriction of including benefits in the WSCPR proposal. We are also applying for additional graduate student, travel, and goods/services support to WSARE and NARBA.

Description:
Weed management during establishment of tissue culture (TC) plugs is a challenge for raspberry growers accustomed to using bare-root canes and root cuttings. Black polyethylene (PE) mulch is

used to control weeds in many annual crops, but the difficulty of removal may limit its application in raspberry. Since 2017, we have been studying the effects of PE and biodegradable mulches (BDM) on weed incidence, root lesion nematode (*Pratylenchus penetrans*; RLN) populations, and growth/establishment of TC raspberry in spring- and fall-planted systems. Results indicate that BDMs and PE mulch improves weed management and increases plant growth relative to bare ground. BDMs and PE mulch also increase soil temperature and potentially parasitism by RLN. Additionally, mulch application adds additional costs to growers and it remains to be determined if increased growth and subsequent yields offset these costs. We propose to continue our evaluation of four BDMs, PE mulch, and bare-ground control in spring- and fall-planted raspberry experiments in Lynden, Washington. Overall, this project will contribute to discovering new techniques to manage weeds, elucidate impacts of mulches on RLN, and lead to the improved establishment of TC raspberry.

Justification and Background:
TC plugs have become increasingly popular within the red raspberry industry. This is largely due to increased plantings of 'Wakefield' and other cultivars exclusively produced through TC. However, plugs resulting from TC are more delicate and difficult to establish relative to bare-root canes and root cuttings, making weed management using herbicides more challenging. PE mulch is widely used to control weeds in annual crops, but is not widely used in perennial cropping systems. Gerbrandt (2015) found improved growth and establishment of TC raspberry under plasticulture in British Columbia, Canada. Yet, PE mulch removal and disposal can be difficult and costly. BDMs could be a suitable alternative for weed management in TC plantings if the BDM controls weeds and biodegrades into the soil, thereby avoiding removal, disposal, and soil ecological issues. There has been limited research testing the efficacy of BDMs in raspberry. Król-Dyrek and Siwek (2015) compared three mulches (biodegradable and non-biodegradable) to bare ground cultivation in Poland and found yield of primocane-fruiting raspberries was greater for the mulched treatments. Our WRRC- and WSCPR-funded project is the first to investigate BDMs and PE mulch in floricane raspberry. Results to date show potential for commercial application (*please see progress report*), but several knowledge gaps remain about their application in raspberry systems.

Plant–parasitic nematodes are another major pest of raspberry, particularly RLN. Gerbrandt (2015) reported increased nematode populations under PE mulched raspberry, indicating mulches may encourage nematode activity. First year results from our spring-planted trial also showed numerically higher RLN populations in samples from mulched plots, but these differences were not statistically significant and it remains to be determined if these increased populations impact plant productivity. To our knowledge, no other studies have explored the impacts of mulches, including BDMs, on RLN parasitism.

This project will address the problem of poor plant establishment and weed management in raspberry systems that use TC plugs, while also evaluating the impact mulches have on RLN. We have been addressing this problem through on-farm experiments in both spring- and fall-planted systems since 2017 and we propose to continue these experiments in 2018.
Relationship to WRRC Research Priorities:

This project addresses labor saving practices and weed management, which are #3 priorities. Additionally, the nematode component of this project addresses priority #2, understanding soil ecology and soilborne pathogens and their effects on plant health and crop yield.

Objectives:
Test the application of BDMs and PE mulch in TC raspberry and compare to bare ground cultivation (control; herbicide plus hand weeding) with consideration to the following: 1) Evaluate weed incidence in fall-planted raspberry; 2) Assess populations of RLN in the soils and roots of spring- and fall-planted raspberry; 3) Monitor surface- and in-soil degradation of BDMs; 4) Evaluate growth and establishment of raspberry; and 5)Evaluate fruit yield and quality of raspberry.

All objectives will be addressed during the 2018 project period. Note that we will collect yield and fruit quality data from the spring-planted trial only, as the fall-planted trial will not yield until 2019. Weed measurements will also only occur in the fall-planted trial, as spring-planted data were collected in 2017.

Procedures:
The project is being carried out as two separate field trials, both established on commercial farms in Lynden, WA. Activities for 2018 are:

1. Soil temperature and moisture will be recorded using a data logger that records every 15 mins from Jan. to Dec. 2018.
2. Surface degradation of BDMs will be assessed as percent soil exposure (PSE) twice monthly until mulch covering/removal.
3. In the spring-planted trial, PE mulch will be removed spring 2018 and all BDMs will be covered with 2-3 inches of soil to initiate degradation. For the fall-planted trial, BDMs and PE will be split along the center in each plot in Aug. 2018. PE will be removed from the field, whereas half of the BDM treatment per row will be removed and the other half raked into the eastern side of the adjacent alleyway to avoid mixing treatments. BDMs will be tilled into the soil. Methods differ between the two sites to avoid contamination because the spring- and fall trials were broadcast and bed fumigated, respectively.
4. For the spring-planted trial, we will use 1.18 mm mesh bags that contain pre-measured BDM samples to assess degradation at 6 and 12 months post-soil coverage; mesh bags will be placed in the field with the mulch prior to soil covering. For the fall-planted trial, degradation will be assessed from alleyway soil samples collected 6 and 12 months after soil incorporation. Exponential decay functions fitted to our degradation data will be used to predict the proportion of mulch remaining in the soil over time. We will also test whether the model's predictions can be improved by accounting for soil temperature and moisture.
5. Weed number and aboveground biomass will be determined monthly from April to Aug. 2018.
6. Populations of RLN will be determined from soil and root samples collected May and Oct. 2018.
7. In the spring-planted trial, primocane emergence through covered BDMs will be measured in April and May 2018, and primocane height and number will be measured in Aug. 2018. For the fall-planted trial, primocane height and number will be measured monthly from Apr. to Oct. 2018.

8. Machine harvestable yield, average berry size, fruit total soluble solids, and pH will be determined in the spring-planted trial in 2018.

Anticipated Benefits and Information Transfer:
BDMs and PE mulch are promising tools to enhance establishment and productivity of TC raspberry plants, control weeds, and reduce labor associated with weeding, thereby promoting on-farm efficiencies. We will present project information at annual small fruit field days and the Small Fruit Conference in Lynden, WA, in 2018-2019. Additionally, we will post project results on WSU Small Fruit Horticulture website (http://smallfruits.wsu.edu/articles-and-publications-on-bdms-in-raspberry/). Results will also be shared through the following mechanisms: *Whatcom Ag Monthly*, Peerbolt Small Fruit Update, WSU Extension Fact Sheet, industry trade journals, and scientific publications.

References:

1. Gerbrandt, E. 2015. New techniques for getting raspberries and strawberries off to a better start. Proceedings from the 2015 Lower Mainland Horticulture Improvement Association Horticulture Growers' Short Course. Available at: http://www.agricultureshow.net/horticulture-growers-short-course.
2. Król-Dyrek, K. and P Siwek. 2015. The influence of biodegradable mulches on the yielding of autumn raspberry (Rubus idaeus L.). Folia Horticulturae 27(1): 15-20.

Budget (2018 only):

	2018
Salaries[1/]	$11,331
Timeslip[/2]	$2,860
Operations (goods & services)[3/]	$1,950
Travel[4/]	$450
Equipment	$0
Benefits[5/]	$8,475
Total	$25,066

[1]Salary - 50% FTE for a MS student starting (1 semester) = $14,450; Research associate (Ed Scheenstra) for 1.3 months @ $4,077/m = $4,200 in 2018; Scientific assistant (Sean Watkinson) for 1 month @ $4,012/m for 2018.

[2]Time slip for summer graduate student in 2017: $11/hour x 40 hours/week x 13 weeks = $5,720.

[3]Nematode assessment from raspberry roots and soil at $30/sample x 120 samples/year = $3,600; Bags, flags, logger batteries, etc. for soil sampling and temperature monitoring = $300.

[4]Travel from Mount Vernon to grower-cooperator site in Lynden, WA: 84 mi RT x $0.54/mi = $45 x 20 trips = $900.

[5]Benefits for graduate student (QTR and health) when salaried and 10.00% when on summer timeslip = $6,852; Benefits for research associate and scientific assistant in 2018 at 38.5% and 40.6%, respectively.

*Note we requested a 50% match with WSCPR, but the amount requested to WRRC is greater due to inclusion of benefits.

Washington Red Raspberry Commission
Progress Report for 2017

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 2017, when the experiment was initiated.

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. Our main accomplishments for 2017 include: 1) Establishment of our microplot study at the Washington State University Northwestern Washington Research and Extension Center; and 2) Collection of data as planned (excluding root biomass data due to technical difficulties). Treatments included: 1) 0 lbs N/acre + RLN (negative control); 2) 30 lbs N/acre + RLN; 3) 60 lbs N/acre + RLN; 4) 60 lbs N/acre – RLN, and; 5) 100 lbs N/acre + RLN. The "+" and "-" indicates microplots were or were not inoculated with RLN, respectively. Inoculation was based on soil samples collected in fall 2016, which determined RLN densities in soil per microplot. Plots were inoculated to achieve an initial density of ~250 RLN/250 g of soil. Project results will be shared at the Washington Small Fruit Conference in 2017. Future extension of project information is planned for 2018.

Results: Plant height data collected from June to Oct. 2017 show primocanes were tallest in the 60 lbs N/acre – RLN treatment. This rate is in accordance with guidelines for establishing floricane raspberry published in PNW 598. In contrast, plant growth was reduced the most in the 0 lbs N/acre rate + RLN treatment. These growth differences were noted starting July 2017 and continued through Oct. 2017, which is when we collected our last plant growth measurement for 2017. The remaining treatments were intermediate to the 60 lbs N/acre – RLN and the 0 lbs N/acre + RLN treatments. Shoot biomass determined in Oct. 2017 followed a similar trend as the plant height data, although the 100 lbs N/acre + RLN treatment was intermediate between the 0 lbs N/acre + RLN and 30 and 60 lbs N/acre + RLN treatments. Soil and leaf tissue nutrients did not show any significant trends. RLN densities determined in root and soil samples collected in Oct. 2017 show RLN populations were the same across all inoculated plots, whereas the non-inoculated plots had essentially no RLN. Populations in the inoculated plots averaged 250 RLN/50 g soil and 1,761 RLN/g root. These results show that higher rates of nitrogen did not reduce the severity of RLN parasitism in establishing raspberry under the conditions of our experiment.

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/

2018 WASHINGTON RED RASPBERRY COMMISSION
RESEARCH PROPOSAL

Project No: 3455-6648 **Proposed Duration:** 2 years

Project Title: Impact of Nitrogen on Nematode Parasitism of Red Raspberry

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Cooperators: None. We are proposing to conduct this study using microplots at WSU NWREC.

Year Initiated: 2017 **Current Year**: 2017 **Terminating Year**: 2018

Total Project Request: $20,719 **Year 1**: $10,182 **Year 2**: $10,537

Other funding sources: None

Description:
The objective of this project is to explore if different nitrogen rates during red raspberry establishment influences plant growth, root lesion nematode (*Pratylenchus penetrans*; RLN) populations, and subsequent damage to plants. We have observed high RLN populations in raspberry roots collected in Whatcom County on plants that display few symptoms of infestation. Many of these plantings are being produced in high input systems, leading us to wonder if nitrogen influences RLN infestations and subsequent impacts on crop growth and yield. In this study, we will evaluate if modification of nitrogen rates during establishment impacts damage due to RLN parasitism. The end goal is to understand if nitrogen rate can be used as a post-fumigation cultural management tool in plantings with high RLN pressure or in instances where fumigation results are poor.

Justification and Background:
Root lesion nematode (*Pratylenchus penetrans*; RLN) is a migratory endoparasite that feeds on plant roots, including red raspberry (*Rubus idaeus*). RLN feeding damages roots, which reduces root functioning (water and nutrient transport), plant growth, and subsequent yields. RLN is one of the key pests in red raspberry systems in Northwest Washington. Most growers utilize pre-plant fumigation using Telone C-35® and/or Vapam® for RLN management. While in some fields RLN suppression using pre-plant fumigation has been observed to be variable to poor, there is currently a strong collaborative effort to improve pre-plant fumigation techniques. Yet, there are few tools to manage RLN in a post-plant situation. This project explores how different nitrogen rates during raspberry establishment impacts RLN populations and subsequent damage to plants. We have consistently observed high RLN populations in raspberry roots collected

from plants that display few symptoms of infestation. Many of these systems are well managed and high input systems, leading us to question if plant growth as impacted by nitrogen applications will enable raspberry plants to compensate for high RLN parasitism and "escape" damage. This project explores this question using microplots previously established at the WSU NWREC.

In 2017, we established a trial at WSU NWREC and compared plant growth among the following treatments: 1) 0 lbs N/acre + RLN (negative control); 2) 30 lbs N/acre + RLN; 3) 60 lbs N/acre + RLN; 4) 60 lbs N/acre – RLN, and; 5) 100 lbs N/acre + RLN (the "+" and "-" indicates microplots were or were not inoculated with RLN, respectively). While growth was least and greatest among treatments #1 and #4, respectively, the remaining treatments were statistically similar. This indicates that modified nitrogen applications do not allow raspberry to compensate for RLN parasitism. To confirm these results, we propose to continue this study into 2018 and collect yield data.

Relationship to WRRC Research Priorities:
This project is related to the following #2 priorities: 1) Soil fumigation techniques and alternatives to control soil pathogens, nematodes, and weeds; and 2) Understanding soil ecology and soilborne pathogens and their effects on plant health and crop yields. It is also related to the #3 priority of nutrient management.

Objectives:
The primary objective will be to explore if different nitrogen rates during red raspberry establishment influences plant growth, RLN population densities, and subsequent damage to plants. We have measured these parameters during the first year of establishment in 2017. In 2018, we will continue to monitor RLN populations, plant growth, and damage, as well as yield and fruit quality.

Procedures:
The experiment was established in field microplots located at WSU NWREC in Mount Vernon, WA in 2017. There is a total of 100 individual microplots spanning five rows that were constructed in 2010 by burying 3 ft diameter polypropylene weed mat cylinders into the soil. Individual microplots were planted with tissue culture 'Meeker' in May 2017 and inoculated with RLN (approximately 250 RLN/250 g soil) at planting to simulate a field situation with moderate RLN pressure. RLN used for inoculation was collected from root samples harvested from a field site in Whatcom County.

Five treatments were applied in 2017: 1) 0 lbs N/acre + RLN (negative control); 2) 30 lbs N/acre + RLN; 3) 60 lbs N/acre + RLN; 4) 60 lbs N/acre – RLN, and; 5) 100 lbs N/acre + RLN (the "+" and "-" indicates microplots were or were not inoculated with RLN, respectively). Nitrogen fertilizers included a mixture of pre-plant and liquid fertilizers. Pre-plant nitrogen provided 10% of the total treatment rate, while liquid fertilizers (urea dissolved in water) were applied weekly from June to mid-July and provided the remaining nitrogen rate for the respective treatment. We based the 30 and 60 lb N/acre rates from OSU nutrient management recommendations for caneberry (Hart et al., 2006), while the 100 lbs N/acre rate was used to observe treatment effects at a higher rate of nitrogen fertilization. While the OSU nitrogen rate recommendation for raspberry after the first year of establishment is 50 to 80 lbs N/acre, we propose to continue our 2017 treatment rates for experimental consistency.

Data to be collected include:

- Populations of RLN in raspberry roots and soil; determined Sept. 2017 and 2018
- Soil chemistry (pH, macro- and micro-nutrients) determined Sept. 2017 and 2018
- Raspberry tissue nutrient concentrations (macro- and micro- nutrients) determined during the last week of July in 2017 and 2018
- Cumulative plant growth measured from all plants per treatment; growth will be measured monthly from primocanes from May-Oct. 2017 and 2018
- Raspberry yield and fruit quality (average berry size and °Brix); measured in 2018 only
- Shoot dry weight biomass (divided by floricane and primocane); 10 plants per treatment in 2017 and 2018

Anticipated Benefits and Information Transfer:
This project will provide information about the impacts nitrogen has on RLN parasitism in red raspberry and subsequent effects on plant growth. Project results will be shared at the 2018 Small Fruit Conference in Lynden, WA. Additionally, project results will be posted on the WSU Small Fruit Horticulture website (http://smallfruits.wsu.edu/) and shared through in the WSU *Whatcom Ag Monthly* and Peerbolt Small Fruit Update in 2018. Final results will be published in a scientific journal.

References:
Hart, J., B. Strik, and H. Rempel. 2006. Nutrient Management Guides: Caneberries. Oregon State University Extension Service. EM 8903-E.

Budget:

	2018
Salaries[1/]	$4,011
Timeslip[/2]	$880
Operations (goods & services)[3/]	$3,300
Travel[4/]	$634
Equipment	$0
Benefits[5/]	$1,711
Total	$10,536

[1]Salary for Scientific Assistant (Sean Watkinson) for 1 month/year = $4,011.
[2]Timeslip at $11/hr x 40 hrs/week x 2 weeks = $880.
[3]RLN extraction by Zasada @ $25/sample x 50 samples in 2018 = $1,250; soil nutrient analyses @ $15/sample x 25 samples/year = $375; tissue sample analyses @ $13/sample x 25 samples/year = $325/year; Land use fees at WSU-NWREC = $1,000/year; Field and lab supplies for DeVetter (fertilizer, syringes, sampling bags, shipping costs) = $350.
[4]Travel for Zasada to visit site/year, 640 RT @ $0.54/mile = $346; per diem rate (lodging, meals, incidentals) for 2 days in Mount Vernon, WA = 144 x 2 days = $288.
[5]Benefits for Scientific Assistant (Sean Watkinson) at 40.6%; Timeslip at 9.5%.

2018 WASHINGTON RED RASPBERRY COMMISSION
RESEARCH PROPOSAL

Project No: New **Proposed Duration:** 2 years

Project Title: Characterizing Changes in Leaf and Fruit Tissue Nutrient Concentration in Commercial Red Raspberry Cultivars

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Cooperators: None identified, but this project will require collaborators support if funded.

Year Initiated: 2018 **Current Year**: 2018 **Terminating Year**: 2019

Total Project Request: $49,163 **Year 1**: $24,327 **Year 2**: $24,836

Other funding sources: Yes - submitted.
Agency Name: United States Department of Agriculture Specialty Crop Research Initiative (USDA SCRI) program
Amt. Requested/Awarded: Total grant request is ~$5.5 million over 4 years for multiple projects. The amount requested for this experiment for research done in WA is $49,163.
Notes: We have included this experiment in the USDA SCRI proposal titled, "Expanding the Berry Crops Industry across Multiple Climactic Conditions through Breeding and Modification of Horticultural Systems". If this project is funded by both WRRC and USDA SCRI, we will return WRRC funds and use USDA funds to complete the project. We expect award announcements for USDA SCRI to be Summer 2018. We are also submitting a similar proposal to the Oregon Raspberry and Blackberry Commission (ORBC) for companion work done in OR. All work done in Oregon will be funded through the ORBC (proposal to be submitted by Strik).

Description:
Washington State is the leading national producer of floricane-fruiting red raspberry (*Rubus idaeus*), with Whatcom County representing ~98% of total in-state production (WRRC, 2017). While 'Meeker' is a historically important and prevalent cultivar that represented 60% of Washington plant sales in 2017, new cultivars are being developed, released, and adopted (Moore, 2017). Examples of these new cultivars include 'WakeHaven', 'Whatcom', and 'WakeField'. These cultivars display very different growth and production characteristics relative to 'Meeker'. Consequently, nutrient demands may be different. Tissue nutrient standards were not developed with these new cultivars and differences may exist due to region of production. This project seeks to explore how these new cultivars differ with regards to seasonal nutrient concentrations and uptake in leaf and fruit tissues in the economically significant

production area of Whatcom County, Washington. Results from this project will allow growers, crop advisors, and specialists to develop more targeted nutrient management practices for these new and increasingly important cultivars in this leading production region.

Justification and Background:
The current recommendation for floricane-fruiting red raspberry is to apply fertilizer nutrients according to research-based rates and to then modify application rates based on the results of annual primocane leaf tissue tests, soil tests every few years and with adjustments for productivity (yield), fruit quality, and observations of plant vegetative growth and leaf color (Hart et al., 2006). Tissue testing should be done on primocane leaves sampled between late-July to early August in the Pacific Northwest (PNW), which is when nutrients are most stable. The results of these tissue analyses are compared to regional standards and allow growers and crop advisors to assess plant nutrient status, which is then used to refine nutrient management programs for the following season.

Cultivars of red raspberry are known to differ in primocane leaf nutrient concentrations. For example, John et al. (1976) demonstrated 'Meeker', 'Glen Cova', 'Willamette', 'Malling Jewel', 'Haida', 'Matsqui', 'Newburgh', and '64-6-169' grown in British Columbia, Canada, differed in the concertation of 12 nutrients plus nitrate-nitrogen. Sampling time and cane age also affected nutrient concentrations. Similar results have been found in other caneberry species, including floricane- and primocane-fruiting blackberry (Fernandez-Salvador et al., 2015a, 2015b; Strik, 2015; Strik and Vance, 2017). These studies and more lead to the recommendation of segregating cultivars when collecting primocane leaves for tissue nutrient analyses. If cultivars are not separated, interpretations of results will be inaccurate.

'WakeField', 'WakeHaven', and 'Whatcom' represent some of the new cultivars of red raspberry that are being developed and adopted by the industry in Whatcom County, Washington. Relatively little research has been done with these new cultivars. It is very likely that these new cultivars have differences with regards to timing of nutrient uptake, content, and concentration in both leaves and fruits relative to traditional cultivars that have been grown in the PNW (e.g., 'Meeker' and 'Willamette'). Furthermore, these new cultivars tend to be more vigorous and productive and have different periods of fruit production, all of which could influence nutrient dynamics.

This project will characterize seasonal changes of macro- and micro- nutrient concentrations and content in leaf and fruit (fruit + receptacle separated) tissues among new and increasingly important cultivars of red raspberry in Whatcom County, Washington. Resultant information will provide information that will allow for more targeted nutrient management.

Relationship to WRRC Research Priorities:
This project is related to priority #3, "Nutrient Management – Revise OSU specs, Consider: timing, varieties, application techniques".

Objectives:
The primary objective of this project is to determine the timing and seasonal changes of macro- and micro- nutrient concentrations and uptake in leaf and fruit (fruit + receptacle separated)

tissues in commercially important floricane-fruiting red raspberry cultivars grown in Whatcom County, Washington. This project will also be part of a larger collaborative project with co-PI Strik whereby we will compare the Washington results with raspberry (red and black) and blackberry in Oregon, which will provide information across caneberry species grown in the PNW. Work done in Oregon will be funded by the ORBC. We propose to complete this in 2018 and repeat in 2019.

Procedures:
Three established fields each of 'WakeField', 'Whatcom', and 'Meeker' (control) will be identified in Whatcom County, Washington by PI DeVetter. Co-PI Strik will likewise identify three fields each of 'Meeker', 'Munger' black raspberry, and 'Columbia Star', 'Black Diamond' and 'Marion' trailing blackberry for work she will be doing in parallel for a ORBC grant. Three blocks/replicates will be established per field and used for sampling. Tissue sampling for nutrient analyses will occur six times during the 2018 season and repeated in 2019. Timing of sampling and the types of tissue to be collected are described in Table 1. In addition, we will also determine soil nutrient status from samples collected Oct. 2018 and 2019. Fresh and dry leaf (primocane and fruiting lateral) and fruit mass will be collected to determine percent dry weight so both nutrient content can be calculated from the concentration. Primocane number and height will also be determined in mid-Aug. of both years to assess plant vigor.

We will work with our grower collaborators to obtain yield data and sample from sections of the field where no foliar fertilizers are applied, which would otherwise confound our results. Information regarding fertilizer application rates and timing over the last two years and current year will also be requested from collaborators for the purposes of the study. Grower collaborator information will remain anonymous.

Table 1. Sample timing and tissues type to be collected in 'WakeField', 'Whatcom', and 'Meeker' red raspberry in Whatcom County, WA, 2018-2019.

Sample timing	**Tissue types sampled**
Bloom	Fruiting lateral leaves, flower/fruit, primocane leaves
+ 2 weeks	Fruiting lateral leaves, flower/fruit, primocane leaves
+ 2 weeks	Fruiting lateral leaves, flower/fruit, primocane leaves
+ 2 weeks: Early harvest	Fruiting lateral leaves, green fruit, immature fruit, ripe fruit, receptacle (from ripe fruit), primocane leaves
+ 2 weeks: Mid harvest	Fruiting lateral leaves, green fruit, immature fruit, ripe fruit, receptacle (from ripe fruit), primocane leaves
+ 2 weeks: Late harvest	Fruiting lateral leaves, green fruit, immature fruit, ripe fruit, receptacle (from ripe fruit), primocane leaves

Anticipated Benefits and Information Transfer:
This project will provide cultivar- and region-specific information on how cultivars of floricane red raspberry vary with regards to leaf nutrient concentrations and accumulation of macro- and micro-nutrients in leaf and fruit tissues. Knowledge on periods of uptake and differences across cultivars in this production area will provide information that will inform and allow for more targeted nutrient management. Project results will be shared at the 2019 Small Fruit Conference in Lynden, WA. Additionally, project results will be posted on the WSU Small Fruit

Horticulture website and shared through field days, electronic newsletters, and published in scientific journals.

References:

1. Hart, J., B. Strik, and H. Rempel. 2006. Caneberries. Nutrient Management Guide. Oregon State University Extension Service. EM 8903-E.
2. Fernandez-Salvador, J., B.C. Strik, and D.R. Bryla. 2015a. Response of blackberry cultivars to fertilizer source during establishment in an organic fresh market production system. HortTechnology 25:277-292.
3. Fernandez-Salvador, J., B.C. Strik, Y. Zhao, and C.E. Finn. 2015b. Trailing blackberry genotypes differ in yield and postharvest fruit quality during establishment in an organic production system. HortScience 50:240-246.
4. John, M.K., H.A. Daubeny, and H.H. Chuah. 1976. Factors affecting elemental composition of red raspberry leaves. J. Sci. Food Agr. 27:877-882.
5. Moore, P. 2017. 2017 Raspberry Plant Sales. Excel Document. Washington State University.
6. Strik, B. 2015. Seasonal variation in mineral nutrient content of primocane-fruiting blackberry leaves. HortScience 50:540-545.
7. Strik, B.C. and A.J. Vance. 2017. Seasonal variation in mineral nutrient concentration of primocane and floricane leaves in trailing, erect, and semi-erect blackberry cultivars. HortScience 52:836-843.
8. Washington Red Raspberry Commission (WRRC). 2017. Statistics - PNW Red Raspberry Production. Accessed 3 Dec. 2017 at: https://www.red-raspberry.org/statistics

Budget:

	2018	**2019**
Salaries[1/]	$7,701	$8,009
Timeslip[/2]	$1,760	$1,830
Operations (goods & services)[3/]	$11,192	$11,192
Travel[4/]	$380	$380
Equipment	$0	$0
Benefits[5/]	$3,294	$3,425
Total	$24,327	$24,836

[1]Salary for Scientific Assistant (Sean Watkinson) at 16% FTE = $7,701 and 8,009 in 2018 and 2019, respectively; values include 4% annual inflation.
[2]Timeslip at $11/hr x 40 hrs/week x 4 weeks = $1,760; values include 4% annual inflation.
[3]Leaf tissue sample analyses at $13/sample x 324 samples/year = $4,212; Fruit + receptacle sample analyses at $16/sample x 405 samples/year = $6,480/year; $300/year for shipping and $200/year for sampling supplies.
[4]Travel from Mount Vernon, WA to Lynden, WA at $0.54/mile x 88 miles roundtrip x 8 trips/year = $380.
[5]Benefits at 40.6% and 9.5% for the Scientific Assistant and timeslip, respectively.

Note – total annual costs can be reduced by ~$3,726 if we reduce sampling from three to two cultivars.

PATHOLOGY
VIROLOGY

Project: 13C-3755-5642
Title: Evaluation of Raspberry Bushy Dwarf Virus strains
Personnel: Patrick P. Moore, Professor and Kara Lanning.
Washington State University Puyallup Research and Extension Center
Cooperator: Bob Martin, USDA-ARS, Corvallis, OR**.**

Reporting Period: 2017 Final Report

Accomplishments:
Plants of 23 cultivars in a field planting at WSU Puyallup were virus tested in 2014. All 16 of the resistant and all 7 susceptible cultivars had at least one plant test virus positive. This indicates a resistance breaking strain of RBDV is widespread in the breeding plots at WSU Puyallup. At least three strains of RBDV could be distinguished by ELISA and two PCR tests. This has direct implications on breeding for RBDV resistance. At this time, we do not know what effects these different strains have on the plants. This study was designed to determine the effects of these three strains of RBDV on three raspberry cultivars.

Results Plants of Chief, Boyne and Latham all tested positive in a PCR test for the viral polymerase gene, indicating they were infected with RBDV. Chief and Boyne both tested ELISA positive for the viral coat protein, but Latham tested ELISA negative. Chief tested positive for the viral coat protein using a PCR test and Boyne and Latham tested negative. These tests can distinguish between the RBDV strains in these plants. A single plant of each of these three cultivars was used to graft sets of plants of Meeker, Chemainus and Willamette.

Virus testing of the grafted plants in 2016 produced ambiguous results and the plants needed to be re-tested in 2017. When they were re-tested only six plants out of thirty-four that were grafted tested RBDV positive. All of the plants that tested RBDV positive were grafted with Chief.

	Boyne		Chief		Latham		Control		Total
	+	-	+	-	+	-	+	-	
Chemainus	0	1	1	2	0	0	0	6	10
Meeker	0	6	5	0	0	3	0	6	20
Willamette	0	6	0	5	0	6	0	6	23
Total	0	13	6	7	0	9	0	18	

The grafting done with these plants did not transmit the different virus strains to Chemainus, Meeker and Willamette and the grafted plants will not be planted in the field as planned.

Dr. Martin will continue investigations of the differences among strains of RBDV. In November 2017, leaves from plants of Cascade Harvest, Haida, Heritage, Latham, Newburgh and Willamette at Puyallup were collected and shipped to Bob Martin's lab for virus testing. All of the cultivars that were sampled in November have been reported as resistant to the common strain of RBDV. Dr. Martin will continue investigations of these resistance breaking strains of RBDV.

Management of Fungicide Resistant Botrytis in Raspberry

Alan Schreiber, Agriculture Development Group, Inc., Eltopia, WA

Tom Walters, Walters Ag Research, Anacortes, WA

Tobin Peever, Washington State University, Pullman, WA

This report is based on three trials, a raspberry efficacy trial, a raspberry program trial and a blackberry botrytis trial.

Raspberry Botrytis Efficacy Trial

Materials and Methods

The staff at the Agriculture Development Group, Inc. started a research trial at Everson, WA in May 2017 to evaluate the effects of different fungicides on the raspberry botrytis disease. In this trial usually a single product was used for each application with the intention of determine whether that product or tank mix is effective against botrytis. But due to the high temperate and low precipitation during research season (see attached weather graphs), we only found 3 berries infected with botrytis out of 8,000 berries evaluated. However, during the course of the trial yellow rust was found in the trial. Therefore, the alternative objective was developed to evaluate the effects of different fungicides on the raspberry yellow rust.

The experimental design for this trial was a RCB with 4 replications and plot sizes of 10ft x 30ft. The treatments applications were made on May 31, June 7, June 14, June 23, July 1, and July 13 on the stages of 10% bloom, 50% bloom, 80% bloom, 100% bloom, first harvest, and mid-harvest, respectively. It is important to note that application timings were for botrytis and not for yellow rust. Treatment 20 to 27 were applied with surfactant SB-56 (NIS) at 6 fl zo/100 gallons solution (see ANOVA table below for treatment details). Applications for this trial were made with an over the row sprayer calibrated to apply treatment sprays at 100 gallons per acre. Both sides of each plot's raspberries were simultaneously sprayed to ensure complete coverage with the experimental products used. The rows of raspberries established for this trial were not treated with any maintenance fungicides in order to prevent the possibility of interfering with the existing trial's objectives. The yellow rust disease was evaluated on July 27 after all applications had been made.

ANOVA Table

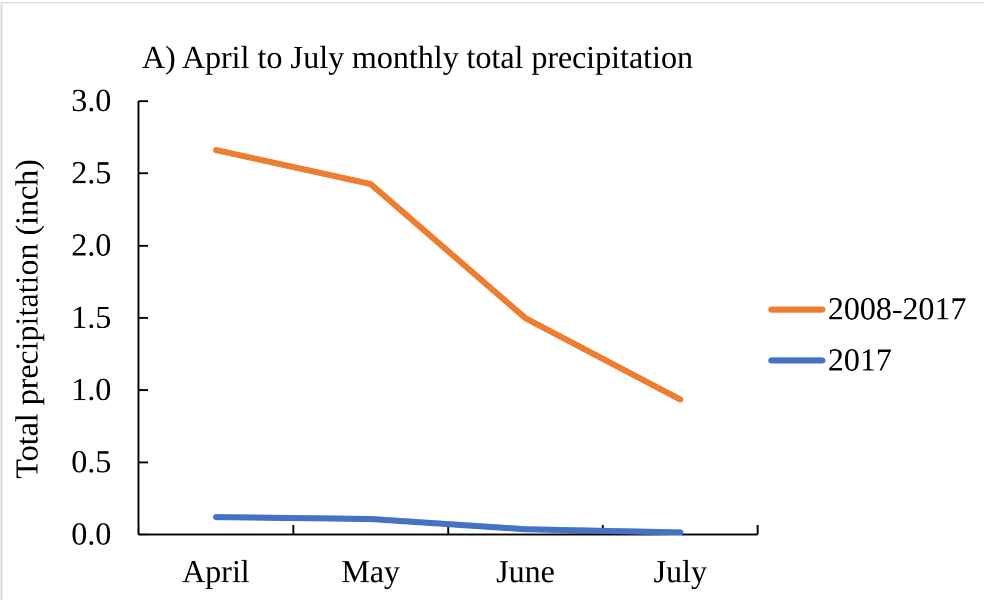
Comparison of 26 fungicidal programs for control of yellow rust on raspberry.

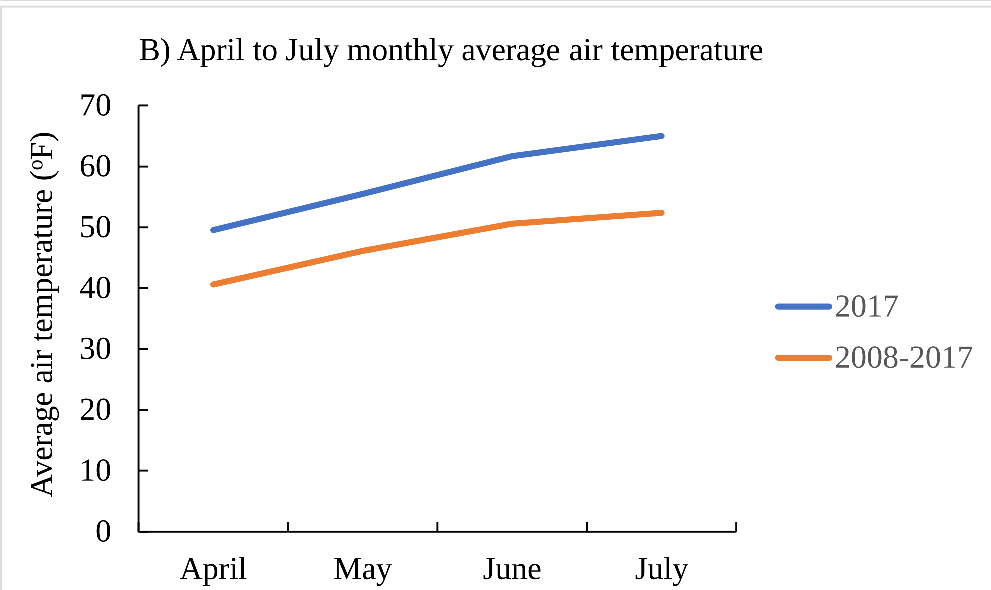
					yellow rust			
Trt No.	Treatment	Rate of Application		# of Appl.	% incidence		severity	
1	Untreated Check				55.0	abcd	0.67	a
2	PhD	6.2	oz/a	ABCDEF	62.5	abcd	0.81	a
3	Omega	1.25	pt/a	ABCDEF	46.3	bcde	0.50	a
4	Luna Tranquility	18	fl oz/a	ABCDEF	52.5	abcd	0.35	a
5	Scala	18	fl oz/a	ABCDEF	73.8	ab	1.14	a
6	Switch	14	oz/a	ABCDEF	60.0	abcd	0.63	a
7	Captan	2.5	lb/a	ABCDEF	68.8	abc	0.67	a
8	Elevate	1.5	lb/a	ABCDEF	63.8	abcd	0.94	a
9	Pristine	23	oz/a	ABCDEF	63.8	abcd	0.60	a
10	Iprodione	2	pt/a	ABCDEF	78.8	a	1.50	a
11	Oxidate	32	fl oz/100 gal	ABCDEF	70.0	abc	0.82	a
12	Proline	5	fl oz/a	ABCDEF	40.0	def	0.50	a
13	Oso	13	fl oz/a	ABCDEF	18.8	ef	0.33	a
14	Fontelis	20	fl oz/a	ABCDEF	18.8	ef	0.11	a
15	Kenja	15.5	fl oz/a	ABCDEF	53.8	abcd	0.85	a
16	Kenja	13.5	fl oz/a	ABCDEF	52.5	abcd	1.23	a
17	Adepidyn	10.5	fl oz/a	ABCDEF	61.3	abcd	1.01	a
18	Serifel 10	4	oz/a	ABCDEF	60.0	abcd	0.67	a
19	Serifel 10	8	oz/a	ABCDEF	61.3	abcd	0.73	a
20	Experimental G	1.5	pt/a	ABCDEF	45.0	cde	0.57	a
21	Expermental G 2	2	pt/a	ABCDEF	71.3	abc	1.34	a
22	Experimental G	3	pt/a	ABCDEF	60.0	abcd	0.75	a
23	Experimental G	1.5	fl oz/a	ABCDEF	63.8	abcd	0.67	a
24	Experiment G	3	fl oz/a	ABCDEF	75.0	a	0.71	a
25	Experimental G 2	3	fl oz/a	ABCDEF	56.3	abcd	0.65	a
26	Fontelis	6	fl oz/100 gal	ABCDEF	16.3	f	0.14	a
27	Captan	2	lb/a	ABCDEF	53.8	abcd	0.67	a
27	Pristine	23	oz/a	ABCDEF				

Results and Discussion

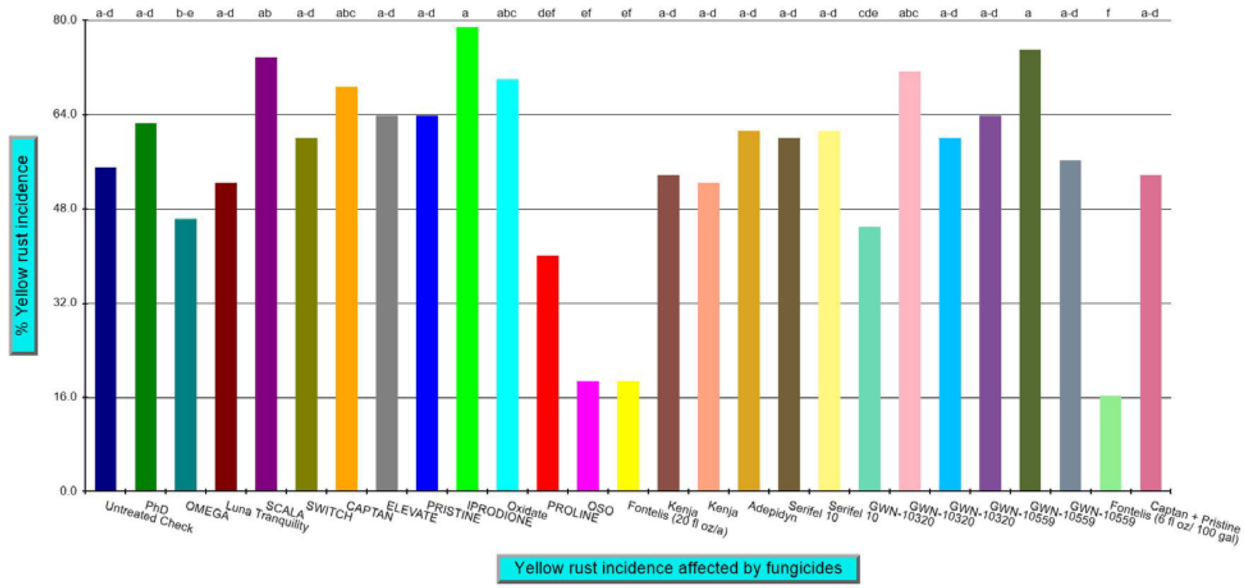
The botrytis disease pressure was extremely low (0.0375% incidence), which was due to the high temperature and low precipitation during summer (Graph 1). The yellow rust severity was relatively high. Treatments OSO, Fontelis (20 fl oz/a) and Fontelis (6 fl oz/100 gallon) showed significantly lower yellow rust incidence, with 65.8%, 65.8%, and 70.4% lower incidence compared to untreated check, respectively. Although not significantly different among treatments, treatments OSO, Fontelis (20 fl oz/a) and Fontelis (6 fl oz/100 gallon) had numerically 50.7%, 83.6%, and 79.1% less severity compared to untreated check, respectively. The results indicated that OSO and Fontelis have the potential to reduce yellow rust severity of raspberry when used for control of botrytis.

Graph 1. April to July monthly total precipitation (A) and average air temperature (B) for year 2017 and 2008-2017.





Graph 2. Comparison of 26 fungicidal programs for control of yellow rust in raspberry-incidence data.



Graph 3. Comparison of 26 fungicidal programs for control of yellow rust in raspberry-severity data.

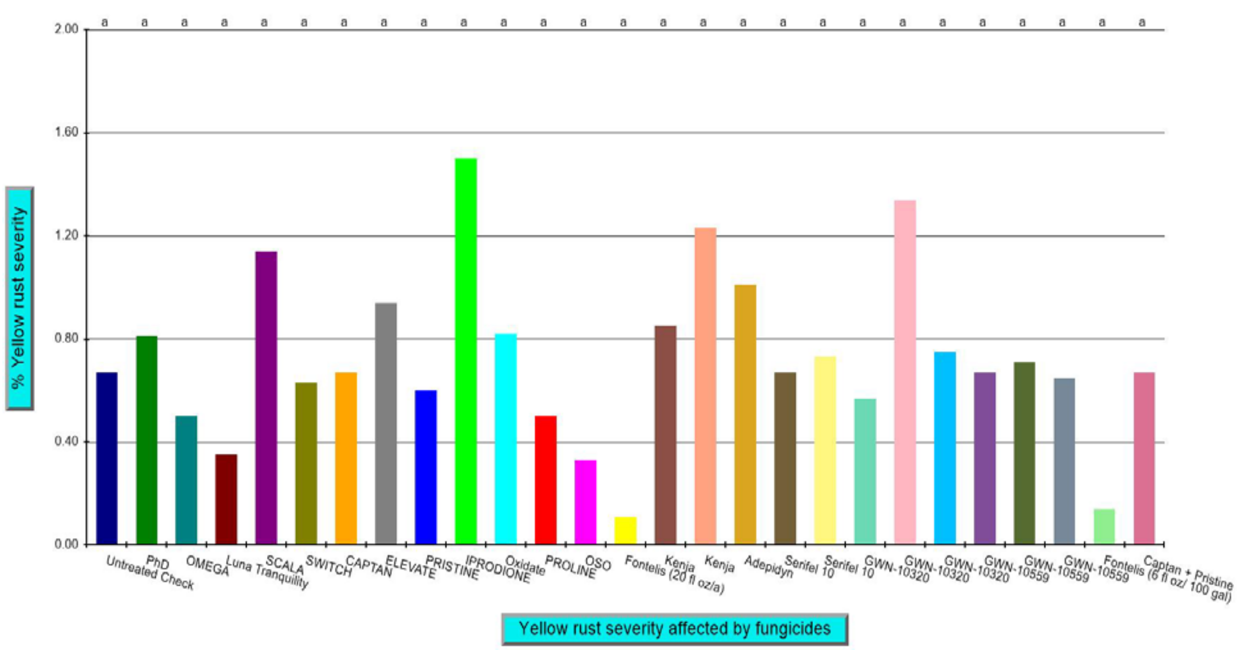


Photo 1. Application B for raspberry disease trial on 06/07/2017.

Photo 2. Yellow Rust of Raspberry in the Raspberry Botrytis Efficacy Trial

Raspberry Botrytis Program Trial

Materials and Methods

The staff at the Agriculture Development Group, Inc. started a research trial at Everson, WA in May 2017 to evaluate the effects of different fungicides on the raspberry botrytis disease. The objective of this trial is to determine comparative efficacy of various programs of products used for control botrytis in raspberry. These programs represent the majority of the programs used by the Washington raspberry industry and some new programs that have not historically been used. Unfortunately, due to the high temperate and low precipitation during summer (see attached weather graphs), we only found 3 berries infected with botrytis out of 8,000 berries evaluated. However, during the course of the trial yellow rust was found in the trial. Therefore, the alternative objective was developed to evaluate the effects of different fungicides on the raspberry yellow rust.

The experimental design for this trial was a randomized complete block design with four replications and plot sizes of 10ft x 30ft. Applications were made on May 29 (10% bloom), June 7 (30% bloom), June 14 (50% bloom), June 22 (1st harvest), July 2, and July 13 (mid-harvest). It is important to note that application timings were for botrytis and not for yellow rust. All treatments were applied with surfactant SB-56 (NIS) at 6 fl zo/100 gallons solution. Applications for this trial were made with an over the row sprayer calibrated to apply treatment sprays at 100 gallons per acre. Both sides of each plot's raspberries were simultaneously sprayed to ensure complete coverage with the experimental products used. The rows of raspberries established for this trial were not treated with any maintenance fungicides in order to prevent the possibility of interfering with the existing trial's objectives. The yellow rust disease was evaluated on July 27.

ANOVA Table

Comparison of 17 fungicidal programs for control of yellow rust on raspberry.

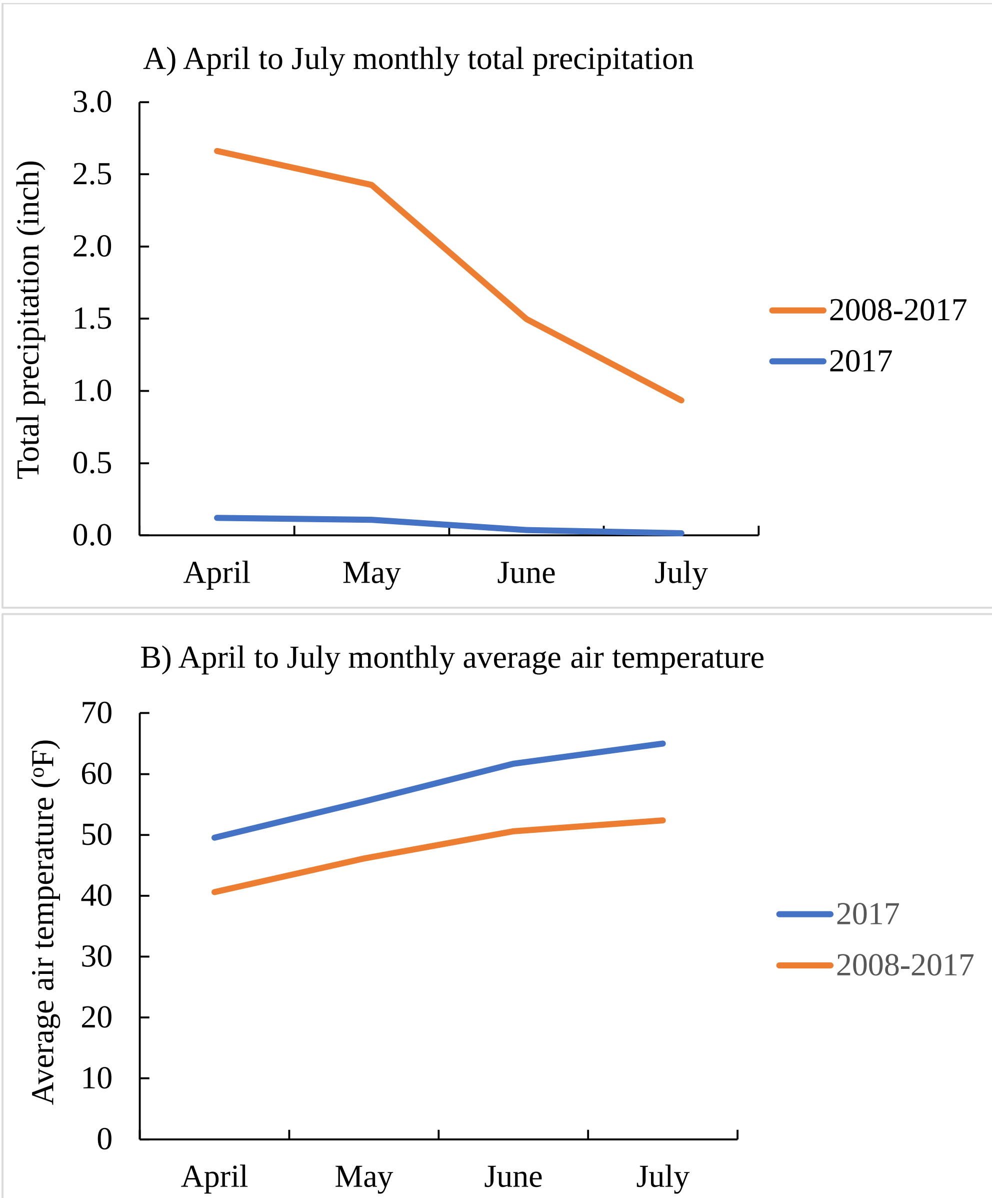
Trt No.	Treatment Name	Rate of Application		Timing of Application	% incidence of yellow rust		Severity of yellow rust	
1	Untreated Check				61.3	ab	4.27	abc
2	Captan	2	lb/a	A	77.5	a	5.39	abc
	Switch	14	oz/a	A				
	Captan	2	lb/a	B				
	Pristine	23	oz/a	B				
	Captan	2.5	lb/a	C				
	Meteor	32	fl oz/a	C				
	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				
3	Captan	2.5	lb/a	A	57.5	ab	4.34	abc
	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				
4	Captan	2.5	lb/a	A	68.8	ab	6.14	a
	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				
5	Captan	2.5	lb/a	A	58.8	ab	4.06	abc
	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				
6	Captan	1.5	lb/a	A	77.5	a	6.07	a
	Captan	1.5	lb/a	B				
	CAPTAN	1.5	lb/a	C				
	Captan	1.5	lb/a	E				
7	CAPTAN	1.25	lb/a	A	72.5	a	6.23	a
	SWITCH	14	oz/a	A				
	CAPTAN	1.25	lb/a	B				
	PRISTINE	23	oz/a	B				
	CAPTAN	2.5	lb/a	C				
	Kenja	15.5	fl oz/a	C				
	CAPTAN	1.25	lb/a	D				
	Switch	14	oz/a	D				
	PhD	6.2	oz/a	E				
	Luna Tranquility	16	fl oz/a	E				
	PhD	6.2	oz/a	F				
	SWITCH	14	oz/a	F				
8	CAPTAN	2	lb/a	A	55	abc	4.85	abc
	SWITCH	11.2	oz/a	A				
	CAPTAN	2	lb/a	B				
	PRISTINE	20	oz/a	B				

	CAPTAN	2.5	lb/a	C				
	Meteor	32	fl oz/a	C				
	CAPTAN	2	lb/a	D				
	SWITCH	11.2	oz/a	D				
	CAPTAN	2	lb/a	E				
	PhD	6.2	oz/a	E				
	CAPTAN	2	lb/a	F				
	SWITCH	11.2	oz/a	F				
9	Kenja	15.5	fl oz/a	ACD	53.8	abc	3.64	a-d
	CAPTAN	2	lb/a	ABCDEF				
	PhD	6.2	oz/a	B				
	Meteor	32	fl oz/a	E				
	SWITCH	14	oz/a	F				
10	ELEVATE	1.5	lb/a	A	61.3	ab	4.59	abc
	Meteor	32	fl oz/a	B				
	Elevate	1.5	lb/a	C				
	Pristine	20	oz/a	D				
	Elevate	1.5	lb/a	E				
	Switch	14	oz/a	F				
11	Switch	14	oz/a	AF	65	ab	5.99	a
	Captan	2	lb/a	ABCDEF				
	Luna Tranquility	16	fl oz/a	BDE				
	Meteor	32	fl oz/a	C				
12	Luna Tranquility	16	fl oz/a	ABCDEF	70	a	6.07	a
13	Luna Tranquility	16	fl oz/a	ABE	62.5	ab	5.74	ab
	Captan	2.5	lb/a	CD				
	Serenade Optimum	16	oz/a	F				
14	Luna Tranquility	16	fl oz/a	ABF	73.8	a	5.55	ab
	Captan	2.5	lb/a	DE				
	Serenade Optimum	16	oz/a	C				
15	Merivon	5.5	fl oz/a	ABCDEF	30	cd	2.74	cd
16	Pristine	23	oz/a	A	43.8	bc	2.97	bcd
	Meteor	32	fl oz/a	B				
	Fontelis	20	fl oz/a	CD				
	Switch	14	oz/a	EF				
17	Fontelis	20	fl oz/a	ABCDEF	15	d	1.04	d
18	Fontelis	24	fl oz/a	ABCDEF	7.5	d	1.13	d

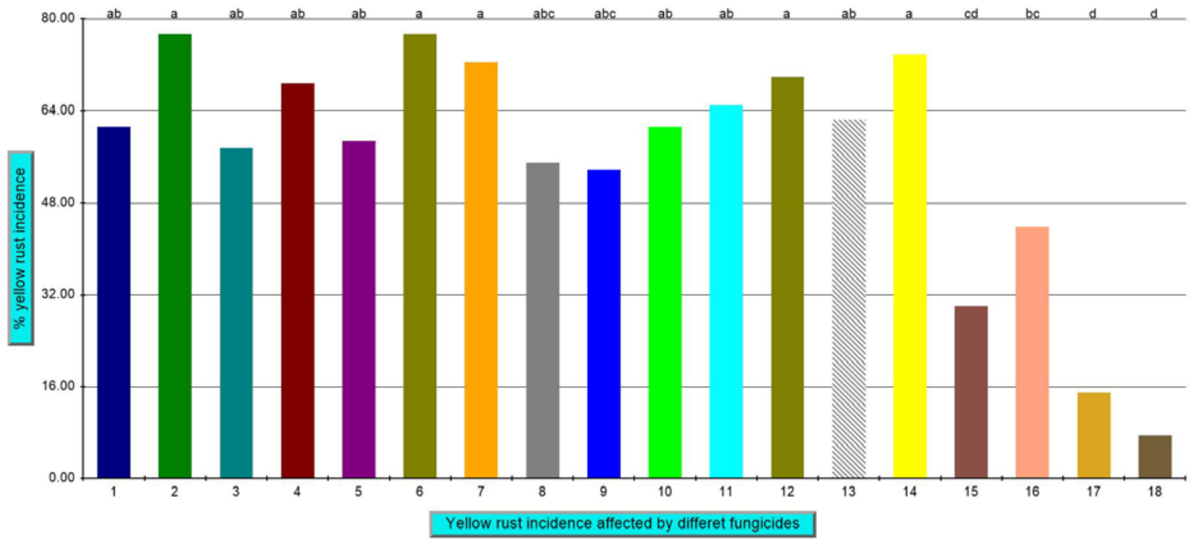
Results and Discussion

The botrytis disease pressure was extremely low (0.0375% incidence), which was due to the high temperature and low precipitation during summer (graph 1). The yellow rust severity was also not high. All treatments with different fungicide combinations did not show improved yellow rust control, statistically as compared to the untreated check, however the treatments with Fontelis along showed significantly lower yellow rust incidence and severity. Fontelis at 20 and 24 fl oz/a showed 75.5% and 87.8% less disease incidence than untreated check. Fontenlis at 20 and 24 fl oz/a showed 75.6% and 73.5% less disease severity than untreated check. The results indicated that Fontelis by itself can provide good control of yellow rust in raspberry when applied for botrytis.

Graph 1. April to July monthly total precipitation (A) and average air temperature (B) for year 2017 and 2008-2017.



Graph 2. Comparison of 17 fungicidal programs for control of yellow rust in raspberry-incidence data.



Graph 3. Comparison of 17 fungicidal programs for control of yellow rust in raspberry-severity data.

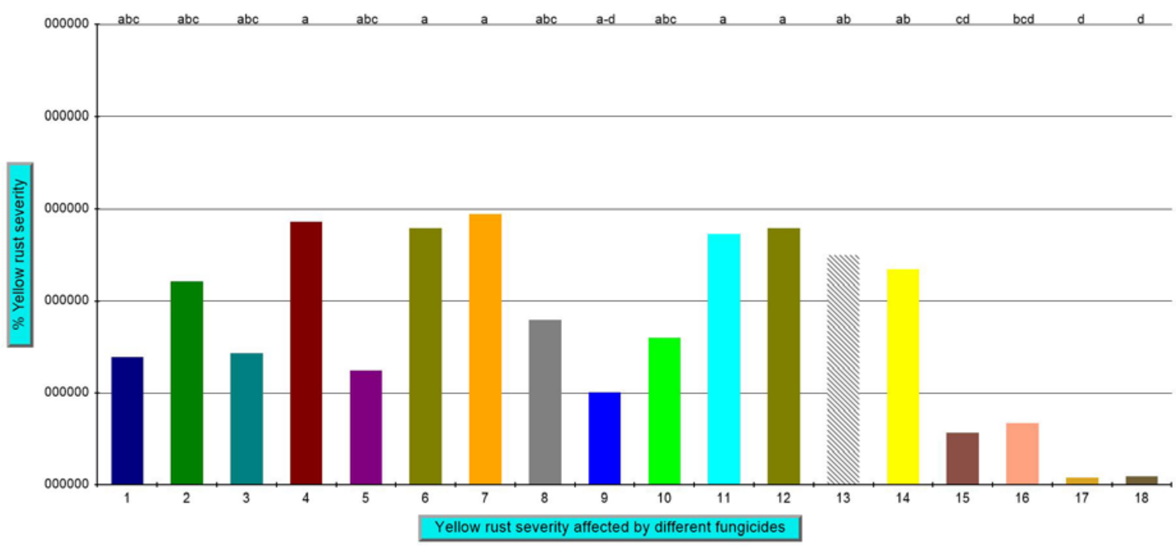


Photo 1. Application A on June 27, 2017.

Photo 2. Representative photos of botrytis symptom on blackberry on September 20, 2017.

Recommendations based on 2017 Research.

- Fontelis and Oso have activity against yellow rust of raspberry when applied for botrytis.
- Fontelis, Luna Tranquility and Kenja have significant activity against botrytis and will have, at least temporarily, value for control in botrytis management programs.
- These products can be used in commercial raspberry production but should not be used as a rotational product with Pristine since all products contain fungicides from FRAC group 7.

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

Project Title: Management of Fungicide Resistant Botrytis in Red Raspberry

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

Cooperators: Dr. Tobin Peever-WSU, Tom Walters-Walters Ag Research

Year Initiated: 2016 **Current Year:** 2017 **Terminating Year:** 2018

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 for $22,500. I expect that registrants will be involved in this project and will contribute, but how much is unknown.

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, 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.

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 take the lead on berry pathology and biological work, but he has no interests in taking the lead on efficacy trials in raspberries. 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 most new and pending registrations are for active ingredients that are in the same FRAC group 7 that is in the commonly used product Pristine.

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 2018 that are similar to the trials done in 2016 and 2017. 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 2018 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:	2017	2018	2019
Salaries	6,000	7,000	8,000
Operations	3,000	3,000	3,000
Travel	1,500	1,500	1,500
Benefits	1,500	1,500	1,500
Total	$12,000	$13,000	$14,000

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. 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.

Chemical company funds would be used to support the grower/crop destruct, travel and operational costs (buy product that is not donated, etc.)

Related Information.

Results from 2017. Due to weather conditions that were highly unfavorable for botrytis, there was virtually no botrytis in the raspberry in 2017. 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.

Washington Red Raspberry Commission
Progress Report for 2017 Projects

Project No: 3061-4303

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

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

Reporting Period: January 2017 to November 2017

Accomplishments: Experiments were performed over two seasons (2015 and 2016) to assess the dynamics of raspberry flower and fruit colonization by *Botrytis cinerea*. Experiments were performed in an unsprayed raspberry. Data were summarized and analyzed and the incidences of colonization at different developmental stages and flower/fruit organs stage determined. Environmental factors associated with *B. cinerea* colonization of raspberry flowers and fruit in NW Washington were identified. An experiment was performed in 2017 to determine the effect of season-long fungicide sprays on *Botrytis* colonization of red raspberry plants at different stages of development. Experiment was conducted in four commercial fields of cultivar Wakefield in NW Washington. Preliminary 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.

Results. *B. cinerea* colonization of raspberry flowers and fruit increased as season progressed, with the first significant increase at the open flower stage (S3) relative to closed green buds (S1) or half-open flowers (S2) (Fig. 1). Colonization of flowers remained limited throughout the season, and only 15% of total sampled open flowers were colonized by the fungus. *B. cinerea* colonization increased significantly as fruit developed and peaked at ripe fruit (Fig. 1). Among 15% of flowers tested positive for colonization by *B. cinerea*, the female part of flower (carpel) was colonized most frequently by the fungus (Fig. 2). Carpels had the greatest incidence of colonization at all stages. As flowers developed into fruit, the incidence of *B. cinerea* colonization of stamens, sepals, receptacles, and pedicles increased (Fig 2.).

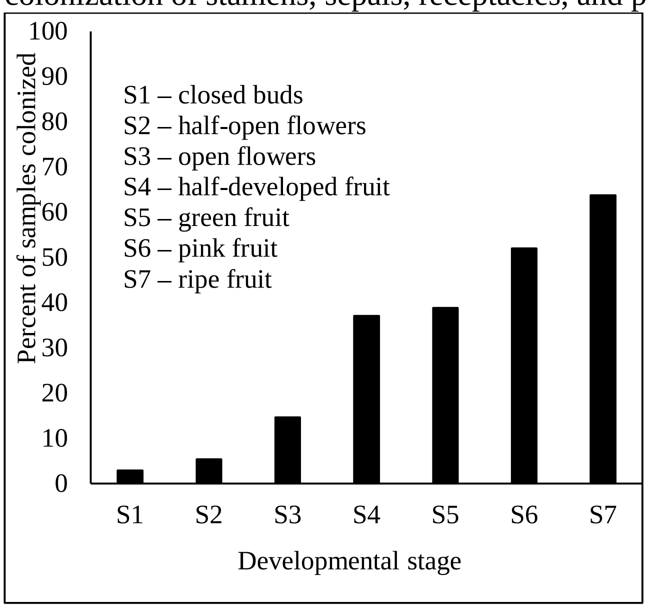


Figure 1. *B. cinerea* colonization of raspberry flowers and fruit in 2016

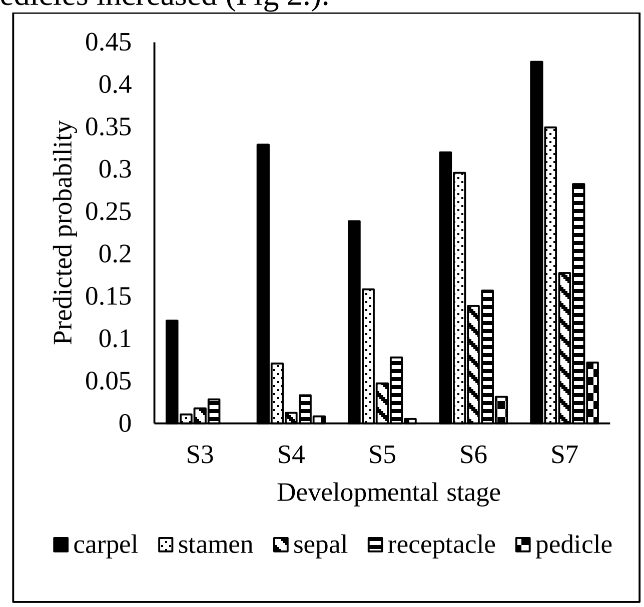


Figure 2. Colonization of flower and fruit organs by *B. cinerea* in 2016

In 2015, among all environmental factors measured, average weekly leaf wetness and average weekly night leaf wetness significantly were associated with *B. cinerea* colonization of raspberry flowers and fruit (Table 1). The odds ratio estimate for leaf wetness showed that for each 10% increase in average weekly leaf wetness, the odds of *B. cinerea* recovery increased 1.3 times.

Average weekly night leaf wetness had an opposite association with the fungal colonization, with each 10% increase in average night leaf wetness, the odds of *B. cinerea* colonization significantly decreased (Table 1). In 2016, average weekly night temperature, maximum average weekly temperature, cumulative rain, and average weekly relative humidity had significant association with *B. cinerea* colonization of raspberry flowers and fruit (Table 1). Cumulative rain had the greatest magnitude of effect on colonization by *B. cinerea*, with each 25 mm (1 inch) increase in cumulative rain the odds of *B. cinerea* recovery increased 1.96 times. With each degree increase in night temperature the odds of *B. cinerea* colonization increased 1.14 times, while with each degree increase in maximum temperature the odds of *B. cinerea* colonization decreased (Table 1). Relative humidity also had negative effect on *B. cinerea* recovery in 2016, with every percent increase in weekly relative humidity the odds of B. cinerea colonization decreased (odds ratio 0.87) (Table 1).

Table 1. Analysis of significant environmental factors associated with *B. cinerea* colonization of red raspberry flowers and fruit in 2015 and 2016 sampling seasons

Odds ratio	Estimate	95% Cl		*P*
2015				
Leaf wetness	1.27	1.04	1.54	0.0170
Night leaf wetness	0.79	0.68	0.93	0.0032
2016				
Night T	1.14	1.07	1.21	<.0001
Max T	0.94	0.90	0.98	0.0026
CumRain	1.96	1.58	2.43	<.0001
RH	0.87	0.83	0.92	<.0001

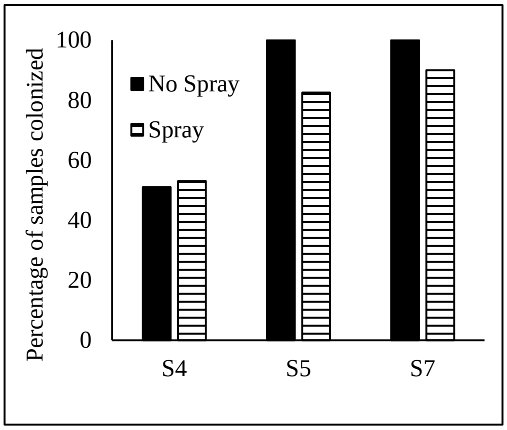


Figure 3. Effect of fungicide applications on *B. cinerea* colonization of red raspberry flowers and fruit in 2017

The colonization incidence of *B. cinerea* on early stages of flower/fruit development averaged at 40% among total 400 samples, stage S4 (Fig. 3). The colonization incidence significantly increased with fruit development and maturation in all four sampled fields. There was no difference in *B. cinerea* colonization of raspberry flowers (stage S4) between flowers sampled from sprayed by fungicides fields and fields not sprayed with fungicides (Fig.3). *B. cinerea* colonization incidence of green fruit (stage S5) and ripe fruit (S7) was significantly different between samples from sprayed and non-sprayed fields (Fig. 3). In non-sprayed fields, the incidence reached 100% at fruit stages (S5 and S7), however, *B. cinerea* colonization incidence of S5 and S7 stages also remained relatively high among samples from sprayed fields (83% and 90% at S5 and S7, respectively).

Sample	Organ	Stage	MLG
1	receptacle	S2	1
2	carpel	S4	2
3	stamen	S7	3
	sepal	S7	4
	‘carpel’	S7	3
4	‘carpel’	S7	5
	sepal	S7	6
	stamen	S7	7
5	sepal	S7	8
	‘carpel’	S7	9
6	receptacle	S7	10

Table 2. Preliminary DNA fingerprinting analysis of *Botrytis* isolates from different organs of flowers and fruit
*different numbers in MLG column represent different multilocus genotypes (MLGs) of the isolates

Genetic analysis of 11 *B. cinerea* isolates from 6 total raspberry flowers and fruit sampled in 2016 revealed overall high genetic diversity (10 multilocus genotypes among 11 isolates) (Table 2). In samples 3, 4, and 5 multiple *B. cinerea* isolates were obtained from different organs of the same sample, but only in sample 3 the same multilocus genotype was isolated from stamen and carpel (Table 2).

Publications O. Kozhar, T. Peever. 2017. How does *Botrytis cinerea* infect red raspberry? Phytopathology. In peer-review.

2018 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

PI: Tobin L. Peever
Organization: Department of Plant Pathology, Washington State University
Title: Associate Professor
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City/State/Zip: Pullman, WA 99164-6430

Cooperators:

Year Initiated __**2018**__ **Current Year** __**2018**__ **Terminating Year** __**2018**__

Total Project Request: Year 1 $23,808

Other funding sources:
Agency Name: Washington State Commission on Pesticide Registration
Amt. Requested/Awarded: $26,985, submitted Nov 13, 2017

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 a detailed study of the timing of infection of raspberry by *Botrytis cinerea* related to the raspberry plant development and the effect of changes in timing of fungicide applications on the development of gray mold in raspberry in Washington. We are also interested in 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. 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. This is due to our limited understanding of the infection process of raspberry plants by the pathogen including the timing of infection in relation to fruit development. In addition to inefficient disease management, current fungicide application programs have led to the development of extensive fungicide resistance problems with four of five fungicides registered to control gray mold in Washington.

Gray mold results from the colonization of mature raspberry fruit by the fungus *B. cinerea* but the initial source of the infection has long been thought to be latent or quiescent infections of flowers (Dashwood & Fox 1988, Jarvis 1962). This hypothesis forms the basis for fungicide application programs on red raspberry in NW Washington and worldwide (Pscheidt and Ocamb 2017). Recent research in our laboratory has shown that infection of raspberry may not be restricted to the flowering stage but rather infections appear to accumulate through the growing season (O. Kozhar and T.L. Peever, *unpublished*). It also appears likely that fruit may be infected externally later in the season, possibly following wounding of the fruit during machine harvesting. We currently have no information related to the efficacy of alternative fungicide spray programs for gray mold control in raspberry. Red raspberry growers in NW Washington may be able to decrease fungicide use substantially by eliminating early sprays currently targeted at protecting flowers and focus disease management on developing and ripe fruit. However, such a strategy would need to be verified with field-based efficacy studies over multiple seasons before being recommended and deployed on a regional scale. Eliminating early sprays and reducing overall fungicide use would contribute to substantial cost reductions and also help reduce the risk of fungicide resistance development by *B. cinerea* by reducing the overall selection pressure for fungicide resistance.

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., *Trichderma* spp., and *Altenraria* 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) Determine the effect of fungicide applications on floral and fruit colonization of raspberry by *Botrytis cinerea* in WA
2) Quantitatively relate *B. cinerea* colonization of fruit in the field to fungal contamination during processing
3) Compare *B. cinerea* isolates colonizing flowers to those colonizing fruit as an alternate test of the hypothesis that fruit infection results from flower infection

Procedures

1) Determine the effect of fungicide applications on floral and fruit colonization of raspberry by *Botrytis cinerea* in WA

Four commercial red raspberry fields of cultivar Wakefield in Whatcom Co. will be selected for this experiment. Two of these fields will be sprayed with fungicides according to an industry-standard, high-input IQF spray program and two field will be left untreated. One hundred samples of raspberry flowers, green fruit, and ripe fruit will be sampled from each field 3 times throughout the season. Samples will be surface-disinfested and plated to *Botrytis*-specific agar medium in the laboratory for detection of colonization by *B. cinerea*. Fungal colonies that grow out of the samples will be identified using morphological and molecular methods, and the number of *B. cinerea* colonies in each sample will be recorded. In order to determine if the fungicides applied are expected to be effective in controlling *Botrytis* at the different plant growth stages (flowers, green fruit, ripe fruit), 12 *B. cinerea* isolates from each of three stages sampled from each of four fields will be screened for fungicide sensitivity to five chemicals that are commonly used for gray mold control in Washington and employed in these fields. These chemicals include fenhexamid, iprodione, boscalid, fludioxonil, and cyprodinil. Mycelial growth assays on discriminatory concentrations of technical grade or formulated fungicides will be used for this experiment.

2) 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 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 among the 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 and that does not decrease fruit quality.

3) Compare *B. cinerea* isolates colonizing flowers to those colonizing fruit as an alternate test of the hypothesis that fruit infection results from flower infection

The two fields unsprayed with fungicides described above will be used for this experiment. In each field, ten raspberry flower clusters will be marked before bloom, and flowers, green fruit and ripe fruit will be sampled from these clusters during the growing season. Samples will be cultured on *Botrytis* specific agar medium, and each *B. cinerea* colony will be isolated for DNA fingerprinting analysis. The isolates will be scored for genetic variation at 8 microsatellite loci previously developed for *B. cinerea* using PCR conditions and relevant methodology (Fournier et al. 2002, Amselem et al. 2011). Standard population genetic analysis will be conducted to compare the fingerprints of *B. cinerea* isolates from flowers to those isolated from green and ripe fruit. This experiment will provide complementary data to the colonization experiment described above (Objective 1) and allow an alternate test of the hypothesis that all fruit infection results from infection of open flowers early in the growing season.

Anticipated Benefits and Information Transfer

This research will address critical gaps in our knowledge of the disease cycle of *Botrytis cinerea* causing *Botrytis* fruit rot of raspberry in the US-PNW and provide important baseline data on the timing of infection of raspberry plants and improvement of the disease management strategies. 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 timing of fungicide applications will allow reductions in overall fungicide use, reduced selection for fungicide resistance and decreased fungicide residues in fruit.

References

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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.

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

	2018
Salaries[1/]	10271
Time-Slip[2/]	2692
Operations (goods & services)[3/]	6000
Travel[4/]	3768
Meetings	0
Other	0
Equipment[5/]	0
Benefits[6/]	1077
Total	**23808**

Budget Justification

[1/] 0.5 FTE Salary for PhD Student Olga Kozhar

[2/] Time-slip employee to help with field sampling, fungal culturing etc.

[3/]Lab supplies (petri dishes, agar, chemicals) = $2970 and DNA fingerprinting = $3030

[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.

*Budget approved by Laura Coughenour at WSU 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	WA Raspberry	22320	01/01/17 to 12/31/17	15	Evaluation of FRAC Group 7 (SDHI) fungicides for control of Botrytis fruit rot of red raspberry in WA
Harteveld & Peever	WA Blueberry	15474	01/01/17 to 12/31/17	15	Mummy Berry of Blueberry: Updates, Prediction Model Validation and Fungicide Resistance
Peever	WSCPR	26442	01/01/17 to 12/31/17	15	Evaluation of FRAC Group 7 (SDHI) fungicides for control of Botrytis fruit rot of red raspberry in WA
Peever & Harteveld	WA Blueberry	12742	01/01/17 to 12/01/17	5	Laboratory Equipment for Small Fruit Pathology at NWREC
Peever	WA Raspberry	13000	01/01/17 to 12/01/17	5	Laboratory Equipment for Small Fruit Pathology at NWREC
Harteveld & Peever	NWCSFR	49969	10/01/17 to 09/30/18	10	Mummy berry of blueberry in the Pacific Northwest: A prediction model for primary inoculum release

	Pending:				
Peever	WA Raspberry	20610	01/01/18 to 12/31/18	15	Boscalid resistance mutations in *Botrytis cinerea* populations infecting red raspberry in WA and relationship to control by other FRAC Group 7 (SDHI)
Peever	WA Raspberry	23808	01/01/18 to 12/31/18	15	Biology and control of *Botrytis* fruit rot of red raspberry in the Pacific Northwest (this proposal)
Peever	WA Blueberry	24062	01/01/18 to 12/31/18	15	Mummy Berry of Blueberry: Updates, Prediction Model Validation
Peever	WSCPR	22721	01/01/18 to 12/31/18	15	Biology and control of *Botrytis* fruit rot of red raspberry in the Pacific Northwest
Peever	WSCPR	25302	01/01/18 to 12/31/18	15	Boscalid resistance mutations in *Botrytis cinerea* populations infecting red raspberry in WA and relationship to control by other FRAC Group 7 (SDHI)

2018 WASHINGTON RED RASPBERRY COMMISSION
RESEARCH PROPOSAL

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

Project Title: Boscalid resistance mutations in *Botrytis cinerea* populations infecting red raspberry in WA and relationship to control by other FRAC Group 7 (SDHI) fungicides

PI: Tobin L. Peever
Organization: Department of Plant Pathology, Washington State University
Title: Associate Professor
Phone: 509-335-3754
Email: tpeever@wsu.edu
Address: P.O. Box 646430
City/State/Zip: Pullman, WA 99164-6430

Year Initiated: __2018__ **Current Year:** __2018__ **Terminating Year:** __2019__

Total Project Request: $20610

Other funding sources: WSCPR

Description

Several recent studies have demonstrated that newly developed FRAC group 7 (SDHI) fungicides may provide control of boscalid-resistant strains even though these fungicides have similar chemistry and mode of action to boscalid and are in the same Fungicide Resistance Action Committee (FRAC) group (Amiri et al. 2014, Olaya et al. 2016, Sierotzki and Scalliet 2013). Frequencies of resistance to boscalid in WA populations of *Botrytis cinerea*, causal agent of gray mold of red raspberry, are high in most fields. New fungicides that are able to control these strains would represent important gray mold management tools for WA raspberry growers. Specific outputs of this project will include a detailed study of the distribution of different types of boscalid resistance mutations in populations of *Botrytis* infecting raspberry in WA. Understanding the types and distributions of these mutations will allow us to predict which of the new SDHI fungicides are likely to be effective in controlling gray mold in red raspberry in WA, particularly in fields with high levels of boscalid resistance. We have previously determined cross resistance relationships among these new fungicides and boscalid (D. Dutton and T.L. Peever, *unpublished*). We are specifically interested in determining if these new SDHI fungicides are able to control *Botrytis* isolates that are resistant to boscalid in WA and thus provide growers with new disease control options. These studies, coupled with in-field efficacy testing of the same products by other scientists, will provide important baseline data necessary for the future registration of these fungicides for use in WA raspberry production and provide WA raspberry growers with additional and critically needed disease control options.

Justification and Background

Washington produces 90% of the US processed raspberry supply with approximately 66 million lbs harvested and a farm gate value of 80 million dollars in 2015. About 10,000 acres are currently in raspberry production and yields average approximately 4 tons per acre. Despite intensive fungicide applications used to control gray mold, caused by *Botrytis cinerea*, it is estimated that fruit losses and downgrades in fruit quality exceed 25% of the harvestable fruit due to incomplete disease control in disease-conducive years. This represents an average loss of 1 ton per acre equating to approximately $1500 per acre. Gray mold is the most economically significant disease affecting raspberry production in WA and aggregate losses are approximately 15 million dollars per year. Of the five major fungicides registered for raspberry gray mold control in WA, resistance has been documented to four of them (boscalid, fenhexamid, and cyprodinil, iprodione) which severely compromises disease control options for WA raspberry growers (T.L. Peever, *unpublished*). New fungicides with different modes of action are urgently needed in WA raspberry production.

Relationship to WRRC Research Priorities

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) Determine the type, frequency, and distribution of boscalid-resistance mutations in *Botrytis cinerea* strains infecting red raspberry in WA in order to predict effectiveness of new FRAC 7 fungicides in these areas

2) Develop a high-throughput sampling method to estimate type and frequency of boscalid-resistance mutations in WA *B. cinerea* populations infecting red raspberry

3) Determine if strains of *B. cinerea* currently exist in WA that are resistant to the new FRAC 7 fungicides

Procedures

1) Determine the type, frequency, and distribution of boscalid-resistance mutations in *Botrytis cinerea* strains infecting red raspberry in WA in order to predict effectiveness of new FRAC 7 fungicides in these areas

To date, approximately 600 isolates of *Botrytis cinerea* have been sampled from WA raspberry from 2014-2016 and these isolates are currently in long-term storage in my laboratory. All of these isolates have been screened for sensitivity to five fungicides commonly used to control gray mold of raspberry in WA including fenhexamid, cyprodinil, boscalid, fludioxonil, and iprodione. Approximately 70% of these isolates are resistant to boscalid. Mycelial growth assays on discriminatory concentrations of technical grade or formulated fungicides is a common method to assay fungicide sensitivity in *B. cinerea* (Leroch et al 2013, Weber 2011) and this method has been used to evaluate fungicide sensitivity in *B. cinerea* in WA in my lab since 2014. Quantitative estimates of sensitivity and the frequencies of isolates in each sensitivity category will be obtained for six new SDHI fungicides including adepidyn, isofetamid, fluopyram, penthiopyrad, fluxapyroxad, and solatenol. We will initially estimate EC_{50} (effective concentration to inhibit 50% growth) values for randomly selected isolates from different raspberry fields in WA on agar amended with different concentrations of technical grade fungicide. Once a mean EC_{50} estimate for this sample is obtained, a single discriminatory dose of each fungicide near the population mean EC_{50} will be used to estimate sensitivity phenotypes among a much larger sample of isolates. Approximately 200 isolates sampled from raspberry in WA during 2015 and 2016 that are sensitive and resistant to boscalid will be screened against six SDHI fungicides to provide an estimate of baseline sensitivity to each of the new SDHI fungicides and to determine if any of these new fungicides are able to inhibit boscalid-resistant isolates in WA.

2) Develop a high-throughput sampling method to estimate type and frequency of boscalid-resistance mutations in WA *B. cinerea* populations infecting red raspberry

Although the newly developed SDHI fungicides mentioned above are in the same chemical class as boscalid (one of the components of "Pristine" along with pyraclostrobin), and have the same mode of action, recent studies (Olaya et al. 2016, Amiri et al. 2014) have suggested that these new SDHIs may be able to control boscalid-resistant isolates due to differences in their molecular targets. Resistance to boscalid is conferred by several mutations in the target site molecule, succinate dehydrogenase in the fungal mitochondrion (Sierotzki and Scalliet 2013). The effectiveness of the new SDHIs in controlling boscalid-resistant isolates will depend upon the types of mutations present in *Botrytis* populations where the fungicides are used (Sierotzki and Scalliet 2013). In order to predict the potential effectiveness of these new SDHI fungicides for use against gray mold in WA raspberry, we need to understand if they are able to control boscalid-resistant isolates that are currently common in WA raspberry fields. We will also determine the cross-resistance relationships among the six new SDHI fungicides and boscalid by growing selected isolates on agar medium amended with each fungicide as described above. Sensitivity to each fungicide will be estimated as proportion growth of the same isolates on un-amended agar as described above. Such cross-resistance data will be critical for the design of effective resistance management strategies to extend the useful life of these new fungicides once they are registered.

3) Determine if strains of *B. cinerea* currently exist in WA that are resistant to the new FRAC 7 fungicides

The mycelial growth assays described above allow an estimate of the *in vitro* sensitivity to each fungicide but do not allow us to predict whether an isolate that is less sensitive to a particular fungicide is resistant to field rates of that fungicide under field conditions. In order to relate fungicide sensitivity phenotypes that we observe on agar medium to the predicted field performance of each fungicide, a raspberry fruit protection assay has been developed (D. Dutton and T.L. Peever, *unpublished*). This assay has allowed us to determine that the isolates that are highly insensitive to boscalid, cyprodinil and fenhexamid in WA are also resistant to field rates of fungicide under field conditions. This gives us confidence in classifying isolates as sensitive or resistant. *Botrytis* isolates displaying different fungicide sensitivities to the new SDHIs will be selected for testing on raspberry fruit treated with each fungicide. Fruit will be treated with field rates of formulated fungicides, then inoculated with a known quantity of *Botrytis* inoculum, incubated and disease allowed to develop. Quantitative estimates of gray mold affecting the fruit will be recorded for 5 days after inoculation allowing us to determine if isolates with different fungicide sensitivities are controlled by field rates of each fungicide. We will be particularly interested in determining which, if any, of the new SDHIs are able to control boscalid-resistant strains on fruit when applied at field rates.

Anticipated Benefits and Information Transfer

This research addresses a critical need in the raspberry industry for effective disease control options for Botrytis gray mold of raspberry in WA. Widespread resistance to three of five main fungicides exists in *Botrytis cinerea* populations infecting small fruit in WA and this has severely compromised disease control options available to growers. Screening several new Group 7 fungicides against the boscalid-resistant strains currently found in WA will allow us to assess the potential effectiveness of these chemicals for use in controlling gray mold in raspberry. Should we find that some or all of these chemicals are effective, this data will then be used to support new registrations of these fungicides for use in raspberry. The availability of additional new disease control options for WA raspberry growers will reduce reliance on a limited number of chemistries and allow the implementation of more effective resistance management strategies.

References

Amiri, A, S.M. Heath and N. Peres. 2014. Resistance to fluopyram, fluxapyroxad, and penthiopyrad in *Botrytis cinerea* from strawberry. Plant Disease 98: 532-539.

Leroch, M., C. Plesken, R.W.S. Weber, F. Kauff, G. Scalliet and M. Hahn. 2013. Gray mold populations in German strawberry fields are resistant to multiple fungicides and dominated by a novel clade closely related to *Botrytis cinerea*. Applied and Environmental Microbiology 79: 159-167.

Olaya, G., R. Linley, K. Edlebeck and T. Harp. 2016. ADEPIDYN fungicide: Cross resistance patterns in *Alternaria solani*. Abstract presented at the 2016 Annual Meeting of the American Phytopathological Society, July 30 to August 3, Tampa, FL.

Sierotzki, H. and G. Scalliet. 2013. A review of the current knowledge of resistance aspects for the next–generation succinate dehydrogenase inhibitor fungicides. Phytopathology 103: 880-887.

Weber, R.S. 2011. Resistance of *Botrytis cinerea* to multiple fungicides in Northern German small fruit production. Plant Disease 95: 1263-1269.

Budget:

Salaries [1]	10,271
Time-slip	5,038
Operations (Goods & Services) [2]	2,500
Travel [3]	1,500
Meetings	0
Other	0
Equipment	0
Benefits [4]	1,301
Total	**$20,610**

Budget Justification:

[1] 0.5 FTE PhD student salary – Olga Kozhar
[2] Travel of student to professional meeting
[3] Lab supplies including petri dishes and agar
[4] Benefits rate = 10.58% for Salaries, 9.5% for Time-slip

*Budget approved by Laura Coughenour at WSU 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	WA Raspberry	22320	01/01/17 to 12/31/17	15	Evaluation of FRAC Group 7 (SDHI) fungicides for control of Botrytis fruit rot of red raspberry in WA
Harteveld & Peever	WA Blueberry	15474	01/01/17 to 12/31/17	15	Mummy Berry of Blueberry: Updates, Prediction Model Validation and Fungicide Resistance
Peever	WSCPR	26442	01/01/17 to 12/31/17	15	Evaluation of FRAC Group 7 (SDHI) fungicides for control of Botrytis fruit rot of red raspberry in WA
Peever & Harteveld	WA Blueberry	12742	01/01/17 to 12/01/17	5	Laboratory Equipment for Small Fruit Pathology at NWREC
Peever	WA Raspberry	13000	01/01/17 to 12/01/17	5	Laboratory Equipment for Small Fruit Pathology at NWREC
Harteveld & Peever	NWCSFR	49969	10/01/17 to 09/30/18	10	Mummy berry of blueberry in the Pacific Northwest: A prediction model for primary inoculum release

	Pending:				
Peever	WA Raspberry	20610	01/01/18 to 12/31/18	15	Boscalid resistance mutations in *Botrytis cinerea* populations infecting red raspberry in WA and relationship to control by other FRAC Group 7 (SDHI)
Peever	WA Raspberry	23808	01/01/18 to 12/31/18	15	Biology and control of *Botrytis* fruit rot of red raspberry in the Pacific Northwest
Peever	WA Blueberry	24062	01/01/18 to 12/31/18	15	Mummy Berry of Blueberry: Updates, Prediction Model Validation
Peever	WSCPR	22721	01/01/18 to 12/31/18	15	Biology and control of *Botrytis* fruit rot of red raspberry in the Pacific Northwest
Peever	WSCPR	25302	01/01/18 to 12/31/18	15	Boscalid resistance mutations in *Botrytis cinerea* populations infecting red raspberry in WA and relationship to control by other FRAC Group 7 (SDHI)

2018 WASHINGTON RED RASPBERRY COMMISSION RESEARCH PROPOSAL

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

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

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 2018 Current Year 2018 Terminating Year 2018
Total Project Request: $ 5,378
Other funding sources: None.

Description:
This proposal focuses on three diseases of red raspberry. We propose to collect leaves with yellow rust and evaluate the sensitivity of isolates to fungicides, particularly those belonging to FRAC group 3. For the disease cane blight, we will collect canes with symptoms of cane blight and isolate fungal pathogens. The fungi from diseased stems will be tested for sensitivity to fungicides. For the novel disease, blossom blight of red raspberry, we will attempt to optimize the media and conditions for culturing the *Monilinia*-like fungal isolates associated with the symptoms.

The outcomes of this project are 1) a collection of current field isolates of yellow rust and cane blight pathogens, 2) information on fungicide-resistance profiles of the yellow rust pathogen and pathogens isolated from canes with symptoms of blight, and 3) basic biological information on the *Monilinia* spp. isolated from red raspberry with symptoms of blossom blight.

Justification and Background:
The focus of this project is to gain information that can contribute to management of yellow rust, cane blight, and blossom blight.

Yellow rust (causal agent *Phragmidium rubi-idaei*) is easily seen as yellow pustules on leaf surfaces. Generally, this is considered a minor disease, but under certain conditions it can be serious. For example, if teliospores are present and conditions are conducive for infection of leaves early in the season, then the disease can cause defoliation (Anthony *et al*. 1985 and 1987). Additionally, yellow rust infections have been reported on young canes and can make them fragile (Williamson, B. 2017).

Cane blight (causal agent *Paraconiothyrium fuckelii* —formerly *Kalmusia coniothyrium* or *Leptosphaeria coniothyrium*) was observed in early summer months of 2016 and after harvest in 2017. Damage associated with cane blight includes lateral shoot wilt, bud failure and death of the cane (Williamson, B. 2017). The fungicide resistance profile of the cane blight pathogen is not documented and will be investigated in this project.

We found an undescribed blossom blight of red raspberry in 2016 (see photo below). The disease was patchy in fields in 2016 and in 2017 the disease was more common in fields. In some areas of fields, the disease was easy to spot with numerous killed blossoms (at least 20 infections per plant) in the canopy. In 2017, we observed the same symptoms of blossom blight on ‘Columbia Star’ blackberry in Lynden, WA. This observation indicates that the blossom blight pathogen may cause disease on raspberry and also blackberries.

Blossom blight on ‘Wakefield’ red raspberry. Left photos: Diseased flower (top) and healthy flower (bottom). Right photo: Branch with three of nine flowers diseased. Progression of the disease was limited to the peduncle and did not extend into the main stem.

We isolated a *Monilinia* spp. from tissues with symptoms of blossom blight. The fungus is difficult to culture and we have not seen spore production structures or spores from the isolates. We need to develop media to culture the fungi, and evaluate environmental conditions to support growth and sporulation of isolates from samples of blossom blight of red raspberry.

Overall, the severity of these diseases on red raspberry is influenced by environmental conditions, host genetic resistance, fungal pathogenicity, cane and overwintering debris management, and the deployment of fungicides. In many years, these diseases may be minor across the industry in Washington, but a change in any of the factors listed above might result in an outbreak of one of these diseases that may significantly decrease fruit yield or quality. If we have a collection of current pathogenic isolates from fields, have optimized screening assays and determined fungicide resistance profiles, then the industry may be able to react quickly to an outbreak and mitigate long-term damage from a disease.

Relationship of the proposed project to other projects: To the best of my knowledge, 1) the objective on cane blight and yellow rust do not overlap with studies of other scientists in BC, OR, WA, or ID, 2) the objective on the blossom blight disease is unique and the disease is not being studied by other BC or PNW scientists.

Relationship to WRRC Research Priority: The proposed research addresses Priority group #2 “Foliar & Cane diseases – i.e. spur blight, yellow rust, cane blight, powdery mildew.”

Objectives:

Objective 1) Evaluate fungicide resistance profiles of yellow rust and cane blight pathogens.

Objective 2) Optimize media and environmental conditions for cultivation of the fungus associated with blossom blight disease of red raspberry.

Procedures: Research on both Objectives will be conducted in 2018.

Objective 1) Evaluate fungicide resistance profiles of yellow rust and cane blight

pathogens.

Sampling: At least 200 leaves with signs of yellow rust will be collected from red raspberry fields and transported dry packaged to the lab. At least 50 canes with symptoms of cane blight and signs of the pathogen (pycnidia) will be collected from red raspberry fields. In the lab, cane segments will be surface-disinfested by submersion in dilute bleach, then ethanol, and then rinsed twice with sterile distilled water. Stem sections will be placed on the surface of potato dextrose agar amended with streptomycin and incubated at 25°C. Fungi growing from cane tissues will be transferred onto new media, identified, stored, and evaluated for sensitivity to fungicides.

Fungicide sensitivity profiles. For cane blight isolates, we will grow isolates on culture media and media containing different concentrations of the fungicides iprodione (FRAC 2), propiconazole (FRAC 3), boscalid (FRAC 7), cyprodinil (FRAC 9), azoxystrobin and/or pyraclostrobin (FRAC 11), fludioxonil (FRAC 12), and fenhexamid (FRAC 17). The methods assess the minimal inhibitory concentration will be adapted from those on the FRAC website (http://www.frac.info/monitoring-methods) and in Fillinger and Walker (2016). This evaluation will determine the discriminary dose for each fungicide to differentiate between fungicide-sensitive and -resistant isolates of the cane blight pathogen. For yellow rust isolates, we will adapt the method of Felsenstein (1997) to test for sensitivity of rust spores to germinate when exposed to propiconazole, mycobutanil, and pyraclostrobin directly on fungicide-amended water agar or on leaf disks placed on water agar amended with a concentration series of fungicides.

Objective 2) Optimize media and environmental conditions for cultivation of the fungus associated with blossom blight disease of red raspberry.

Additional blossom blight samples will be collected from fields when we sample for cane blight and yellow rust. The fungus can be isolated initially on potato dextrose agar, but thereafter grows poorly. We have had some success with growing the fungus on a tart cherry medium at 20°C, but the growth is slow and the fungus does not sporulate. We will test the influence of nutrient amendments to tart cherry agar and other complex media on fungal morphology, sporulation, and growth rates. Some species of *Monilinia* sporulate over a broad temperature range and others only under cool (10°C) temperatures (Baltra 1991). In growth chambers, we will test the effect of temperatures (between 8 to 24°C), illumination, and media on conidia production. If conidia are produced, then the spores can be used in subsequent pathogenicity assays and fungicide sensitivity assays.

Anticipated Benefits and Information Transfer: (100 words maximum)

This project will generate fungicide sensitivity profiles of isolates of the pathogens that cause cane blight and yellow rust. This information could guide management options for growers that have persistent problems with cane blight and/or yellow rust. The study of the blossom blight pathogen will provide information about the biology of the pathogen and how to culture it. If we can induce conidia production in culture, then we can conduct pathogenicity assays and fungicide sensitivity assays. Project information will be delivered to growers and extension personnel through presentations at grower and commission meetings and through scientific publications.

References:

1. Anthony, V.M., Shattock, R.C., Williamson, B. 1985. Life-history of *Phragmidium rubi-idaei* on red raspberry in the United Kingdom. Plant Pathology 34:510-520.
2. Anthony, V.M., Williamson, B., Shattock, R.C. 1987. The effect of cane management techniques on raspberry yellow rust (*Phragmidium rubi-idaei*). Annals of Applied Biology 34:510-520.
3. Baltra, L.R. 1991. World Species of Monilinia (Fungi): Their Ecology, Biosystematics, and Control. Mycologia Memoir No. 16. 246 pp. J. Cramer, Berlin.
4. Felsenstein FG. 1997. Brown rust of wheat – a European wide monitoring programme to study its fungicide sensitivity. Resistance ´97: Integrated Approach to Combating Resistance, IACR-Rothamsted, Harpenden, UK, 70.
5. Fillinger, S., and Walker, A-S. 2016. Chemical control and resistance management of *Botrytis* diseases, pp189-216, *In*: Botrytis-the Fungus, the Pathogen and its Management in Agricultural Systems, S. Fillinger and Y. Elad, eds. Springer, New York.
6. Williamson, B. 2017. Cane and foliar diseases caused by fungi and Oomycetes. In: Compendium of Raspberry and Blackberry Diseases and Pests, 2nd edition. R.R.Martin, M.A. Ellis, B. Williamson, and RA Williams (eds). APS Press, St. Paul, MN.

Budget:	**2018**
Salaries[1/]	$ 3,780
Operations (goods & services) [2/]	$ 1,000
Travel[3/]	$ 220
Meetings	$ 0
Other	$ 0
Equipment	$ 0
Benefits[4/]	$ 378
Total	**$ 5,378**

Budget Justification

[1/] Undergraduate student for 360 hours (12 weeks, 30 hours/week, at $10.50 per hour). Student will assist with media production, sample processing, and development of fungicide resistance assays for fungal isolates.

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

[3/] Stockwell, 2 trips from Corvallis to Lynden raspberry fields; Hotel cost @$110/night.

[4/] Benefits for the undergraduate student worker at 10%

Virginia Stockwell ***Current & Pending Support***

Name (List PI #1 first)	Supporting Agency and Project #	Total $ Amount	Effective and Expiration Dates	% of Time Committed	Title of Project
	Current:				
Stockwell	NWCSFR	$65,996	10/1/2016 to 9/30/2018	35%	Survey of diseases of small fruits and prevalence of fungicide resistance in Oregon
Stockwell & Pscheidt	OR Blueberry Commission	$8,000	4/1/17 to 3/30/2018	20%	Survey of *Botrytis* Green Fruit Rot and Silver Leaf in Oregon blueberry fields
Stockwell	WRRC	$ 5,919	2/14/2017 2/15/2018	15%	Development of novel disease management methods for fruit rots of raspberry.
Stockwell	OR Raspberry & Blackberry Commission	$6,699	2/1/2017 to 1/31/2018	15%	Fungicide Resistance Profiles of *Botrytis* Isolates Collected from Raspberry and Blackberry in Oregon.
	Pending:				
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	$ 5,378	2/14/2018 2/15/2019	15%	Characterization of pathogens that cause blossom blight, cane blight, and yellow rust of red raspberry (this proposal)

Washington Red Raspberry Commission
Progress Report for 2017 Projects

Project No: MA-WRRC2016-001
Title: Development of novel disease management methods for fruit rots of raspberry.

Personnel: Virginia Stockwell with Gayle McGhee and Brenda Shaffer. USDA-ARS HCRU, Corvallis, Oregon
Reporting Period: Year 1 & 2 (termination report): 2/13/2016 to 2/14/2018

Accomplishments:

One objective of this project was to define the microbiome of red raspberry floral buds, flowers, green fruit, and ripe fruit. Microbiome studies can provide useful information about the microbes (bacteria, fungi, and yeasts) on plant surfaces and their impact on crop health. We are interested in which microbes are present and if their prevalence influences the establishment and growth of plant pathogens. We sampled five fields in 2016 and isolated and characterized microbes that were capable of growing on artificial media. We know that many microbes cannot be cultured on artificial media and would be missed with that approach, for example the powdery mildew and rust pathogens do not grow on the artificial media that we used. This year, we are using new molecular techniques to identify and determine the prevalence of microbes and pathogens on red raspberry floral buds, flowers, green fruit, and ripe fruit sampled from the same fields. We freeze-dried 580 samples, ground the tissues, and extracted total DNA from individual samples of floral buds, flowers, green fruit and ripe fruits. We used PCR to amplify bacterial 16S sequences (a gene used to identify bacterial genera) from the samples. We then, labeled 384 of the PCR products with unique barcodes and generated a 'library' of all of the bacterial 16S DNA from each tissue sample, or in other words, we made a 'library' that is filled with 'books' and each 'book' contains the sequence of bacterial 16S DNA from a single floral bud, flower, or fruit. The entire library was sequenced and the generated data is being separated into 'books.' Each of the 384 'books' is being read (analyzed) to identity the bacteria (the characters in each book) residing on tissues and the prevalence of various bacteria on each tissue sample. We also have amplified fungal ITS-regions from the same samples. Fungal ITS-regions are used to identify fungi and yeasts. Similar to the 16S procedure, we will label the ITS-region samples with barcodes, generate a library, sequence and analyze the data for the presence and prevalence of yeasts and fungi, both beneficial and plant pathogens. We are being methodical in our approach and taking time to troubleshoot methods because the expense of just sequencing a library of 384 samples costs about $8000. Nonetheless, it is important to sequence a large number of samples to capture the commonality, the diversity, and prevalence of microbes on red raspberry buds, flowers, green and ripe fruits from the five locations. Understanding the timing of colonization and microbial interactions that may impact the absence or presence of pathogens may lead to novel approaches for disease management and optimize timing of chemical control methods.

In 2017, we focused on two diseases (cane blight and blossom blight) that we observed in red raspberry fields in 2016. In 2017, we sampled red raspberry canes after harvest with symptoms of cane blight and isolated fungi for identification. Blossom blight is an undescribed disease of red raspberry. In 2017, we sampled dead flowers/green fruit with necrosis extending to the floral stem pre- and post-harvest from several fields and isolated fungi. Gaining knowledge about the current status of cane blight, a well-described disease, and identifying the causal agent of blossom blight would be important for the development of methods to mitigate damage if there is an outbreak that significantly impacts yield or productivity.

Results:

Most of our knowledge about microorganisms (fungi, yeasts, and bacteria) on red raspberry buds, flowers, and fruits has come from studies where tissues are crushed and suspended in buffer, spread on artificial culture media, and microorganisms that can grow on the media are enumerated and isolated. In 2016, we started research on the culturable microbiome of red raspberry. We isolated and stored microbial communities from tissues representing different stages in fruit development (floral bud emergence, prebloom, early bloom, full bloom, green fruit, and ripe fruit) from three 'Meeker' and two 'Wakefield' fields in Whatcom County. The incidence of colonization of tissues from bud emergence to early bloom varied among sites from ~30% to 90% of samples harboring populations of yeasts, bacteria or fungi. At full bloom, nearly every flower in most sites was colonized by culturable bacteria. In contrast, only 30% of flowers at full bloom at each site had culturable populations of yeasts and fungi. The low incidence of colonization of flowers by yeasts and fungi may be due to the application of fungicides. Nearly every sample of green fruit and ripe fruit harbored bacteria and yeasts (primarily on the surfaces of fruits) and fungi (isolated from fruit surfaces and internal tissues). The most abundant microorganisms found on fruit were: *Bacillus* spp. (bacteria), *Aureobasidium pullulans* (yeast), and *Alternaria* spp, *Botrytis* spp., *Diaporthe* spp., and *Penicillium* spp. (fungi). Data from the molecular characterization of the microbe will be compared to that from the culturable microbiome. This comparison will be useful to determine the benefits and possible shortfalls of studies utilizing culture-based and/or molecular-based approaches to understand microbiome interactions on raspberry.

In 2016, cane blight symptoms (death of entire canes) were observed before harvest, primarily in fields with 'Wakefield' red raspberry. In 2017, cane blight symptoms were scarce before harvest. Fields were re-visited post-harvest and cane samples were collected from 'Wakefield' and 'Wakehaven' plants. In addition to cane blight, zonate lesions from Cane *Botrytis* also were observed on these cultivars. We surface-disinfested tissues with symptoms and/or signs of cane blight and isolated fungi with a morphology similar to *Paraconiothyrium fuckelii* (formerly known as *Kalmusia coniothyrium* or *Leptosphaeria coniothyrium*). The identity of isolates from raspberry canes will be determined with molecular methods. Tolerance to various fungicides also will be determined.

In 2016, blossom blight symptoms were observed primarily in one site on 'Wakefield' and less frequently on nearby 'Meeker' red raspberries. Blossom blight is our 'in-house name' for an undescribed disease of raspberry. The disease will not have an official name until the pathogen is fully characterized. We isolated fungi with the morphology of a *Monilinia* spp., but it is difficult to culture the fungi for additional tests. The current symptoms associated with blossom blight are: complete death of a young, developing green fruit, necrotic sepals, and necrosis extending into the peduncle (or floral stem). In 2017, the frequency of detection of blossom blight had increased in the 'Wakefield' site compared to observations in 2016. In pockets of that field, the disease was easy to spot with numerous killed blossoms (around 20 per plant) in the canopy. The disease symptoms were observed in other 'Wakefield' fields in 2017, often with a lower frequency of ~5 or more killed flowers on plants with symptoms. Symptoms also were observed sporadically on other red raspberry cultivars in a cultivar evaluation field. Finally, a planting of 'Columbia Star' blackberry had numerous dead immature green fruits (>25 per plant). If confirmed, the observation of blossom blight symptoms on 'Columbia Star' extends the host range of the putative pathogen from red raspberry to blackberry.

Publications: No publications.

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

SOILS

Project No: WRRC 2017 Contract 3

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: 1/1/2017 through 12/31/2017

Accomplishments:

- Established a trial comparing tarped and nontarped bed applications Telone C-35 and Strike 60 for control of root lesion nematode and Phytophthora root rot
- Established a trial to evaluate Vapam crop termination treatment to enhance fumigation efficacy
- Documented deeper-dwelling nematode populations in a silt loam soil than in a sandy soil, established trials comparing shallow-applied Vapam, deep-applied Telone C-35 and a combination treatment in these soils

Results: *Bed fumigation trial.* A field was identified with a history of Phytophthora root rot and heavy root lesion nematode infestation. 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. Prior to fumigation, Phytophthora inoculum bags were buried at four locations in each bed; these were retrieved 11/13/17. Post-fumigation nematode numbers were zero, as expected. Phytophthora results are in process. We will also follow plant performance, nematode numbers and root rot symptoms through next season

Crop termination trial: A field with heavy root lesion nematode populations in an existing raspberry crop was identified. Vapam (74 gpa) was applied to the old raspberry via drip tape 8/25/17. Foliar symptoms visible within 5 days. Symptoms were most pronounced when plants were also sprayed with Crossbow and Roundup (Figure 1). Pretreatment root and soil samples were generally very high in *P. penetrans*; root and soil *P. penetrans* numbers appeared lower in plots treated with both Vapam and herbicide (Table 1). Grower cooperator plans to have this field bed-fumigated by Trident in 2018 we will follow nematode numbers and plant performance through next season.

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. Four deep core samples were collected at each of those locations in September, prior to fumigation. Consistent with earlier observations on other fields, *P. penetrans* were found throughout the soil profile to 36" deep in the silt loam soil, but were only found to a 12" depth in the sandy soil. At each location, 4 replications of 4 treatments were applied: an untreated check, Vapam (74gpa) applied at 5-10" depth, Telone C-35 (35 gpa) applied at 16" depth, or both fumigants. Vapam was applied by the grower, Telone C-35 was applied by Trident. Post fumigation deep core soil samples were collected; *P. penetrans* numbers were very low in these.

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

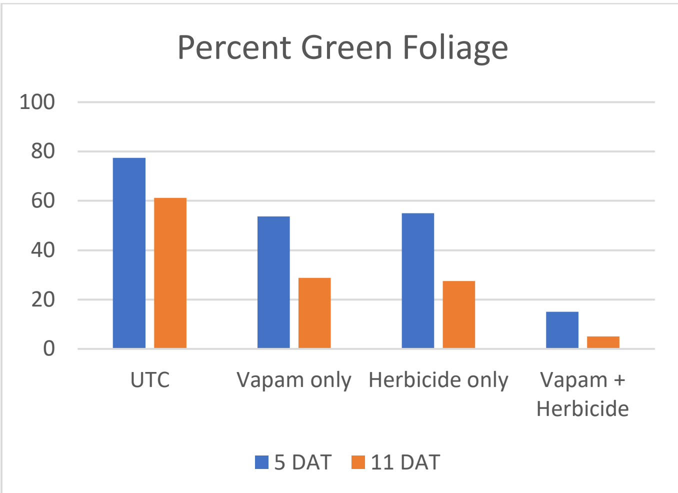

Figure 1. Percent green foliage in plots treated with Vapam, Herbicide or both 5 and 11 days after Vapam treatment (DAT).

Publications: none yet.