1993

RED RASPBERRY RESEARCH PROPOSALS

1992 PROGRESS REPORTS

to the

WASHINGTON STATE RED RASPBERRY COMMISSION

and

NORTHWEST RED RASPBERRY GROWERS ASSOCIATION

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1992-93

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SUMMARY
BUDGET REQUEST

PROJECT NUMBER	*SHORT TITLE*	*LEAD SCIENTIST*	*AMOUNT REQUESTED*
ON-GOING PROJECTS			
13C-3755-5641	Red Raspberry Breeding	Moore	$26,860
13C-3755-8640	Advanced Testing	Moore	800
13C-3761-2763	Root Rot/Ridomil	Bristow	4,019
13C-3755-3775	Cold Hardiness	Hummel	4,447
13C-3555-2783(Part A)	Testing/New Compounds	Cameron	9,586
13C-3555-2783(Part B)	Caneburning Management	Cameron	4,928
13C-3555-4883	Mite Feeding - Physiology	Cameron	3,900
13C-3555-5783	Yield Efficiency	Cameron	7,496
13C-3543-4958	Root Weevils	Shanks	4,200
13C-3543-2857	Native Predators	Shanks	12,500
--- ---- ----	Transformation	Martin	4,500
		SUB-TOTAL	**$83,236**
NEW PROJECTS			
	Pruning Practices	Kader	$23,400
	Raspberry Breeding	Daubeny	10,000
		SUB-TOTAL	**$33,400**
		GRAND TOTAL	**$116,636**

PROJECT NO.: 13C-3755-5641

TITLE: Red Raspberry Breeding, Genetics and Clone Evaluation

PERSONNEL: Patrick P. Moore, Assistant Horticulturist, WSU Puyallup

JUSTIFICATION:

The production of red raspberry and climate of the Pacific Northwest are unique in North America with most of the production being machine harvested and over 90% being used for processing. Currently over 60% of the production and most of the new plantings are a single cultivar, Meeker.

New cultivars are needed to complement or replace Meeker that will be adapted to the region, productive, with fruit suitable for processing. It would be desirable to have a series of cultivars ripening in succession, each with a short fruiting season. Meeker is relatively slow to cold acclimate in the fall and does not reach extreme levels of cold hardiness. Earlier acclimating cultivars that have greater levels of cold hardiness are needed. Root rot has become an increasing problem and none of the current cultivars have significant levels of resistance. With the increase in labor costs and difficulty in obtaining labor, suitability to machine harvesting is increasingly important. Finally, cultivars with improved marketable yields and fruit quality are needed.

OBJECTIVES:

1. Develop red raspberry cultivars with improved yields and fruit quality, and resistance to root rot and raspberry aphids. Selections adapted to machine harvesting or fresh marketing will be identified and tested further.

2. Study variability and inheritance of fruit characteristics especially color, soluble solids, firmness, and fruit weight.

3. Propagate and evaluate red raspberry clones for trueness to type, yield and fruit quality.

PROGRESS:

Fifty-eight crosses were made in 1992. Fifty-four of these crosses used a root rot resistant clone as a parent. Approximately 2,000 seedlings from crosses made in 1991 were planted in 1992. These seedlings will be evaluated in 1993 and 1994.

Thirty-four selections and cultivars were planted in replicated trials for yield and fruit quality evaluations. Selections were also planted in soil infested with root rot at Puyallup to determine the level of susceptibility to disease.

Twenty-four selections were made among seedlings planted in 1990. The best parents were WSU 994, Tulameen, Cherokee and Chilliwack.

The 1989 selection trial was harvested for the second time in 1992 (Table 1). WSU 994 was the highest yielding clone with 14.0 t/a. WSU 933, Chilcotin, Centennial and Meeker were the next highest yielding with 11.1 to 11.7 t/a. WSU 994 had large fruit, but it is too soft for the fresh market. It is aphid resistant and should be machine harvestable. The color of WSU 994 may be somewhat light. WSU 933 had high yields, but one plot that was not harvested died, most likely from root rot. WSU 994 is the only selection that will be tested further.

The 1990 selection trial was harvested for the first time in 1992 (Table 2). WSU 1024 had the highest yield (10.0 t/a). WSU 1027, WSU 1019, WSU 1017, and WSU 1020 had yields similar to Meeker (7.4 t/a). All of these selections except WSU 1027 have harvest seasons similar to Meeker. WSU 1027 is an early season gold colored raspberry. WSU 1020 is extremely firm.

Five fall fruiting cultivars planted in 1990 were evaluated for the second time in 1992 (Table 3). In 1991, Summit was the earliest maturing, two weeks ahead of Autumn Bliss. In 1992, the harvest seasons of Summit and Autumn Bliss were the same. Summit, Autumn Bliss and Ruby had the highest yields.

Fruit color of all plots harvested were measured with a Minolta Tristimulus Colorimeter and fruit saved for anthocyanin measurement this winter. Fruit samples were collected of the most promising selections for acidity, pH, soluble solids, and anthocyanin determinations.

Virus-negative propagation material was maintained at Puyallup. Plants of Pacific Northwest cultivars and advanced selections were distributed to certified plant propagators.

PROPOSED RESEARCH:

Crosses in 1993 will again emphasize aphid resistance and root rot resistance. Selections made in 1992 will be planted along with standard cultivars in replicated yield trials and root rot evaluation plantings at Puyallup. Selections will be made among seedlings planted in 1991. Selections in the 1990 and

1991 selection trials will be harvested for yield, fruit weight, firmness, preharvest fruit rot, and season of harvest.

Plants of WSU 994 will be propagated for distribution to growers. Plants from nuclear stock will be distributed to Washington certified plant propagators. A sample of plants will be fruited out at Puyallup to test for freedom from crumbliness and trueness to type.

TERMINAL DATE OF BASE PROJECT: June 1994.

DURATION OF THIS PROPOSAL: Third of three years.

BUDGET:

	1992-93		1993-94	
00 Salary				
(Tech. Farm Laborer)	$10,283	(.45 FTE)	$11,051	(.45 FTE)
(Plant Tech. II)	0		2,605	(1/12 FTE)
01 Timeslip	5,000		4,000	
03 Supplies and Services	4,124		4,019	
04 Travel	300		300	
07 Benefits				
(Tech. Farm Laborer)	3,393		3,490	
(Plant Tech. II)	0		755	
(Timeslip)	400		640	
Total	$23,500		$26,860	

Tech. Farm Laborer has been funded by the Washington Raspberry Commission, Oregon Caneberry Commission, Washington Strawberry Commission and Oregon Strawberry Commission in previous years.

Table 1. 1991-92 harvest of 1989 planted raspberries at Puyallup, WA.

CLONE	Yield (t/a) 1991	Yield (t/a) 1992	Yield (t/a) Total	Fruit weight (g)	Fruit firmness (g)	Harvest season 5%	Harvest season 50%	Harvest season 95%	Length of season
WSU 994	7.3 A B	14.0 A	21.3	4.4 A	154 D - E	6/10 C - D	6/24 C - G	7/8 D - F	28 C - F
Meeker	7.8 A	11.1 A - C	18.9	3.4 B - E	216 A - B	6/16 B	6/30 B	7/14 A - C	27 D - F
WSU 933	5.9 A - F	11.7 A - B	17.6	4.1 A - C	192 B - D	6/16 B	6/29 B - C	7/15 A - B	29 A - E
Centennial	5.7 A - F	11.2 A - C	16.8	3.6 A - D	185 B - D	6/13 B - C	6/28 B - C	7/12 A - D	29 B - E
Chilcotin	5.1 B - H	11.3 A - C	16.3	3.7 A - D	169 B - D	6/9 C - D	6/26 B - E	7/14 A - C	34 A
Willamette	5.5 A - G	9.3 B - E	14.9	3.4 B - E	164 B - E	6/11 C - D	6/25 B - G	7/10 B - E	29 A - E
WSU 1006	6.1 A - F	8.3 B - E	14.4	4.1 A - C	210 B - C	6/13 B - C	6/28 B - D	7/13 A - D	29 A - E
WSU 997	5.3 A - H	8.7 B - E	14.0	3.5 B - E	146 D - E	6/12 C - D	6/25 B - G	7/7 D - F	26 D - F
Comox	3.9	10.1 B - E	14.0	3.4 B - E	169 B - D	6/10 C - D	6/21 E - G	7/5 E - F	25 E - F
WSU 908	3.4 F - I	10.4 B - D	13.9	3.8 A - D	260 A	6/21 A	7/5 A	7/17 A	26 D - F
WSU 1007	6.7 A - D	6.6 E	13.3	3.5 B - E	192 B - D	6/11 C - D	6/26 B - F	7/14 A - C	33 A - C
Skeena	5.4 A - H	7.5 D - E	12.9	3.3 C - E	161 C - E	6/9 D	6/21 E - G	7/6 E - F	27 D - F
WSU 1003	4.6 C - I	8.0 B - E	12.6	3.1 D - F	154 D - E	6/11 C - D	6/25 B - G	7/10 B - E	29 B - E
WSU 1009	5.5 A - G	6.7 E	12.3	4.2 A - B	172 B - D	6/10 C - D	6/21 G	7/3 F	23 F
Chilliwack	4.5 D - I	7.7 C - E	12.2	3.1 D - F	198 B - D	6/11 C - D	6/23 D - G	7/6 E - F	25 D - F
WSU 996	3.0 G - I	8.9 B - E	12.0	3.8 A - D	188 B - D	6/11 C - D	6/26 B - F	7/14 A - C	33 A - B
WSU 1001	5.1 B - H	6.6 E	11.8	2.5 F	116 E	6/9 D	6/21 F - G	7/9 C - E	30 A - D
WSU 995	4.5 D - I	7.1 D - E	11.5	2.7 E - F	186 B - D	6/9 D	6/23 D - G	7/12 B - D	33 A - C
Average	5.3	9.2	14.5	3.5	180	6/12	6/25	7/10	29

Means are averages of three 3 hill plots at 3 ft x 8 ft spacing, except Comox which was present in two plots and omitted from the statistical analysis.
Means within columns followed by the same letter are not significantly different using Duncan's multiple Range Test, P=0.05

Table 2. 1992 harvest of 1990 planted raspberries at Puyallup, WA.

CLONE	Yield (t/a)	Fruit weight (g)	Fruit firmness (g)	Harvest season 5%	Harvest season 50%	Harvest season 95%	Length of season
WSU 1024	10.0 A	3.2 C - E	197 B - C	6/13 B - C	7/1 A - C	7/16 A - B	33 A
WSU 1027	7.8 A - B	3.2 C - F	131 E - G	6/7 F - I	6/20 I - K	7/6 E - F	29 A - E
WSU 1020	7.5 B - C	3.4 C	259 A	6/11 B - D	6/28 B - D	7/14 A - C	33 A - B
MEEKER	7.4 B - C	2.6 H - J	134 E - G	6/12 B - C	6/29 A - D	7/15 A - B	33 A - C
WSU 1019	7.0 B - D	2.5 I - K	161 C - E	6/11 B - E	6/30 A - D	7/13 A - D	32 A - E
WSU 1017	6.9 B - D	3.1 C - G	143 D - F	6/14 B	6/28 B - D	7/16 A - B	32 A - C
WSU 1018	6.5 B - E	2.2 K	103 F - G	6/8 F - H	6/21 H - K	7/6 E - F	28 B - E
WILLAMETTE	6.1 B - F	2.9 D - H	132 E - G	6/6 G - I	6/19 J - K	7/4 E - F	28 C - E
WSU 1016	5.8 B - G	2.6 H - K	158 C - E	6/5 G - I	6/22 G - J	7/9 C - E	34 A
WSU 1022	5.8 B - G	2.3 J - K	95 G	6/8 D - G	6/26 D - G	7/12 A - D	34 A
WSU 1014	5.4 B - G	2.4 I - K	121 E - G	6/5 H - I	6/18 K	7/3 F	28 B - E
CHILLIWACK	5.1 C - G	2.8 E - I	149 D - E	6/8 E - H	6/24 F - I	7/7 D - F	29 A - E
CHILCOTIN	5.1 C - G	2.8 E - I	119 E - G	6/7 F - I	6/23 G - J	7/8 D - F	32 A - E
WSU 1021	4.9 C - G	3.1 C - G	184 B - D	6/14 B	7/2 A - B	7/14 A - C	32 A - D
WSU 1026	4.8 D - G	2.5 H - K	119 E - G	6/4 I	6/18 K	7/4 E - F	30 A - E
WSU 1023	4.7 D - G	4.9 A	177 B - D	6/10 C - F	6/27 C - F	7/9 C - E	29 A - E
WSU 1013	4.6 D - G	2.6 H - J	131 E - G	6/10 C - F	6/24 E - H	7/7 D - F	27 D - E
WSU 1028	3.9 E - G	4.2 B	215 B	6/12 B - C	6/28 B - E	7/12 B - D	29 A - E
WSU 1012	3.7 F - G	2.8 F - I	195 B - C	6/13 B - C	6/29 B - D	7/13 A - D	30 A - E
WSU 1015	3.4 F - G	2.7 G - J	120 E - G	6/7 F - I	6/18 K	7/3 E - F	27 E
WSU 1025	3.2 G	3.3 C - D	181 B - D	6/20 A	7/3 A	7/18 A	28 B - E
Average	5.7	3.0	154	6/10	6/25	7/10	30

Means are averages of three 3 hill plots at 3 ft x 8 ft spacing.
Means within columns followed by the same letter are not significantly different using Duncan's multiple Range Test, P=0.05

Table 3. 1991-92 harvest of 1990 planted fall-bearing raspberries.

Clone	Yield (T/M) 1992	1991	Total	Fruit weight (g)	Harvest Season 5%	50%	95%	Length of Season
SUMMIT	5.7 A	2.8 A	8.5	2.3 C	7/28 C D	8/15 C	9/7 B	41 A B
AUTUMN BLISS	5.0 A	2.4 A	7.5	3.2 B	7/27 D	8/15 C	9/7 B	42 A
RUBY	4.9 A	2.1 AB	7.0	3.4 A	8/3 B	8/22 B	9/10 A B	39 B
HERITAGE	3.4 B	1.5 B	4.9	2.1 D	8/11 A	8/30 A	9/12 A	32 C
AMITY	1.9 C	0.8 C	2.7	2.3 C	7/31 B C	8/24 B	9/10 A B	41 A B
Average	4.2	1.9	6.1	2.7	8/1	8/21	9/9	39

Means are averages of three 4 hill plots, at 1m x 3 m spacing (3.3 ft x 9.8 ft)
Means within columns followed by the same letter are not significantly different using Duncan's Multiple Range Test, P=0.05.

PROJECT NO.: 13C-3755-8640

TITLE: Advanced Testing of Washington State University Raspberry Selections

PERSONNEL: Patrick P. Moore, Assist. Horticulturist, WSU Puyallup
J. Scott Cameron, Assoc. Horticulturist, WSU Vancouver

JUSTIFICATION:

Developing a new raspberry cultivar is a long-term process. Promising selections are tested against standard cultivars in a replicated trial. If the selection performs well in this test, it then needs to be tested against standard cultivars in several locations throughout the region in which it will be grown. Accurate records of yield, fruit quality, susceptibility to pests at these locations is necessary in deciding to release or discard a promising selection. Many characters under genetic control are affected strongly by environment. Estimates of the effect of location on these characters will provide useful information which can improve the efficiency of a breeding program.

Selections that are grown in small test plots at research facilities may perform differently when grown in larger amounts in grower fields. Disease problems, difficulties in harvesting, or lack of suitability of the fruit for the intended use may become apparent only when suitable quantities of selections enter commercial cultivation. It is essential that promising selections be grown at several locations throughout the region by commercial growers.

OBJECTIVES:

1. To establish and maintain replicated plantings at WSU Puyallup, WSU Mt. Vernon, and WSU Vancouver of advanced selections from the Washington State University and other regional raspberry breeding programs.

2. To measure yield, fruit quality, and susceptibility to pests in these selections as part of the ongoing cultivar development process.

3. Propagate an adequate number of plants of advanced selections for grower trial, distribute these plants to growers, and obtain grower reaction to advanced selections.

PROGRESS:

Twelve hundred plants of WSU 908 were propagated for grower trials and were distributed to two growers in Washington in 1992.

Eight hundred fifty plants of WSU 968 were propagated for grower trials and distributed to three growers in Washington in 1992 and additional growers will receive plants winter 1992-93.

WSU 991 was distributed to four growers in Washington for grower trial in 1991. Plants were distributed to commercial propagators in 1992. Decisions regarding naming and release will be made in 1993 after grower evaluation.

WSU 988, WSU 984 and WSU 983 from the 1988 selection trial were observed in 1992. All three selections had yields over 10 t/a in 1991 at Puyallup. WSU 988 is the most promising of the three selections, with high yields with fruit that released well, but the fruit color may be somewhat light. New plots of WSU 988 will be fruiting in 1994 and the productivity and fruit quality will be evaluated again. WSU 983 lacked vigor and somewhat difficult to harvest. WSU 984 fruit was light colored. Based on the 1991 yields at Puyallup, all three selections were repropagated for new test plantings. Plantings of these selections along with other promising selections and standard cultivars were established at WSU research facilities at Mt. Vernon, Puyallup and Vancouver. Decisions regarding further testing will be made after harvest in 1994 and 1995.

PROPOSED RESEARCH:

The performance of WSU 991 in commercial grower fields will be evaluated in 1993 and if the response of the growers is positive, decisions regarding naming and release will be made in 1993.

WSU 994 yielded 14.0 t/a in 1992 at Puyallup and will be propagated for grower trials and further testing. Roots will be dug from field plots at Puyallup winter 1992 and planted in fumigated ground in 1993 to produce field grown plants for distribution to growers in 1994.

WSU 1024 and WSU 1020 are the most promising new selections based on the first year's harvest of the 1990 replicated planting. Roots of these selections will be dug from field plots at Puyallup winter 1992 and planted in fumigated ground in 1993 to produce field grown plants for 1994. Decisions regarding distribution to growers will be made after the second year's harvest

of the 1990 replicated planting. If these selections perform well in 1993, field grown plants will be available for grower trials. If these selections do not perform well, the plants will be discarded.

The plantings established in 1992 at Puyallup and Vancouver will be maintained with the first harvests in 1994.

TERMINAL DATE OF BASE PROJECT: June 1994.

DURATION OF THIS PROPOSAL: Second of three years.

BUDGET:	1992-93	1993-94
03 Goods and Services	$1,500	$800
Total	$1,500	$800

PROJECT NO.: 13C-3761-2763

TITLE: Reaction of red raspberry cultivars and advanced selections to the root rot controlling fungicide Ridomil

PERSONNEL: Peter R. Bristow, Associate Plant Pathologist and
Patrick P. Moore, Assistant Horticulturist,
WSU Puyallup Research and Extension Center

JUSTIFICATION:

Previous research has shown that the yield of 'Sumner' and other selections increased when the soil was treated with Ridomil to control root rot caused by the soil-borne fungus *Phytophthora erythroseptica*. 'Sumner' and those selections are resistant or at least moderately resistant to root rot caused by this pathogen. The positive response to Ridomil indicates that root rot is causing damage to resistant cultivars and selections even though there was minimal cane death and wilting. In short, resistance is not complete and maximum yield potentials are not being realized when plants are infected. Recent selections, which exhibit no obvious symptoms of root rot, may similarly sustain yield losses when infected. Comparing the yields of Ridomil-treated and untreated plants will help determine the true yield potential of those selections.

OBJECTIVE:

To evaluate the performance of cultivars and advanced selections in both the presence and absence of Ridomil on a site naturally infested with *P. erythroseptica*.

PROGRESS:

The replicated experimental plots which were planted in 1990 were harvested for the first time in 1992. The plots were harvested by hand instead of by machine as originally proposed. Regardless of genotype (cultivar or selection), the use of Ridomil increased yield. This was even the case for Cherokee, which possesses a very high level of resistance to root rot. Yield from untreated plots of Cherokee was nearly 90% of that from paired treated plots. WSU 1001 was the most resistant advanced selection. WSU 1007 had the highest yield potential but it is susceptible. It might do well on sites where the pathogen is not present. Plots of WSU 1002 were not harvested because the berries were crumbly.

One reason plants in untreated plots yielded poorly was that fruiting canes collapsed earlier than those on plants treated with Ridomil. Results from related field experiments showed that stress form root rot causes fruit to mature earlier.

Primocane wilting has been an indicator of root rot severity and it has been used to rank genotypes for resistance. Few primocanes wilted in 1992. Probably more primocanes were killed before they broke through the soil surface this year. The low number of primocanes per hill in untreated plots supports this explanation.

The level of resistance in each genotype was also expressed in the growth of the primocanes. When resistance was present, the number and height of primocanes in the untreated plots was closer to those in the plots treated with Ridomil. Resistance will help to insure that there are enough primocanes present so that the most vigorous canes can be trellised for the next year's crop.

Table with data is in the Appendix.

PROPOSED RESEARCH:

Primocanes will be trellised for harvest in 1993. Ridomil treatments will be continued on designated plots. Yield and berry size will be determined. Also data on root rot severity and primocane growth will be collected. 1993 will be the final year for this project.

BUDGET:

		1992-93 Last year	1993-94 Proposed year
A.	Operations		
	Wages (timeslip)	$1,500.00	$1,200.00
	Supplies and Services	100.00	80.00
	Travel*	80.00	600.00
	Employee benefits (16% of wages)	120.00	192.00
	Total	$1,800.00	$2,072.00

* $500 toward travel costs of attending International Rubus/Ribes Symposium in Poland (July 1993).

		1993-94 Proposed year
B.	Technical support	
	Wages (0.5 month)	$1,540.00
	Employee benefits (26% of wages)	407.00
		$1,947.00
	GRAND TOTAL	$4,019.00

APPENDIX

Table 1. Response of red raspberry genotypes to Ridomil, 1992 data.

Measurement	Genotype	Grams/fruiting cane Untreated	Grams/fruiting cane Treated	Untreated as % of treated
Yield				
	Cherokee (R)[z]	158	178	89
	WSU 1001 (R)	141	197	71
	Tulameen (I)	168	275	61
	Newburgh (R)	104	199	52
	WSU 892 (R)	122	381	32
	BC 8028-50 (S)	60	190	32
	WSU 1007 (S)	120	423	28
	Chilliwack (I)	140	374	28
	Willamette (S)	57	238	24
	Meeker (I)	40	219	18
	Comox (S)	39	250	15
	WSU 1002 (R)	Not harvested because of crumbly fruit		

[z] Reaction to root rot: R=resistant; I=intermediate; S=susceptible.

		Time[y] Untreated	Time[y] Treated	Untreated as % of treated
Time of fruiting cane senescence				
	Cherokee	1.8	1.6	113
	WSU 1001	2.4	2.0	98
	Tulameen	1.8	2.8	52
	Newburgh	1.6	2.4	65
	WSU 892	1.8	2.3	79
	BC 8028-50	2.0	2.7	86
	WSU 1007	1.3	2.7	48
	Chilliwack	1.3	2.0	67
	Willamette	1.3	1.8	73
	Meeker	1.3	1.8	67
	Comox	1.0	2.0	53
	WSU 1002	1.0	1.3	83

[y] Rating Scale: 1=collapse during bloom; 2=collapse during fruit ripening; and 3=still alive in mid-July.

Table 1. (continued)

Measurement	Genotype	Number per hill Untreated	Number per hill Treated	Untreated as % of treated
Number of primocanes per hill				
	Cherokee	17.9	22.5	85
	WSU 1001	26.0	42.2	67
	Tulameen	3.4	13.7	46
	Newburgh	20.2	27.6	73
	WSU 892	15.8	21.4	77
	BC 8028-50	2.0	20.0	25
	WSU 1007	2.8	26.8	12
	Chilliwack	12.3	26.0	44
	Willamette	11.3	29.8	32
	Meeker	5.8	20.7	20
	Comox	2.1	28.6	9
	WSU 1002	7.3	25.8	29

		% wilted Untreated	% wilted Treated
Percent primocanes wilted			
	Cherokee	0	0.2
	WSU 1001	0	1.3
	Tulameen	0	0
	Newburgh	1.7	0
	WSU 892	2.4	0
	BC 8028-50	0	1.5
	WSU 1007	24.3	1.3
	Chilliwack	3.5	1.0
	Willamette	2.8	1.1
	Meeker	20.0	0.2
	Comox	28.6	0.9
	WSU 1002	4.2	0.4

Table 1. (continued)

Measurement	Genotype	Centimeters (cm)[x] Untreated	Treated	Untreated as % of treated
Height of healthy primocanes				
	Cherokee	118	121	97
	WSU 1001	119	148	81
	Tulameen	65	120	58
	Newburgh	109	141	77
	WSU 892	109	155	70
	BC 8028-50	70	97	72
	WSU 1007	76	120	65
	Chilliwack	113	165	68
	Willamette	105	153	68
	Meeker	147	182	76
	Comox	62	108	70
	WSU 1002	80	146	54

[x] Canes measured October.

PROJECT NO.: 13C-3755-3775

TITLE: Cold Hardiness of Red Raspberry

PERSONNEL: Rita L. Hummel, Associate Horticulturist and Patrick P. Moore, Assistant Horticulturist, Washington State University Puyallup Research and Extension Center

JUSTIFICATION:

Crop loss due to cold damage is a recurring problem for Washington red raspberry growers. According to the 1986-1987 edition of Washington Agricultural Statistics, the extreme cold during the winter of 1985-1986 and spring frosts caused an average decrease in yield of 1,050 pounds per acre from 1985. The freeze damaged 1986 red raspberry crop was the lowest in average production since 1956. Following the 1987-1988 and 1988-1989 winters, injury attributed to cold was again detected in Washington red raspberry plantings.

The results of this proposed research would provide information on the seasonal change in red raspberry cold hardiness, identify existing red raspberry cultivars and numbered selections adapted to Washington conditions, and identify appropriately cold hardy parents for use in the breeding program.

OBJECTIVES:

1. To measure the seasonal change in cold hardiness of buds and stems of field-grown *Rubus* genotypes.

2. To identify cold hardy *Rubus* genotypes of potential importance to the breeding program.

PROGRESS (1991-1992 Winter):

Cold hardiness of stems and buds of 5 named cultivars ('Chilcotin', 'Chilliwack', 'Comox', 'Meeker', and 'Willamette') and 7 numbered selections (WSU908, WSU933, WSU991, WSU994, WSU1007, WSU1009, ORUS1836) was tested on November 20, 1991, January 22 and March 17, 1992. Cold hardiness of two-bud cane sections prepared from 3 plants of each genotype growing in the field at Farm 5 near Puyallup, Washington, was determined in controlled laboratory freezing tests following previously described procedures (Hummel and Moore, 1990, Proc. W. Wash. Hort. Assoc. 80:110-112). Samples were tested at 2°C intervals and tissue injury was determined by the visual browning method. A Tk_{50}, defined as the temperature at which

50% freeze damage occurred, was calculated for the buds and stem of each cane section from the visual browning data.

Results of the November 20, 1991, January 22 and March 17, 1992, freezing tests are shown in Tables 1, 2 and 3, respectively. In general, red raspberry buds were freeze damaged at warmer temperatures than the stems. This is consistent with previous observations.

In the November 20, 1991, freeze test (Table 1), cold acclimation of ORUS1836 was similar to that of 'Willamette' a cultivar which has been shown to be slow to cold acclimate in the fall of the year (Moore and Hummel, 1991, Proc. W. Wash. Hort. Assoc., 81:168-171). WSU994, a high yielding selection from the Washington State University breeding program, cold acclimated early in the season and, on November 20, 1991, was the hardiest genotype tested. However, Tk_{50} values for the buds of WSU1007, WSU991 and WSU908 were not significantly different from WSU994 buds in the November freeze test.

The apparent decrease in cold hardiness of WSU1007 between the November and January freeze tests (Tables 1 and 2) was most likely due to the fact that canes collected in January were showing disease symptoms. Portions of the cane appeared to have been killed by the disease rather than the freezing temperatures. Similar results for canes showing symptoms of spur blight were observed in a January 25, 1989, freeze test (Hummel and Moore, 1990, Proc. W. Wash. Hort. Assoc. 80:110-112). Crandal (1974, Proc. W. Wash. Hort. Assoc. 64:103-105) indicated that cane diseases like spur blight and anthracnose make the raspberry plant more susceptible to cold damage. By the March 17, 1992, freezing test, buds of many of the cultivars had initiated growth and the Tk_{50} values of bud and stem tissues show the concomitant loss of freeze tolerance (Table 3).

The tendency of some red raspberry cultivars to produce fruit in the fall may influence their winter survival. Cold acclimation, ultimate midwinter hardiness and deacclimation of buds and stems of 'Willamette' canes that bore fruit during the fall of 1991 were compared to nonfruiting 'Willamette' canes in controlled laboratory freezing tests. Results of the November and March laboratory freezing tests indicated fall fruiting had no influence on either bud or stem cold hardiness of 'Willamette' red raspberry. However, Tk_{50} values for the January freeze test indicated buds and stems of 'Willamette' canes that had fruited during the fall of 1991 were less hardy than canes that had not fruited. The Tk_{50} difference, while

statistically significant in January, was not large. It was 1.1°C (2°F) for the buds and 1.6°C (2.9°F) for the stems.

PROPOSED RESEARCH (1992-1993 Winter):

The seasonal cold hardiness pattern in buds and stems of additional red raspberry cultivars and selections important in the breeding program will be measured during the 1992-1993 winter.

TERMINAL DATE OF BASE PROJECTS: June 30, 1993 and June 30, 1994

DURATION OF THIS PROJECT: Cold hardiness evaluation of red raspberry genotypes with potential importance to the breeding program is an ongoing project.

BUDGET:	Current 1992	Proposed 1993
00 Salaries	$3,165	$3,420
03 Supplies and Services	100	100
07 Benefits	858	927
TOTAL	$4,123	$4,447

Table 1. Cold hardiness of red raspberry cultivars collected from the field November 20, 1991.

Cultivar	Bud Tk_{50}[z] °F	(°C)		Stem Tk_{50} °F	(°C)	
ORUS 1836	9.0	(-12.8)	A[y]	6.4	(-14.2)	A
Willamette	5.2	(-14.9)	AB	5.0	(-15.0)	AB
Meeker	3.0	(-16.1)	BC	0.7	(-17.4)	C
Chilcotin	2.3	(-16.5)	BCD	1.8	(-16.8)	BC
WSU 933	2.3	(-16.5)	BCD	0.3	(-17.6)	C
Chilliwack	1.8	(-16.8)	BCD	-0.4	(-18.0)	CD
Comox	1.4	(-17.0)	BCD	-2.2	(-19.0)	CDE
WSU 1009	1.2	(-17.1)	BCD	0.3	(-17.6)	C
WSU 1007	-0.4	(-18.0)	CDE	-2.0	(-18.9)	CDE
WSU 991	-1.1	(-18.4)	CDE	-4.4	(-20.2)	DE
WSU 908	-2.2	(-19.0)	DE	-5.1	(-20.6)	E
WSU 994	-3.5	(-19.7)	E	-5.8	(-21.0)	E

[z] Tk_{50} = Temperature at which 50% damage occurred.

[y] Means followed by the same letter are not significantly different at the 5% level using Tukey's Studentized Range (HSD) test.

Table 2. Cold hardiness of red raspberry cultivars collected from the field January 22, 1992.

Cultivar	Bud Tk_{50}[z] °F	(°C)		Stem Tk_{50} °F	(°C)	
WSU 1007	2.8	(-16.2)	A[y]	2.7	(-16.3)	A
Willamette	1.9	(-16.7)	AB	0.5	(-17.5)	A
WSU 1009	-0.9	(-18.3)	BC	-0.9	(-18.3)	AB
ORUS 1836	-0.9	(-18.3)	BC	-2.2	(-19.0)	AB
WSU 994	-1.8	(-18.8)	BC	-1.7	(-18.7)	AB
WSU 933	-2.7	(-19.3)	CD	-2.2	(-19.0)	AB
Meeker	-3.6	(-19.8)	CD	-5.3	(-20.7)	BC
Comox	-4.5	(-20.3)	CDE	-5.6	(-20.9)	BC
WSU 908	-6.3	(-21.3)	DEF	-7.8	(-22.1)	CD
WSU 991	-7.6	(-22.0)	EF	-8.0	(-22.2)	CD
Chilcotin	-8.7	(-22.6)	F	-9.8	(-23.2)	C
Chilliwack	-8.9	(-22.7)	F	-11.6	(-24.2)	D

[z] Tk_{50} = Temperature at which 50% damage occurred.

[y] Means followed by the same letter are not significantly different at the 5% level using Tukey's Studentized Range (HSD) test.

Table 3. Cold hardiness of red raspberry cultivars collected from the field March 17, 1992.

Cultivar	Bud Tk_{50}[z] °F (°C)		Stem Tk_{50} °F (°C)	
Chilliwack	23.0 (-5.0)	A[y]	19.6 (-6.9)	A
WSU 1009	22.6 (-5.2)	AB	15.8 (-9.0)	ABCD
WSU 1007	22.5 (-5.3)	ABC	18.9 (-7.3)	AB
WSU 933	22.5 (-5.3)	ABC	16.3 (-8.7)	ABC
WSU 994	21.7 (-5.7)	ABC	15.8 (-9.0)	ABCD
WSU 908	21.2 (-6.0)	ABC	16.1 (-8.8)	ABC
Chilcotin	20.7 (-6.3)	ABC	17.8 (-7.9)	ABC
Willamette	19.9 (-6.7)	ABC	18.9 (-7.3)	AB
Meeker	19.8 (-6.8)	ABC	14.7 (-9.6)	BCD
ORUS 1836	18.9 (-7.3)	ABC	11.1 (-11.6)	D
Comox	17.8 (-7.9)	BC	11.1 (-11.6)	D
WSU 991	17.2 (-8.2)	C	14.0 (-10.0)	CD

[z] Tk_{50} = Temperature at which 50% damage occurred.

[y] Means followed by the same letter are not significantly different at the 5% level using Tukey's Studentized Range (HSD) test.

PROJECT NO.: **13C-3555-2783, PART A**

TITLE: **ADVANCED TESTING OF NEW COMPOUNDS FOR CANEBURNING OF RED RASPBERRY**

PERSONNEL: **J. Scott Cameron**, Assistant Horticulturist
Chuhe Chen, Postdoctoral Research Associate
Stephen F. Klauer, Research Technologist II
WSU Research and Extension Unit, Vancouver

Kassim Al-Khatib, Assistant Weed Scientist
Carl Libbey, Research Technologist II
WSU Research and Extension Unit, Mt. Vernon

JUSTIFICATION: A number of years ago, the loss of dinoseb for caneburning in red raspberries left the red raspberry industry without an effective tool for primocane suppression. Since that time, research programs in Washington, Oregon, and British Columbia have been seeking to register effective alternatives to dinoseb. After careful screening of many compounds in Washington, oxyfluorfen (**GOAL**) has been used on a Section 18 basis for three years with considerable success.

Three problems currently exist with regard to our primocane management strategy in Washington. First is our continued reliance on one compound (as with dinoseb) for this critical management practice. The second is the fact that while an excellent choice for most situations, oxyfluorfen does not meet the needs of every situation. Third is our continued reliance on chemicals for primocane suppression.

The use of herbicides for primocane suppression in red raspberries presents a number of dilemmas. These chemicals are applied directly to the crop plant while it is actively growing with the purpose of killing part of the plant. This perhaps exacerbates the problem that chemical companies often are not interested in minor use registrations for high value, low acreage crops. We have recently identified a number of compounds with potential for both efficacy and registration. The purpose of this project is to initiate a second round of field trials for evaluating new, potential compounds for caneburning.

OBJECTIVES:

1. Evaluate primocane suppression characteristics and yield component relationships associated with the use of new caneburning compounds.
2. Study the long term effects of using these compounds on productivity and growth of established red raspberry plants.
3. Collect residue and efficacy data in order to work toward the registration of promising new caneburning compounds.

PROGRESS: In 1992 this project continued with a fifth year of testing of dinoseb alternatives in replicated plots at Vancouver and Mt. Vernon. Oxyfluorfen (**GOAL**) was again applied once to newly emerging primocanes at five different rates: 0.1, .2, .4, .8, and 1.6 lbs/A. Multiple applications have also been tested. Other treatment groups included one receiving two applications of dinoseb and an untreated control. A new, dinoseb-alternative compound (Uniroyal C4345) has also been put into this trial and appears promising. Horticultural and physiological evaluations of primocane suppression and crop response (short and long term) have been made.

After obtaining Section 18 status for oxyfluorfen in 1990-92, research emphasis has again been placed on **GOAL** in 1992 as we proceed with the registration process. Multiple applications are not recommended in most cases as primocane regrowth is delayed to the extent that cane length and diameter do not recover sufficiently by the end of the season. This material should be applied according to the label and it is suggested that the lowest effective rate possible be used. Prolonged use of higher rates will reduce plant vigor. In the short term this should not present a major problem for most fields as the raspberry plant appears to demonstrate high levels of compensation. Compensation is the process by which the plant is able withstand changes in plant size or architecture while still maintaining yield.

We have learned much about oxyfluorfen but need to proceed with advanced testing of other compounds which show promise for primocane suppression. First, we need to avoid reliance on one compound for this critical management practice. Secondly, we need to identify chemicals whose characteristics will broaden our strategies for vegetative management. Thirdly, we need to look for new cultural strategies to deal with this problem with a view towards eliminating chemical management of primocanes.

PROPOSED RESEARCH: A number of compounds will be tested at two sites in a new, replicated trial with the cultivar 'Meeker'. Sites will be in Clark (WSU REU, Vancouver) and Skagit (grower's field) counties. Plots will be 10' in length containing three hills trained in a modified hedgerow. Yield component analysis will be accomplished by removing and analyzing four random canes per plot just before the first harvest. Data will include cane length, counting and measuring laterals per cane, and counting flowering/fruiting points. During each week of harvest, plots will be partially harvested in a random manner and the weight of 50 berries will be recorded. Yield potential will be estimated on both a per acre and per cane basis. At the end of the season, primocane numbers per plot will be counted. All data will be analyzed at Vancouver.

The materials to be tested will include three materials for advanced testing, oxyfluorfen and an untreated control. Each of the materials will be tested at three rates. These materials will include:

- ☑ **UNIROYAL C4243** - Has shown promise at Vancouver and Mt. Vernon in the last several years. It appears to be effective in killing primocanes while perhaps being "softer" on the plant.
- ☑ **IGNITE** (**GLUFOSINATE**) - Has shown promise in Oregon and Washington and is worth pursuing. May desiccate more slowly than dinoseb. Scottish researchers claim it may translocate into fruiting canes.
- ☑ **SODIUM MONOCHLORACETATE (SMA)** - This is an old broccoli herbicide which has shown promise in the United Kingdom. It should not pose a residue hazard, should not pose an operator risk, and is apparently not hard on primocane regrowth or fruiting canes.

In addition to these materials, a new Monsanto compound (MON 13200 [thiazopyre]) will be put into a preliminary trial. This material has potential for use as a pre-emergent and in granular form.

Promising compounds will be pursued for possible registration as efficacy data is collected and residue trials will be initiated as appropriate. There are a number of reasons to be optimistic about the success of this field trial. We have the advantage that some information is already available from the Northwest and UK on the potential performance characteristics of these compounds. Secondly, we know alot more about primocane biology and red raspberry productivity than we

did when we first started to screen dinoseb alternatives, thus we will be more able to identify advantages and disadvantages of these compounds from a new perspective. Thirdly, and certainly not least important, all of these compounds have potential for registration.

TERMINAL DATE OF BASE PROJECT: JSC 10A-3555-0783 June 30, 1993
KAK 10A-3419-0740 June 30, 1995

DURATION OF THIS PROJECT: First year of a proposed three year project. Renewal will be requested as materials enter the registration process.

BUDGET: In 1992, the $5,400 budget was split between Vancouver and Mt. Vernon primarily to provide labor for yield component analyses, harvests and plot maintenance. In 1993, project implementation will again require temporary labor for the above activities as well as for data entry and analysis at Vancouver. In addition, a portion of technical salaries is being requested for program support.

PART A - *TECHNICAL SALARIES*		Mt. Vernon		Vancouver
00	Salary (.05 FTE)	$1,500		$1,500
07	Benefits (28%)	420		420
Subtotal		$1,920		$1,920
TOTAL A			**$3,840**	
PART B - *PROJECT IMPLEMENTATION*				
01	Wages	$1,500		$2,200
03	Supplies and Services	750		500
04	Travel	500		-----
07	Benefits (08%)	120		176
Subtotal		$2,870		$2,876
TOTAL B			**$5,746**	

GRAND TOTAL A&B **$9,586**

PROJECT NO.: **13C-3555-2783, PART B**

TITLE: **CANEBURNING MANAGEMENT AND PRIMOCANE BIOLOGY**

PERSONNEL: **J. Scott Cameron**, Assistant Horticulturist
Chuhe Chen, Postdoctoral Research Associate
Stephen F. Klauer, Research Technologist II
WSU Research and Extension Unit, Vancouver

JUSTIFICATION: The loss of dinoseb allowed our research program to take a step back and evaluate the primocane management practices of the last 30 years while asking if there might be a better approach. Over the last four years we have been re-evaluating the practice of caneburning while trying to learn everything we can about primocane biology and its impact on yield. We have concluded that a major, fundamental change in our approach to primocane management is long overdue. The purpose of this project is to investigate alternative strategies for primocane management while gaining a better understanding of the biology of the process by which the balance between vegetative and reproductive development determines red raspberry productivity.

OBJECTIVES:

1. Identify and evaluate changes in yield component relationships as modified by caneburning.
2. Model primocane regrowth and eventual productivity relative to caneburning protocols and new compounds.
3. Investigate growth retarding strategies to replace caneburning.
4. Determine possible contribution of primocanes to yield.
5. The role of internode length and lateral numbers in yield as influenced by caneburning.
6. Vigor recovery - how long does it take for plants to recover from high rates of dinoseb and oxyfluorfen.

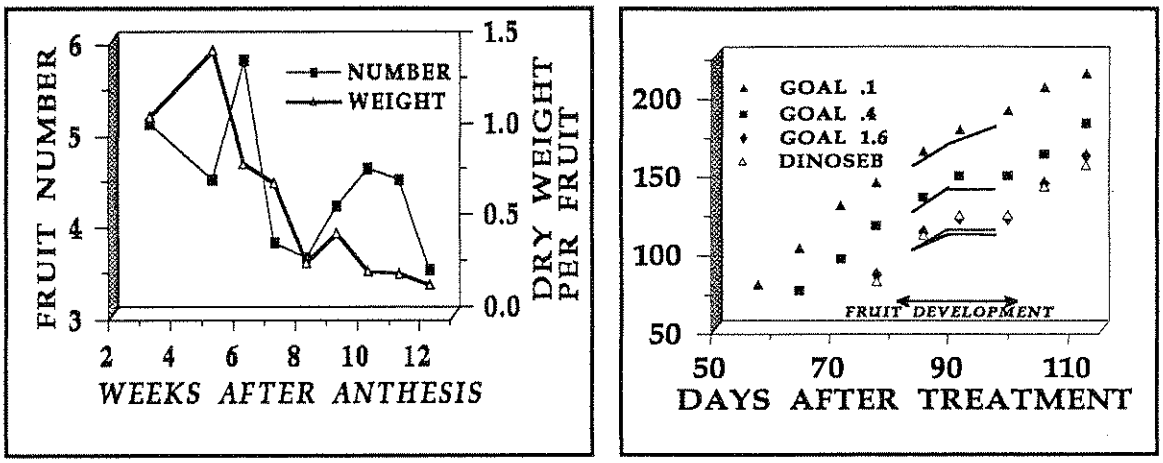
PROGRESS: In 1992 this project continued with a fifth year of testing of dinoseb alternatives in replicated plots at Vancouver and Mt. Vernon. Oxyfluorfen (**GOAL**)

was applied once to newly emerging primocanes at five different rates: 0.1, .2, .4, .8, and 1.6 lbs/A. Multiple application treatments were also tested. Other treatment groups included one receiving two applications of dinoseb and an untreated control. Studies have been undertaken in order to better understand the primocane suppression process and the plant's response to fruit load and compensatory relationships relative to primocane management.

Two aspects of primocane management have been considered. In considering chemical/rate combinations, one aspect is that of primocane suppression and the other is that of regrowth and long-term productivity. Yield per cane is a function of berry number and berry size, but repeated use of higher rates of oxyfluorfen tends to reduce primocane number and size, thus weakening the planting and reducing overall productivity.

Studies have been undertaken in order to understand the primocane suppression process and the fundamental vegetative/reproductive relationships which precipitate the need for chemical primocane management. For example, one study involves collecting primocane diameter and height data on a weekly basis in order to obtain primocane growth curves from northern and southern regions of Western Washington. This study is providing information as to patterns of primocane growth during the season as influenced by chemical primocane management compared to untreated controls. In general, as the rate of oxyfluorfen applied increases, the longer the delay of primocane regrowth, and thus the next year's fruiting cane is reduced in size. This leads to a situation which has been described as **progressive decline**. The same problem was experienced with certain dinoseb use patterns in the past.

The carbon dynamics of primocane suppression are also being studied. After five years of oxyfluorfen treatment, samples for analyses of leaf anatomy, starch quantification/deposition, and protein assays/SDS polyacrilamide gel electrophoresis were taken approximately during anthesis, green fruit, red fruit and postharvest stages. These assays helped to qualify and quantify characteristics of carbon dynamics during the fruiting process and as a result of primocane suppression. For example, we have discovered that, during the peak fruit development period (4-6 wk postanthesis, Figure 1A), primocanes stop growing and resume when assimilate demand decreases after harvest (Figure 1B). Radioactive tracers were used to investigate possible contributions of primocanes to fruit. Developing leaves were the heaviest primocane sink for photoassimilates.



1A. **1B.**

Figure 1A. Primocane growth slows or ceases in response to assimilate demand during fruit development. This response is most dramatic in plants whose architecture has been altered through chemical primocane suppression.
Figure 1B. Fruit development peaking 4-6 weeks after anthesis. This period coincides with the slowing or cessation of primocane growth in Figure 1A.

Preliminary labeling work was not able to show ^{14}C movement from primocanes into fruiting canes, but the technique is very promising. This work will be repeated now that we have recently obtained suitable facilities for radiaoactive work in Vancouver. While always assumed that primocanes act as a competing sink with fruit development, it appears that they provide photoassimilates during peak fruit development periods. Later, however, they may compete for light, thus halting/delaying fruit development within the canopy. We have seen that photosynthesis decreases 60-70% in leaves along the lateral between the exterior and interior portions of the canopy in response to fruit load and shading.

Studies in fruiting physiology have also been conducted in order to better understand inter/intraplant competition and the biology of primocane suppression. Dawn to dusk measurements of carbon assimilation, fourth derivative spectroscopy, total protein and leaf anatomy/starch deposition are being made at critical stages from flowering through postharvest in order to quantify assimilate demand relationships influenced by primocane development and compensation potential of the plant. This information is allowing us to develop a model of how

the red raspberry plant harvests light energy, assimilates and partitions carbon, and maximizes productivity. Such a model will eventually integrate the cumulative influence of environmental and cultural stresses as well as cultural management practices such as caneburning which regulate red raspberry productivity.

Valuable new information has been gained from this work and suggests new avenues of investigation. While chemical primocane management using herbicidal compounds is still the most effective technique known, alternative strategies must be considered. Our improved understanding of raspberry biology will help us to make the fundamental changes needed in our current approach to raspberry culture.

PROPOSED RESEARCH: In 1993, we propose a number of new approaches to this project while maintaining studies started over the past several years.

Yield components: Using field trials established for testing new caneburning compounds, yield component relationships will be studied in order to determine those chemicals which promote the most sustainable yield patterns. For example, high rates of oxyfluorfen encourage many short laterals, short internodes and larger numbers of fruit of reduced size. While this architecture is desirable and has potential for high yields, the plants are weak and in decline, unable to maintain this growth pattern.

Primocane regrowth: Primocane regrowth will again be studied in northwestern and southwestern Washington. Weekly measurements of primocane length and diameter will be made in order to model the growth of primocanes as a function of primocane suppression practices. This study identifies the potential role of primocanes in yield, provides information on differences in vigor and growth rates in the two major production areas of the state, and will help to identify compounds which are "softer" on the plant.

Primocanes and yield: In order to most effectively manage primocanes we need to know exactly the role they may play in producing fruit. Radioactive labeling studies will allow us to determine how much of a contribution is being made to fruit by primocanes. This involves gassing a primocane leaf with radioactive carbon dioxide and then looking for radioactivity in parts of the fruiting cane. The reverse experiment will be done early in the primocane's development in order to determine whether the fruiting cane supplies resources for the primocane.

Internode length and lateral numbers: The influence of various primocane

suppression treatments on internode length and lateral number will be studied. The relationship between fruit weight and number will be of particular concern.

Vigor recovery: While the raspberry plant compensates quite readily for changes in plant habit caused by primocane suppression practices, the onset of progressive decline may be inevitable with many caneburning compounds. Using five year old plots from dinoseb and oxyfluorfen trials in Vancouver, primocane regrowth and yield components will be monitored in order to determine the rate of vigor recovery from these regimes. It is possible that less frequent caneburning may be more effective than yearly management for long term plant productivity.

Growth retardants: One alternative to killing the first flush of primocanes is to temporarily retard their growth. A class of chemicals which interfere with the plant hormones called gibberellins may be an effective way to slow growth and shorten internode lengths before harvest. The gibberellins are responsible for growth behaviors such as stem elongation and leaf expansion. It is possible that primocanes could be sprayed prior to harvest toinduce temporary dwarfing. It is possible that this approach might shorten primocanes and internodes so that topping may become unnecessary.

Growers are strongly encouraged to share their experiences and ideas with our program. We are open to any alternative approaches to vegetative management which field experience has suggested.

TERMINAL DATE OF BASE PROJECT: 10A-3555-0783; June 30, 1993

DURATION OF THIS PROJECT: Third year of a three year project, with intent to pursue renewal based upon results in 1993.

BUDGET:

		Request 1992
01	Temporary employees	$4,100
03	Supplies and services	500
07	Benefits (5% of 01)	328
	TOTAL	$4,928

PROJECT NO.: **13C-3555-4883**

TITLE: **THE INFLUENCE OF MITE FEEDING AND MITICIDES ON THE GROWTH AND PHYSIOLOGY OF RED RASPBERRY**

PERSONNEL: **J. Scott Cameron**, Associate Horticulturist
Carl H. Shanks, Jr., Entomologist
Stephen F. Klauer, Agricultural Research Technologist II
Chuhe Chen, Research Associate
WSU Research and Extension Unit, Vancouver

JUSTIFICATION: The two spotted spider mite, *Tetranychus urticae* Koch, is a sporadic and potentially serious pest of red raspberries. The actual influence of mite feeding and damage on the growth and physiology of red raspberry is poorly understood. While mite damage can cause defoliation and thus reduce winterhardiness, it is less clear as to what influence minor or intermediate mite damage might have on overall growth and ultimately yield. We have already demonstrated the potential physiological costs associated with mite feeding in red raspberry. We have also demonstrated potential physiological costs associated with the use of miticides. A clear picture of whole-plant response to mite feeding is still lacking. All of this information should be considered when developing strategies for efficient control of this pest.

We have also demonstrated that the damage caused by mite feeding on red raspberry leaves is capable of significantly reducing photosynthetic rates before visible damage occurs to the leaf. We have observed this phenomenon at the chloroplast level and have discovered what may be an important mechanism in plant response to insect feeding and other stress factors.

While breeding for mite ***resistance*** is a primary nonchemical line of defense, little attention has been paid to ***tolerance*** to mite feeding. Genetic resistance may not always remain stable across a range of environments and new biotypes of pests may render certain types of genetic resistance useless. By looking for tolerance, one may actually be able to find plants which exhibit the lowest physiological cost in response to a certain stress, in this case, mite feeding.

While predators and genetic resistance have much potential as nonchemical

control methods, the last line of defense will always be the plant's response when it is attacked. Developing plants that are tolerant to mite feeding is an important and underutilized strategy which needs to be incorporated into this process.

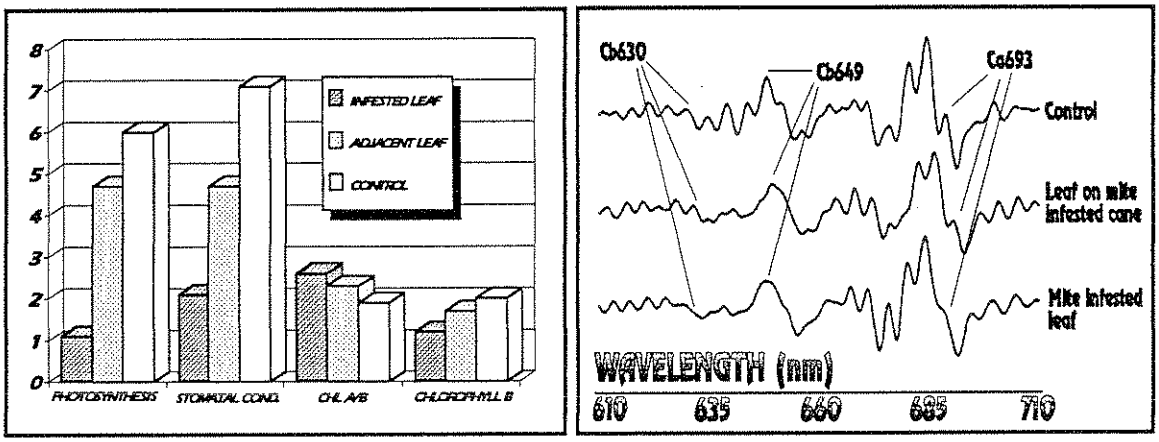
OBJECTIVES:

1. To determine the influence of mite feeding and miticide applications on the physiology of red raspberry.
2. To evaluate economic damage thresholds in light of plant response to limited mite feeding.
3. Evaluate native and cultivated *Rubus* for variable physiological responses to mite feeding and determine whether feeding ***tolerance*** exists.

PROGRESS: We have previously demonstrated that carbon dioxide assimilation rate (photosynthesis) and mesophyll conductance are negatively correlated with mite number per leaflet prior to visual damage. After physical damage to leaves was apparent, mite number per leaflet was correlated with all gas exchange parameters as well as chlorophyll content. The significance of this observation was that the initial depression in photosynthetic processes appeared to be related to some factor which influenced the biochemistry of photosynthesis. As mite populations peaked and leaves became physically damaged, declines in chlorophyll content and stomatal control also depressed photosynthesis. Under greenhouse conditions, the threshold at which chemical control is recommended, 25 mites per leaflet, photosynthesis was reduced by 20%. In addition, miticides were also found to cause serious, but temporary reductions in photosynthetic activity.

Using potted plants in the greenhouse, single leaflets were infested with twospotted spider mites and leaf physiology was compared to uninfested adjacent leaflets and uninfested plants. After six days of infestation on one leaflet, photosynthetic rates of infested leaves were lower than those of uninfested plants (Figure 1). Perhaps the most significant observation was that ***uninfested leaflets above or below infested leaflets also had reduced physiological processes, intermediate between that of infested leaflets and controls.*** This has again supported our hypothesis of the last three years that there is some kind of signal which causes the whole plant to be influenced by localized stress such as pest damage. While it was not surprising that mite feeding reduces the total content of

leaf chlorophyll, the observation that feeding reduced **chlorophyll b** content relative to **chlorophyll a** was an exciting discovery. This lead to analysis of the photosynthetic apparatus using fourth derivative spectroscopy. This experiment revealed that two parts of the chl b spectra were damaged. The appearance of these peaks reflected the photosynthetic behavior described in Figure 1A. Again, leaves which had never been attacked by mites but which were on the same plant as one which had were also negatively impacted (Figure 1B). This observation strongly supports the hypothesis that mite feeding triggers a biochemical response



A. ***B.***

Figure 1. Response of red raspberry leaves to feeding by twospotted spider mites. 1A. Photosynthesis, stomatal conductance and Chl b decrease after six days of mite feeding while Chl a/b ratio increases. 1B. Fourth derivative spectroscopy shows damage to photosynthetic apparatus.

which reduces physiological processes throughout the plant. This also parallels the recent discovery of a new type of plant hormone produced in response to insect feeding in tomato. For red raspberry, identifying the level at which mite feeding can reduce plant productivity is a very significant step forward in this process.

Attempts to study these relationships in the field have thus far been plagued by hot weather during the growing season and wet weather in the Fall. Thus far, preliminary field results have been inconclusive and unreliable.

PROPOSED RESEARCH: Experiments will be conducted which will continue to examine the response of red raspberry physiology to mite feeding. We will be able to define economic thresholds from the standpoint of how the plant responds physiologically to mite feeding, and not just how the plant appears. We are currently working with limited mite feeding scenarios under controlled conditions in order to document the speed, distribution and duration of this influence. Potted plants in the growth chamber and greenhouse will be used to allow for repetitive experiments and for uniformity of plant material and environment. Similar experiments are being designed for plants in the field. Leaves of fruiting and nonfruiting canes will be examined for the influence of localized mite feeding on carbon dynamics. Gas exchange measurements will be made using an ADC-LCA2 portable photosynthesis measurement system, proteins will be characterized using SDS-PAGE, and action spectra relationships quantified using fourth derivative spectroscopy.

Tolerance to mite feeding will be evaluated among a number of native and cultivated genotypes in the greenhouse. *Rubus parvifolius* and 'Dormanred' will be of special interest as they exhibit characteristics of both resistance and tolerance. After infestation, gas exchange measurements and chlorophyll analysis will be performed. Fourth derivative spectroscopy will be done in order to determine the level of damage sustained by key components of the photosynthetic apparatus, particularly light harvesting structures in Chl b.

TERMINAL DATE OF BASE PROJECT: June 30, 1993 (JSC)

DURATION OF THIS PROJECT: Third year of a three year project. The decision to continue, end or modify this project will depend on results obtained in 1993.

BUDGET:

		1991 Funding	1992 Funding	1993 Request
01	Temporary employees		$1,500	$3,380
03	Supplies and services	$ 500	1,000	250
05	Computer services		180	---
07	Benefits (8% of 01)	____	120	270
	TOTAL	$ 500	$2,800	$3,900

PROJECT NO.: **13C-3555-5783**

TITLE: **ACHIEVING GREATER YIELD EFFICIENCY FOR WASHINGTON RED RASPBERRY PRODUCTION**

PREVIOUS TITLE: LEAF/FRUIT RATIO AND YIELD POTENTIAL IN RED RASPBERRY

PERSONNEL: **J. Scott Cameron**, Assistant Horticulturist
Chuhe Chen, Research Associate
Stephen F. Klauer, Research Technologist II
WSU Research and Extension Unit, Vancouver

JUSTIFICATION: Horticultural scientists doing research with red raspberries in the Pacific Northwest routinely estimate crop yield potential to be 3-5X greater than the average yields reported by industry. Previous work has shown that our mechanically-harvested canopy may actually account for the loss of 50% of our potential yield through harvester losses and poor light interception/fruit set. The remaining yield potential is still likely to be 2-3 times greater than that which is actually harvested. Yield is a function of cane number, fruit number and fruit size. In its simplest form, yield efficiency relates to obtaining the greatest yield per unit of land area. Theoretically, higher yielding varieties would increase yield efficiency, but we are currently harvesting only a fraction of the yield potential of the cultivars we already have. Plant breeding is an important part of maintaining the productivity of the industry, but plant breeders have little information on the areas of crop improvement which would make the largest gains. For example, while we are very concerned about cold hardiness, there have been no efforts made in the area of heat tolerance when it would appear that, physiologically, the raspberry plant is more cold tolerant than it is heat tolerant. In other words, while in some years hardiness and cold temperature fluctuations can lead to crop losses, we ***regularly*** experience warm temperatures during critical stages of fruit development which significantly reduce the plant's potential to assimilate the carbon it needs.

Price fluctuations, limitations on available land, water issues and increasing production costs suggest that a major priority within the industry should be to increase yield efficiency. Increasing yield efficiency can often be a fairly simple and inexpensive process. For example, cane densities in most of our fields are probably

too low due to factors which include tradition and over-management. Increasing cane density will increase yield per unit area with possible reductions in fruit size. This will then impact other questions related to internode length, lateral number, canopy architecture and pruning/training practices.

In order to increase yield efficiency, one must first understand the biology of the plant, the influence of the cultural environment, and be able to determine cost effective approaches to improving productivity. For the last five years, we have studied the biology of the red raspberry plant and have provided much new information where little or none previously existed. While continuing this work, we also need to start applying what we know in designing practical solutions to these problems. The purpose of this project is to develop new, cost effective strategies to increase the efficiency of red raspberry culture. Through this work we will also continue to model the biology of this plant in order to provide information concerning the influence of cultural management and stress on sustainable yields.

OBJECTIVES:

1. Survey yield components in the Washington industry in order to establish a basis for estimating yield efficiency and potential.
2. Model the yield potential of the red raspberry plant.
3. Model the influence of fruiting on the physiology of red raspberry over the course of the season.
4. Model interplant and intraplant competition and its influence on cultural management strategies such as optimal cane density and training systems.
5. Initiate preliminary studies with cost effective approaches to recovering yield potential.

PROGRESS: Over the last several years, we have undertaken numerous studies relating to the growth and development of the raspberry plant with a special emphasis on the physiology of fruit development and productivity. Leaves from fruiting and nonfruiting canes have been sampled for physiological and anatomical analyses over entire seasons or during critical developmental stages. Fourth derivative spectroscopy, gas exchange, chlorophyll, dry weight per unit leaf area, SDS PAGE, and anatomical analyses were conducted. We now understand what happens to chlorophyll in raspberry leaves over the course of the season and see the structure and potential of the photosynthetic apparatus change. Photosynthetic

behavior in response to stresses, cultural management, developmental stages and diurnal changes has been characterized. We have initiated studies with radioactive tracers which tell us specifically where a plant chooses to channel its resources and when. A preliminary model for how and when fruit develops in relation to whole plant development has been established and ties much of this scientific information together. It also suggests potential routes for increasing yield efficiency.

Over the past five years, the picture of the raspberry which has emerged is one which describes a plant susceptible to many stresses and potential losses in productivity. Fortunately, this plant is also able to strongly compensate in a number of ways to protect its productivity. The cultural system we use encourages a great deal of inefficiency on the part of the plant, but allows for mechanical harvest. Major dilemmas exist in this situation:

- ☑ By analyzing yield components we estimate that red raspberry plantings can potentially yield 3-5X what our state average is reported to be. Where is this productivity going and what can we do about it?
- ☑ While much of the productivity of the plant is near the top of the cane where internode lengths are shorter, our practice has been to top the canes or bundle and bunch them together. This is not an optimal situation.
- ☑ Since we believe that primocanes provide competition for developing fruit and pose a mechanical impedance to harvest, we have developed a system for chemically killing the first flush of primocanes while expecting the second flush to develop sufficiently by the end of the season to be productive the following year. Now it appears that primocanes may actually contribute to yield, and we know that yearly suppression takes its toll on vigor and productivity.
- ☑ The physiological costs associated with stress can individually or cumulatively rob us of productivity, particularly during fruit development. We understand very little about the consequences of stress and how we deal with it. For example, while mite feeding reduces physiological processes, so do miticides. We know that mechanical stress can reduce plant growth, yet our harvesters beat the foliage every other day during a crucial period of fruit development. Stresses we can't even see evidence of such as short periods of wet soil, weather fluctuations, etc., take their toll.

PROPOSED RESEARCH: It is proposed that, in 1993, this project begin to apply what has been learned about raspberry physiology in a more practical way. While

the physiological work would continue as we proceed to develop our models of growth and development, a number of new approaches will be taken. Projects we propose for 1993 include the following:

- ☒ ***INDUSTRY SURVEY:*** With grower cooperation, we intend to survey fields throughout the state in order to assess yield component relationships within our industry. Data collected will include cane density, lateral number, internode length and fruit size. This data will help us to assess yield potential on a larger scale to confirm or modify the estimates we have made in Vancouver.
- ☒ ***CANE DENSITY TRIALS:*** Trials will be set up initially in Vancouver and elsewhere later in order to study the impact of higher cane densities on yield potential and yield components. Of particular interest will be the influence of density on cane and internode length, fruit size and total yield. Higher density will also be studied as a method for control of vegetative growth. Physiological evaluations of the impact of denser canopies and shading will also be conducted. Relationships reported from previous studies done under the hill system will be used as a baseline for experimental design.
- ☒ ***ARCHITECTURE AND INTERNODE LENGTH:*** Plantings at Vancouver will be studied for variability in plant architecture and internode length. Useful variability such as shorter internodes or opposite phyllotaxy may exist within clonal populations.
- ☒ ***CYTOKININS AND SENESCENCE:*** As a biennial, *Rubus idaeus* fruiting canes die after harvest due to severed vascular connections at the base of the cane. The girdling and subsequent senescence of leaves often begins while the plant is still developing fruit. Our studies with weekly measurements of chlorophyll have confirmed this. One class of growth regulators, the cytokinins, is responsible for cell division, and, when applied to senescing leaves, helps to maintain chlorophyll content and active growth. Our studies have also shown that individual fruit weight peaks before the largest number of fruit are produced. By encouraging active growth later into the fruit development period, yield potential could be recovered by increasing fruit size and number.
- ☒ ***RADIOACTIVE LABELING:*** Our lab now has the capability to do work with radioactive tracers. Radioactive carbon dioxide ($^{14}CO_2$) is fed to the plant and traced within the plant over time. This will establish how far and how fast fixed carbon moves within the plant. Initial work combined with physiological data indicates that carbon fixed on a fruiting lateral stays there. We have also established that photosynthesis decreases 60-70% in leaves along the lateral

between the exterior and interior portions of the canopy in response to fruit load and shading. This is very important information for designing new approaches to canopy architecture and management.

☒ ***FLORAL BUD INITIATION (FBI):*** This is a complex subject which will require a significant amount of review and consideration. The structure/function anatomist in our program (SFK) is currently reviewing a large body of literature as well as data and samples collected here over ten years ago. While FBI is known to occur in late Fall, the more important question is what we can do to improve it. We have observed plant characteristics which seem to enhance FBI, and we feel that better light penetration and a more efficient canopy will ultimately provide a solution. For the most part, FBI is just something which "happens" in our fields without any attempt to increase potential fruit numbers. We will incorporate studies of this nature into the project after a full review of where we currently are in terms of theory and practice.

In our attempts to increase yield efficiency, we encourage industry to share new ideas and possible approaches with us. As time and funding permit, we intend to test as many approaches as possible and encourage grower participation.

TERMINAL DATE OF BASE PROJECT: J. Scott Cameron June 30, 1993

DURATION OF THIS PROJECT: Third year of a three year project. The decision to propose renewal for 1994 will be based on 1993 data and industry enthusiasm.

BUDGET: Funding is used for labor-intensive analyses of plant material, data collection and supplies.

	1992	1993
01 Temporary employees	$2,500	$6,200
03 Supplies and services	600	500
04 Travel	----	300
05 Computer services	300	----
07 Benefits (5% of 01)	200	496
TOTAL	$3,600	$7,496

PROJECT NO.: 13C-3543-4958.

TITLE: Control of root weevils in red raspberries

PERSONNEL:

Carl H. Shanks, Jr., Washington State University, Vancouver.
John D. Stark, Washington State University, Puyallup.

JUSTIFICATION:

Root weevils, especially black vine weevil, are an increasing problem to red raspberry growers in the Pacific Northwest. There are few chemical insecticides registered on raspberries which will give good control of adults and virtually none that can be used to control the larvae. Entomogenous nematodes have not worked well for several people who have tested them on raspberries or strawberries. Better control methods are needed for these pests.

OBJECTIVES:

1. Test biological and chemical agents for efficacy against root weevils.
2. Provide services and data to the manufacturers and IR-4 Program for registration of efficacious materials.

PROGRESS:

Objective 1. A strawberry field infested by strawberry root weevil (SRW) and black vine weevil (BVW) was observed before and after the grower sprayed with Brigade. We counted 45 SRW and 30 BVW on the foliage of 260 ft. of row at night before the first spray. The night after spraying, no weevils were found on the foliage. We found 12 dead SRW and 6 BVW , even though it was difficult to find them by flashlight. Two weeks after the first spray we found 5 SRW and 7 BVW and the field was sprayed again. No weevils were found four nights after the second spray.

Lorsban 15G, suSCon Green (a slow-release formulation of chlorpyrifos, the same chemical in Lorsban), and Brigade 10W were applied as preplant soil treatments in a strawberry planting. Two strains of an entomopathogenic fungus, *Metarhizium anisopliae*, and Furadan 4F were applied to the soil in mid-summer in the same planting. The treatments will be evaluated for root weevil control in spring, 1993 and 1994.

The same materials were tested with potted strawberries. Three months after placing black vine weevil eggs on the soil, weevil larvae were counted. The numbers varied considerably from pot to pot but the results indicate that all rates of suSCon Green and Lorsban 15G gave complete control of the larvae. The two strains of the fungus, *M. anisopliae*, did not kill the larvae. However, two-thirds of the larvae in the fungus-treated soil were only half the size of the larvae in the untreated check soil. Apparently the fungi had a detrimental effect on the larvae. The results from this experiment do not reveal how well or long the materials will perform in the field but do indicate that they have possibilities.

Margosan-O (neem seed extract) was applied to small strawberry field plots on September 17, 1992. Water was applied by sprinklers after treatment. Weevil larvae will be counted in spring, 1993.

Margosan-O and RH-9999 (both neem products) were applied to additional strawberry plots in Clark and Whatcom Counties and raspberry plots in Whatcom County in October, 1992. The planting was irrigated after treatment. The treatments will be evaluated in spring, 1993.

In an effort to find a substance that would increase feeding by adult BVW, strawberry leaves were dipped in solutions containing 25% molasses or 0.75% Coax.

Coax. Adult weevils were placed on the leaves. After 48 hr., there were no significant differences between feeding on those treatments or untreated leaves.

Two trials comparing malathion alone and in combination with Coax were conducted on raspberries. Sprays were applied at night and weevils were counted two nights later. There were not significant differences between the two treatments and the untreated checks.

Malathion is one of many pesticides undergoing reregistration. In 1992 we applied malathion to raspberries and sent fruit to the USDA-ARS laboratory at Yakima, WA for residue analysis. The residue data will be used to support reregistration of malathion on raspberries.

PROPOSED RESEARCH:

The materials tested will include any chemical and biological agents that are available. Examples of the former are Margosan-O (extract from neem seed) and pyrethroid chemicals. Laboratory trials have indicated that combinations of some insecticides, which by themselves are only marginally effective against adult weevils, are more effective than the single chemicals alone. Combinations of such insecticides, which are currently registered on raspberries or probably will be registered, will be tested. Biological agents include items such as entomopathogenic fungi. There are some fungi available for testing now and others are expected to become available.

Some materials will be aimed at adult weevils to prevent egg laying. They will be tested first in the laboratory, if possible. That procedure involves placing adult weevils on raspberry leaves that have been treated with the candidate material and observing the weevils for mortality. Promising materials will be tested on

raspberries or strawberries in replicated field plots. The results obtained on one of these crops usually will apply to the other crop also.

Materials to be tested for control of larvae in the soil will usually be tested in replicated field trials. Candidate materials must have the ability to move downward into the root zone with water but must not be a threat to ground water. Applications usually will be made in the fall and evaluated in the following spring by comparing numbers of larvae in treated and untreated plots.

If a material is worthy of registration on raspberries, we will cooperate with the manufacturer and IR-4 Program in obtaining registration. Such work will include providing efficacy information and treated raspberries for residue studies.

TERMINATION DATE OF BASE PROJECT: March 31, 1994.

DURATION OF THIS PROJECT: 2/3 years.

BUDGET:

		1992-93	1993-94
00	Salary	$ 0	$ 1,932[a]
01	Temporary worker	$ 3,000	1,000
03	Material & services	340	300
04	Travel	420	306
07	Employee benefits (26% of 00)	0	502
07	Employee benefits (16% of 01)	240	160
	Total	$ 4,000	$ 4,200

[a] One month's salary for an Agricultural Research Technologist I.

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PROJECT NO.: 13C-3543-2857

TITLE: The impact of overwintering native predators on spider mite populations in red raspberry fields.

PERSONNEL:

Carl H. Shanks, Jr., Entomologist, WSU-Vancouver.
Arthur L. Antonelli, Extension Entomologist, WSU-Puyallup.
Bruce D. Congdon, Associate Professor of Biology, Seattle Pacific University.

JUSTIFICATION:

The twospotted spider mite, *Tetranychus urticae*, is a sporadic pest of red raspberries. Large populations of the mite can severely injure raspberry leaves during the summer.

Our research in recent years has shown a strong correlation between insecticide usage and mite numbers. The most important predator of spider mites in raspberry fields is a small ladybird beetle, *Stethorus* sp. In order to best utilize this predator in a pest management program, more information is needed on the source of the beetle, the time that the beetle becomes active in late winter or early spring, the effect of prebloom chemical insecticide sprays on *Stethorus* numbers, and how the beetle locates its prey when mites are at extremely low numbers.

OBJECTIVES:

1. Study the effects of prebloom sprays on *Stethorus* and spider mite populations.
2. Determine how quickly *Stethorus* populates new raspberry plantings.
3. Determine the natural source of *Stethorus* in areas surrounding raspberry fields.
4. Determine how *Stethorus* locates its mite prey.

PROGRESS:

The research conducted during the summer of 1992 on the role of *Stethorus* in the biological control of *Tetranychus urticae* in red raspberries was the third of a three-year study. The data added during this previous year provided further confirmation of the pattern observed in previous years: *Stethorus* is the most important predator of spider mites in this system. They also indicate the possible causes of chronic spider mite problems in particular fields and the sporadic nature of spider mite outbreaks in general.

As in past years, trap colony sampling on three occasions (May 2, June 11, and June 25, 1992) demonstrated that *Stethorus* is widespread, active early in the season, and has a remarkable searching capacity at very low spider mite densities.

The fields studied this year showed a range of peak spider mite densities, providing the opportunity to compare them on the basis of predator and prey population patterns and aspects of field situation and cultural and pest management practices. Although the patterns observed are still tentative, they suggest what the important factors in spider mite outbreaks may be.

The fields with the highest spider mite densities showed two patterns of *Stethorus* activity. Three Whatcom County fields on June 11 showed high percentages (16-18%) of the trap colonies with *Stethorus.* However, on June 25 they all showed 0%. At this time, leaf samples from two of these fields showed less than 1 spider mite female per leaf, the other was at 1.7. These spider mites could have lowered the trap colony counts by competing with the trap colonies in attracting *Stethorus*. However, past studies suggest that spider mite densities of 1 - 2 per leaf are not sufficient to confound the trap colony measurements. It

appears more likely that some factor caused high mortality in the *Stethorus* population between June 11 and 25 in these fields and was responsible for the subsequent increases in spider mite densities. Insecticide application is the most likely explanation, but spray records have not been obtained from these growers.

Two fields, which have in past years had significant spider mite problems, showed only moderate increases in spider mites this year. The three trap colony samples early in the season revealed moderate numbers of *Stethorus* (10-4-2 % in one field, 20-0-2 % in the other.

The other fields exhibited spider mite levels far below the economic threshold and several different patterns of predator activity. *Stethorus* was found in all of them and was common in all but one.

There were indications of some *Stethorus* activity into the latter part of the season in all of them. In two cases, significant *Stethorus* activity was evident even in the leaf samples. One unusual field had very little predator activity, but consistently low spider mite populations both this and last year. This suggests that some fields may be less favorable to spider mite growth for some reason not related to predators.

Malathion is commonly used on machine-harvested raspberries. A one-acre block of raspberries was sprayed with malathion on April 28 and May 14. Trap colonies of spider mites were placed in the field during the week prior to the first spray and the week after each spray. The percentages of traps with *Stethorus* were 16, 20, and 12%, respectively. Apparently malathion by itself does little damage to *Stethorus* populations.

Trap colonies of mites were placed in a commercial field of raspberries at intervals from April 20 to July 9. The percentages of traps with *Stethorus* on April 27, May 12, and June 5 were 33, 15, and 17% respectively. The field was sprayed with permethrin on June 5 and on June 17 and July 9 no *Stethorus* were detected. On July 23, 5% of the traps had *Stethorus* and on August 5, 27% had the predator. Random samples of 60 leaflets were picked every two weeks from June 5 to October 21 and examined for spider mites and *Stethorus*. Mite numbers rose from zero on June 5 to 1,873 mites per 60 leaflets on July 29 and peaked at 14,111 mites per 60 leaflets on August 26. *Stethorus* numbers were zero from June 5- July 15 but on July 29 there were 20 *Stethorus* (all stages) per 60 leaflets. *Stethorus* peaked at 139 on September 23, by which time spider mite numbers had dropped. On October 7, spider mites were at zero again and there were 5 *Stethorus* per 60 leaflets. No mites and two adult *Stethorus* were found on October 21. These results show: (1) permethrin is very toxic to *Stethorus*, (2) spider mite numbers increase rapidly in the absence of *Stethorus*, (3) *Stethorus* was able to repopulate the field 6-8 weeks after the spray was applied, and (4) *Stethorus* began reducing the mite numbers 4-6 weeks after it appeared.

Phytoseiids (predatory mites), as in past years, were generally associated only with the early season pollen production, or the late season surge in spider mite numbers in the most heavily invested fields. Their role in maintaining low stable densities of mites is apparently small. However, in fields receiving no insecticide applications, other general predators were sometimes common, suggesting that in a "natural" state, a complex of predators competes for spider mite prey. Their relative contribution to biological control is not well understood.

PROPOSED RESEARCH:

Objective 1. Trap colonies of spider mites will be placed in raspberry fields, beginning as soon as the first leaves are large enough (probably March), at two-week intervals. In April or early May, sprays of diazinon and/or Guthion will be applied. Trap colonies will be put in the field at intervals thereafter to monitor *Stethorus* numbers. Random samples of 50 leaflets will be collected and examined for spider mites each time trap colonies are examined.

Objective 2. Trap colonies of mites will be put in newly planted raspberry fields as soon as leaves are large enough. This will be continued at two-week intervals to determine how quickly *Stethorus* can populate a new planting. Spider mite populations will be monitored at the same time.

Objective 3. Trap colonies of mites will be placed on non-raspberry plants in the general vicinity of raspberry fields. The plants will also be examined for the presence of mites or other possible prey. Also, sticky board traps of various colors will be placed near raspberry fields and also in non-raspberry areas in the vicinity and examined for the presence of adult *Stethorus*. These experiments will help us determine from where *Stethorus* are coming and when they are flying.

Objective 4. A simple olfactometer will be used to help determine whether adult *Stethorus* locates its mite prey, especially when prey density is low, by random searching or by its olfactory senses. If there is evidence of the latter, extracts of mites will be made with solvents and the extracts will be tested to see if they attract *Stethorus*.

TERMINAL DATE OF BASE PROJECT: March 31, 1994.

DURATION OF THIS PROPOSAL: One year. The research conducted during the 3 years of the original project revealed areas of interest which require additional investigation. We hope to complete the work in 1 year but may need additional time beyond 1993.

BUDGET:

		1992	1993
00	Salary	$ 0	$ 1,932[b]
01	Wages	$ 8,100[a]	$ 8,300[c]
03	Supplies	100	100
04	Travel	1,000	338
07	Benefits for 00[d]	0	502
07	Benefits for 01[e]	648	1,328
	Total	$ 9,848	$12,500

[a] $6,000 for 2 months research by Ph.D. entomologist, $2,100 for student assistant.

[b] One month's salary for an Agricultural Research Technologist I.

[c] $6,200 for 2 months research by Ph.D. entomologist, $2,100 for student assistant.

[d] 26% of object 00.

[e] 8% of object 01 in 1992, 16% in 1993.

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Project No:

Title: Transformation of Raspberry with the Coat Protein of Raspberry Bushy Dwarf Virus and a herbicide resistance gene

Personnel: Robert R. Martin, Agriculture Canada Research Station, 6660 NW Marine Dr., Vancouver, B.C. V6T 1X2, Kirsten Finstad, a post doctorate fellow that will be working on this project.

Justification:

Raspberry bushy dwarf virus (RBDV) is the most common virus disease of raspberries in the Pacific Northwest. Currently, only two raspberry cultivars (Willamette and Chilcotin) grown in this area are resistant to RBDV. Transmission of RBDV is associated with flowering and therefore control is very difficult or impossible by chemical means. With the technology of incorporating plant virus coat proteins stably into plants and the finding that these plants express some form of resistance to subsequent infection by the virus we have the tools required to develop synthetic resistance to plant viruses. We have successfully carried out similar research with potato and have obtained very high levels of resistance in greenhouse trials.

Objectives:

This will be the second year of this project. To date we have developed diagnostics that will be required to test for the expression of the RBDV coat protein in transgenic raspberries. During the second year of this project we will clone the coat protein of RBDV which is a prerequisite to developing synthetic resistance. We will also work on developing a useable transformation system for raspberry based on information obtained from the group at the Scottish Crops Research Institute. During the third year of the project the coat protein gene of RBDV and a herbicide resistance gene will be put into several raspberry cultivars and these lines challenged with virus to evaluate their reaction to RBDV.

Progress:

To date we are developing the tools required for testing the transgenic plants. We have now prepared a number of specific monoclonal antibodies that will be useful for detecting the expressed gene in the raspberry plants. In my lab we have completed the transformation of several potato cultivars with a virus coat protein gene and obtained high levels of resistance to the virus in potatoes. We have developed some

expertise in the transformation of plant tissue using Agrobacterium tumefaciens as well as experience with tissue culture of raspberry. We have prepared the coat protein gene of RBDV and are now combining this with a herbicide resistance gene. Development of a suitable regeneration and transformation system has progressed very little. We are getting a post doctorate fellow to work on this problem starting in Nov. 1992. This will speed up this aspect of the work. We are also working on developing other types of virus resistance with potato leafroll virus. If these systems prove more useful than coat protein mediated resistance they will be applied to RBDV.

Proposed Research:

The coat protein gene will be combined with a herbicide resistance gene and the combination used to transformed raspberry leaf disks. The transformed plants (plants with the coat protein gene inserted into the plant genome) will be tested for the presence of the inserted DNA, then checked to make sure the corresponding RNA is produced and that the gene is expressed and the coat protein is produced in the plants. Plants expressing high levels of coat protein will be graft inoculated with RBDV to test for resistance. One of the major concerns with the commercialization of genetically engineered plants is the presence of the antibiotic resistance gene that is used as a selectable marker during the regeneration step. By using a herbicide resistance gene we can avoid having to use the kanamycin resistance gene. Also, the herbicide resistance gene should be useful to the growers when weeds become a problem.

Since we want to see a response in the field, initially we will want to use cultivars that are readily infected with RBDV in the field. Meeker will be our first choice of cultivar to work with.

Termination date of Base Project: Jan. 1, 1995.

Budget:	1992	1993
01 Salaries (This is to get hourly help for virus testing during the summer.		1000.00
03 Goods and Services	4500.00	3500.00
TOTAL	4500.00	4500.00

I had a student working the project that has quit, As I mentioned above I have been able to get a post doctorate fellow to work on developing transformation and regeneration systems for raspberry, strawberry and blueberry. I also, plan to get another student to work on the project. The funding for the post doctorate fellow is for 2.5 years and was only possible because of the progress that we have made on small fruit research during the past several years. Much of the funding for this initial work has been funded by grower funds. I would like to thank you for your support and also point out that we have been able to compound your support with funding from other granting agencies. In these tough economic times granting agencies are more likely to fund research projects when there is some "seed" money available from industry. Again thank you for your support.

PROJECT NO. : New

TITLE: Effect of pruning practices on growth, yield, and yield components of red raspberry

PERSONAL: **Sorkel Kader**, Research Associate

Wilbur Anderson, Horticulturist, WSU-Mt. Vernon

JUSTIFICATION:

Red raspberry canes grown in one year, branched and produce a crop in the next growing season, then die. While one set of canes is fruiting another is growing to produce their crop in the year following. The biennial floricane should be removed, and pruning has been proposed to start soon after the harvest season or at the early spring. Early pruning would control some diseases and insects; canes are less tough and easier to remove; will help in the hardening processes and facilitate cultivation. On the other hand, floricane can protect and support the primocanes against storms and heavy snow drift; the amount of diseases controlled by early pruning is usually negligible; damage wood during winter could be removed during late spring; and it is more convenient to do all the pruning in spring in one operation. However, little is known about the immediate and long-term effects of pruning on raspberry yield and components. The optimal pruning system for a particular raspberry cultivar is a complex operation since it depends on inherent vigor, number of primocanes produced, interrelationships among yield components, susceptibility to diseases, response to environment, and other factors, thus a specific pruning system needs to be developed for individual cultivar.

OBJECTIVES:

To identify a pruning system for the most popular red raspberry cultivars grown in the

Pacific Northwest that would optimize productivity and fruit quality over the life of the planting.

PROPOSED RESEARCH: Experiments will be conducted which will examine the response of red raspberry to cane density, time of density adjustment, primocane tipping, and length of canes or branches on yield and fruit quality. The floricanes will be tied and primocanes will be allowed to grow up between the floricanes. Different time of canes density adjustment, several cane density levels, several levels of primocane tipping and three heights of branch adjustment of floricanes will be applied on red raspberry. In early summer, just before harvest, the number of dead, vegetative, and fruitful laterals will be counted. The number of flower per lateral, fruits per lateral and lateral length will be measured. Fruit weight from 50 fruits per treatment will be estimated for five or more times throughout the season and yield will be estimated for each plant.

TERMINAL DATE OF BASE PROJECT: December 1993.

DURATION OF THIS PROJECT: Two years with the possibility of renewal depending upon the results from 1993.

BUDGET: 1992-93

00	Salary	$15,000 (.5 FTE)
01	Wages	3,000
03	Supplies & services	1,000
04	Travel	500
07	Benefits	3,900
Total		$23,400

PROJECT: Raspberry breeding with specific emphasis on disease and pest resistance and improved fruit quality and higher yield.

TITLE: Raspberry breeding for the Pacific Northwest

PERSONNEL: Hugh Daubeny, Agriculture Canada, Research Station, 6660 N.W. Marine Drive, Vancouver, B.C. V6T 1X2

JUSTIFICATION: The B.C. raspberry breeding program has already made significant contributions to the Pacific Northwest raspberry industry through the introduction of cultivars such as Chilcotin, Chilliwack, Comox, Skeena and Tulameen, each of which has proven to be better suited to the fresh market than cultivars grown primarily for processing. In fact, the B.C. cultivars are now the prime source of the high quality fresh market raspberries produced in late June through July and into early August in the Pacific Northwest. The fruit realizes a premium price on the fresh market. Because of this and the potential for future contributions from the program, I am approaching the Washington State Red Raspberry Commission regarding the possibility of funding for the program.

OBJECTIVES: Funding is requested to assist in the evaluation of advanced selections for fruit quality and reactions to various economically important diseases and pests. Regarding fresh market suitability, evaluations will involve reactions to postharvest fruit rot causal organisms and for shelf life. At the same time, there will be evaluations for processing suitability. Pests and diseases of concern are Phytophthora-incited root rots, the aphid vector(s) of the raspberry mosaic virus complex, raspberry bushy drawf virus and various cane diseases. The requested funding would also be used in evaluating established seedling populations for potential selections.

PROGRESS: Forty-eight selections are now in first test plots and are at varying stages of evaluation. At least three of those with several years of evaluation data are considered to have cultivar potential. In 1993, approximately 2,000 seedlings will be examined for the first time for horticultural traits. Thus, there are a considerable number of selections and seedlings already established for further evaluation. In addition, seedlings from crosses made in 1992 are now growing in the greenhouse and will be prescreened for aphid reaction this winter before planting into the field in 1993.

TERMINATION DATE: Indefinite, as the research is of a long term nature

BUDGET: I am requesting approximately $10,000 to hire two university students to assist in the project during the 1993 growing season.