Fruit Varieties Journal 46(3):132-137 1992

Productivity and Vigor of Sixteen Raspberry Cultivars in Central Pennsylvania

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Abstract

Sixteen cultivars of four year old red (*Rubus idaeus*, L.), purple (*Rubus occidentalis X Rubus idaeus*) and black raspberry (*Rubus occidentalis*, L.) plants were evaluated for yield, fruit size, winter injury and vegetative characteristics under reduced pesticide applications in 1989 and 1990. The black raspberries generally yielded better with reduced pesticide applications in the first year, but were badly damaged from anthracnose (*Elsinoe veneta*) infections. 'Jewel' had the highest yield and largest fruit of the black and purple raspberries. Among red raspberries, 'Madawaska' and 'Newburgh' produced the highest yields and fruit size of each was large. However the poor flavor of 'Madawaska' was a limitation. Black raspberries varied little in cold hardiness; however, there was considerable variation among red raspberries in cold hardiness, with 'Festival' particularly hardy over both years, and 'Willamette' particularly cold tender. Rapid decline from winter-induced tip dieback on 'Boyne' and 'Sentry' was probably due to the high level of anthracnose cane lessions. Phenological stages of development were monitored for all cultivars. Dates of first bloom varied 15 days among cultivars, however days from first bloom to first ripe fruit varied from 21 to 43 days.

Raspberries are a relatively expensive crop to establish and maintain, but offer a correspondingly high profit potential (1). This high investment and crop value, as well as susceptibility to numerous insects and diseases, encourages most producers to use high levels of preventative pesticides. With the loss of availability of many pesticides on minor crops, due to either new regulatory restrictions or unprofitability for the manufacturers, it will be necessary to rely more heavily on alternative means of controlling pests, one of which might be using cultivars with inherent resistance or tolerance to pests. Many sources of resistance to various diseases and insects have been identified in *Rubus* species (2, 3). These sources have been incorporated into currently grown cultivars to some degree, however most cultivars grown in the United States are still susceptible to many potentially damaging insects and diseases. Little evaluation of specific cultivar ability to produce while tolerating disease or insect pests has been conducted. One means of determining an individual genotype's tolerance to pests is to withhold or lower pesticide applications and evaluate plant responses under these reduced pesticide conditions. The objective of this research was to evaluate specific black, purple and red raspberry cultivar responses to reduced pesticide regimes under central Pennsylvania conditions.

A four year old raspberry planting on a Hagerstown silt loam containing 16 cultivars was evaluated for yield, fruit size, growth and disease and insect susceptibility for 2 years, 1989 and 1990. Disease and insect susceptibility data has been published elsewhere, and will only be referred to briefly in this paper (4, 5). Three replications of 5 plants originally spaced 0.9 meter apart in rows 3.7 m apart were arranged in a completely randomized design. Black and purple raspberry cultivars were maintained as stools, while red raspberries were grown in a hedgerow system. No fungicides, miticides or insecticides were used for the duration of the 1989 season. Herbicides (dichlobenil, simazine and oryzalin) were applied according to labeled recommendations

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to control weeds. In 1990, Captan fungicide was applied (in addition to the herbicides) every 2 weeks due to the very wet seasons and the resulting high incidence of anthracnose and cane Botrytis (*Botrytis cinerea*). Black raspberry cultivars were 'Allen,' 'Bristol,' 'Cumberland,' 'Early Black,' 'Haut,' 'Jewel' and 'New Logan.' Red raspberry cultivars were 'Amos,' 'Boyne,' 'Festival,' 'Heritage,' 'Madawaska,' 'Newburgh,' 'Scepter,' 'Sentry,' and 'Willamette.' The one purple raspberry cultivar was 'Lowden's Sweet Purple.' Because 'Heritage' is a primocane bearer, and is usually mowed in the dormant season commercially, comments regarding 'Heritage' will be restricted to vegetative characteristics. 'Heritage' was also used as a standard for fall fruiting tendency.

Harvest data were collected every other day (Monday, Wednesday and Friday) from 5 July through 26 July 1989. Marketable and non-marketable fruit were picked separately and weighed, and individual fruit size determined by weighing 25 fruit and dividing the weight by 25. Marketable fruit was any fruit which was unmarred in appearance. Unmarketable fruit included fruit with visible signs of disease or insect injury. Yield data for 1990 was not collected due to the degenerated condition of the planting which resulted from the reduced pesticide applications treatments the previous year.

During the dormant season, plots were evaluated for winter injury (0 = whole plant dead, 4 = no cane dieback), branching (0 = 0 branches/cane, 3 = > 10 branches/cane), fall bearing tendency (0 = none, 2 = up to 3 fruit clusters/plant, 3 = prolific fall-bearing habit), cane height and density (for red raspberries only, since black and purple raspberries had been tipped to 152 cm and thinned to 4 canes/plant during the previous growing season), cane diameter (at 5 cm above ground level), and suckering ability (0 = no canes, 1 = 1-4 canes, 2 = 4-12 canes, 3 = over 12 canes between original plants). Cane density was evaluated by counting the number of canes in a 675 cm^2 (15 X 45 cm) frame. For cane height, density and diameter, 5 canes per replication were randomly selected, measured and values averaged. Phenological stages of each cultivar were monitored during the 1990 season. Leaf, flower and fruit development was assessed twice a week early in the season (through flowering), and once a week as the season progressed.

Environmental conditions were exceptionally wet in spring and early summer of both years (Table 1), providing optimal conditions for disease proliferation.

Data for black and purple raspberries were analyzed separately from red raspberries. All data except for phenological data were analyzed using an analysis of variance, and means were separated using the Waller-Duncan mean separation test. Phenology values were averaged over replications. Because there was essentially no variation within cultivars, it was not necessary to subject phenology data to statistical analysis.

Yield. Among black raspberries, 'Jewel' had high yields and excellent

Table 1. Temperature and total rainfall for 1989, 1990 and the mean for 1965-1990.

	Month					
	Apr	May	June	July	August	Sept
Temperature (C)						
1989	9.1	14.3	19.6	21.5	20.2	15.8
1990	10.2	12.3	19.0	20.1	19.4	15.4
1965-1989 mean	8.8	14.9	19.5	21.9	21.1	16.8
Rainfall (cm)						
1989	2.6	16.9	21.8	14.6	2.2	9.1
1990	9.5	17.2	8.0	11.5	9.5	10.0
1965-1989 mean	7.1	9.6	10.6	9.3	7.8	8.3

fruit size, as well as a high percentage of marketable yield (Table 2). However, 'Jewel''s susceptibility to post-harvest gray mold (*Botrytis cinerea*) infections was the highest of any of the black raspberries (4). 'Allen' and 'New Logan' were comparable to 'Jewel' in productivity, but had smaller average size. 'Bristol,' 'Cumberland' and 'New Logan' were all particularly small, in spite of more than adequate rainfall. Percent marketable yield under reduced pesticide applications was about 80% for all black raspberry cultivars.

Generally, red raspberry yield and size was inferior to that of the black raspberries (Table 2). Anthracnose infections were severe (5) and productivity poor. Red raspberries were also generally more attractive to Japanese beetles (*Papillia janponica* Newman), with 'Newburgh' the most susceptible (4). 'Madawaska' had the highest yield and good size, however, the fruit was unattractive (large drupelets, uneven light colored) and the taste was unacceptable 'Willamette' fruit had large size, however productivity was low, probably due to winter injury. 'Sentry' and 'Boyne' had less than 10% marketable fruit, as well as the smallest fruit size. Damaged fruit resulted from anthracnose infections and beetle feeding injury. The proportion of marketable fruit was uniformly less for red raspberries than black raspberries. 'Lowden's Sweet Purple' (the only purple in the study) was predictably intermediate in most responses between the red and black raspberries. Only 48% of its fruits were marketable. There was no consistent relationship between productivity and fruit size among all types and cultivars tested.

Winter injury and vegetative characteristics. In 1989, there were no differences in winter injury and vege-

Table 2. Raspberry cultivar yield, percent marketable yield and fruit size.

Cultivar[z]	Total yield (kg/H)	% Mkt. yield	Size/fruit (g)	Harvest season[y]
BLACK AND PURPLE RASPBERRIES				
Allen	6005.9ab	81	2.1b	5 July-19 July
Bristol	4495.4ab	75	1.9bc	5 July-19 July
Cumberland	4424.9ab	81	1.7c	5 July-17 July
Early Black	4473.7ab	82	2.2b	5 July-19 July
Haut	3664.4ab	84	2.2b	5 July-17 July
Jewel	6523.2a	83	2.9a	5 July-21 July
New Logan	5411.8ab	82	1.9bc	5 July-19 July
Lowden's Sweet Purple	3335.2b	48	2.2b	10 July-26 July
p(F)	0.04		0.001	
RED RASPBERRIES				
Amos	2008.1b	62	2.7ab	5 July-18 July
Boyne	1148.5cd	7	1.9d	x
Festival	879.2d	46	2.7ab	x
Madawaska	3526.6a	40	2.9ab	5 July-21 July
Newburgh	3322.5a	42	2.6bc	7 July-21 July
Scepter	626.4d	23	2.4bcd	x
Sentry	1263cd	4	2.0cd	x
Willamette	1724.6bc	57	3.2a	7 July-21 July
p(F)	0.0001		0.008	

[z]Means separated at the 0.05 level using the Waller-Duncan mean separation test. p(F) values indicate signifiance level of the analysis of variance for cultivar.
[y]Includes dates when the equivalent of 25 lb/A (50 g/plot) or more was harvested.
[x]Yield for these cultivars was too small to accurately assess harvest dates.

tative characteristics among black and purple raspberry cultivars (Table 3). In 1990, differences were still minimal, with only 'Lowden's Sweet Purple' significantly more hardy than all black raspberry cultivars except 'Allen.' 'Early Black' was also less hardy than 'Allen.'

Among red raspberries, 'Willamette' suffered the most winter injury in 1989. However, in 1990, 'Willamette,' 'Sentry' and 'Boyne' were equally damaged (Table 3). The increase in cane dieback after the winter may have been due to the increased stress from the higher incidence of anthracnose lessions on canes of 'Sentry' and 'Boyne' as compared to other red raspberries (Rajotte et al., 1990). This may also account for the overall increase in black raspberry cane dieback from 1989 to 1990, since all of the black raspberries displayed higher numbers of anthracnose lessions than the reds.

The degree of branching on red raspberry was also dependent on cultivar, with 'Scepter' more highly branched than all others except 'Newburgh' (Table 3). 'Heritage' had the most fall fruiting, but both 'Scepter' and 'Madawaska' displayed some fall-fruiting capability. 'Festival' and 'Heritage' were the shortest cultivars in both years, and 'Madawaska,' 'Festival' and 'Amos' had the lowest cane densi-

Table 3. Vegetative characteristics and winter injury of 16 raspberry cultivars in central Pennsylvania: 1989-1990.

	Cane Density[2]		Cane Diameter (mm)[3]		Winter injury[4]		Ht (m)[5]		Suckering[6]	Fall bearing[7]	Branching[8]
Cultivar[1]	1989	1990	1989	1990	1989	1990	1989	1990	1990	1989	1989
BLACK AND PURPLE RASPBERRIES											
Allen	.	.	15.0	13.5	3.2	2.0ab	.	.	.	.	1.7
Bristol	.	.	15.9	14.0	3.0	1.3bc	.	.	.	.	2.0
Cumberland	.	.	13.4	14.7	3.4	1.7bc	.	.	.	.	2.7
Early Black	.	.	11.7	12.5	3.4	1.0c	.	.	.	.	2.0
Haut	.	.	16.3	15.0	3.2	1.5bc	.	.	.	.	1.3
Jewel	.	.	14.7	13.7	3.2	1.7bc	.	.	.	.	2.0
New Logan	.	.	13.8	14.0	3.0	1.3bc	.	.	.	.	2.3
S.L. Purple	.	.	13.5	14.9	3.0	2.7a	.	.	.	.	1.7
p(F)	.	.	0.25	0.75	0.47	0.04	.	.	.	.	0.12
RED RASPBERRIES											
Amos	9.5cd	12.0b	9.7b	10.3a	3.2ab	4.0a	1.12b	1.44cd	2.0b	0.0	1.0bc
Boyne	12.9bc	22.5a	9.0bc	8.6b	3.2ab	3.3bc	1.19ab	1.36de	3.0a	0.0	0.7c
Festival	5.4d	12.0b	7.2d	8.4b	3.4a	4.0a	0.66d	0.82e	1.7b	0.0	1.0bc
Heritage	11.4bc	11.8b	8.8bc	10.5a	—[9]	—[9]	0.89c	1.51bc	2.0b	3.0	0.3c
Madawaska	9.2cd	12.0b	11.8a	10.0ab	3.2ab	3.7ab	1.32a	1.54b	2.7a	1.0	1.0bc
Newburgh	15.2b	18.0ab	8.2cd	10.3a	2.6b	4.0a	1.16ab	1.42cd	2.0b	0.0	1.7ab
Scepter	15.6ab	21.3a	9.2bc	8.6b	—[9]	—[9]	1.07b	1.38de	2.7a	2.3	2.0a
Sentry	14.6b	23.8a	9.8b	9.8ab	3.0ab	3.0c	1.25ab	1.31e	2.8a	0.0	0.3c
Willamette	19.7a	18.8ab	9.4bc	9.9ab	1.6c	3.0c	1.35a	1.87a	1.6b	0.0	1.0bc
p(F)	0.0001	0.02	0.0001	0.04	0.0002	0.005	0.0001	0.0001	0.001	N/A	0.001

[1]Means separated at the 0.05 level using the Waller-Duncan mean separation test.
[2]For red raspberries, density is number of canes/625 cm^2.
[3]Measured at 5 cm above ground. Each mean in the table is the average of 15 canes.
[4]0 = all dead, 1 = 60 cm or more tip dieback., 2 = 15-60 cm tip dieback, 3 = 7.5-15 cm tip dieback, 4 = no visible winter injury.
[5]For red raspberries only. Black raspberries were all maintained at a height of 1.5 m.
[6]Degree to which red raspberries filled in hedgerow with suckers between original plants. 0 = no canes, 1 = 1-4 canes, 2 = 4-12 canes, 3 = over 12 canes between original plants.
[7]For fall-bearing tendency, 0 = none, 1 = 1-2 clusters/plant, 3 = comparable to Heritage.
[8]0 = 0 branches/cane, 1 = 1-4 branches/cane, 2 = 5-10 branches/cane, 3 = > 10 branches/cane.
[9]No data. Could not ascertain tip dieback due to fall fruiting nature of plants.

ties. Stem diameter was largest on 'Madawaska,' and smallest on 'Festival.'

Phenological characterization. Phenological information is valuable when planning pest control strategies. Black raspberry cultivars varied little in seasonal development, however red raspberries, however, were highly variable (Table 4). Days from first bloom to first ripe fruit differed among red raspberries, varying from 21 days ('Willamette') to 43 days ('Scepter'). 'Lowden's Sweet Purple' usually lagged one to two weeks behind the red raspberries in most phenological stages of development. Flower bud emergence occurred at very nearly the same time for all cultivars of tested, regardless of type (Table 4).

Two years of data on any field-related research project is not intended to be used as a basis for grower recommendations, but rather as a guide for future research. Under these conditions, black raspberries performed best, with highest marketable yields on 'Jewel' and 'Allen,' and acceptable yields for all of those black raspberries tested. Among red raspberries, 'Amos,' 'Madawaska' and 'Newburgh' had highest yields, though the marketable percentage (between 40 and 60%) was unacceptable. The poor performance of some cultivars may be due to the disease and insect infestations that resulted from the reduced pesticide regime. These cultivars may still be acceptable for commercial use in Pennsylvania if grown using a prudent spray schedule.

This paper does not evaluate long term effects of reduced pesticide use, particularly on the longevity of a given planting. While no symptoms of virus infection were apparent in the planting during the study, it is highly likely that, given higher aphid populations which occur under low pesticide regimes, risk of the development of aphid transmitted virus diseases would increase. The high levels of insect and disease infestation in this research plot suggest that, given the current state of knowledge of both pests and cultivars, pesticide use is easily justified, particularly in years with normal or higher than normal precipitation.

Table 4. Dates of phenological stages in black and red raspberry cultivars: Rock Springs, Pennsylvania, 1990.

	Calendar date						
Cultivar	Budbreak	Flowerbud emergence	First bloom	50% Bloom	50% Green	First ripe	Days from 1st Bloom to 1st ripe
Allen	23 April	3 May	28 May	28 May	3 June	24 June	27
Bristol	23 April	3 May	19 May	28 May	3 June	24 June	35
Cumberland	20 April	3 May	22 May	28 May	3 June	24 June	33
Early Black	20 April	3 May	22 May	28 May	3 June	24 June	33
Haut	23 April	3 May	22 May	28 May	3 June	1 July	40
Jewel	20 April	3 May	22 May	3 June	3 June	1 July	40
New Logan	23 April	3 May	19 May	28 May	3 June	24 June	36
Amos	23 April	3 May	19 May	28 May	3 June	17 June	29
Boyne	23 April	8 May	3 June	10 June	24 June	1 July	28
Festival	20 April	3 May	22 May	3 June	17 June	24 June	33
Heritage	20 April	3 May	22 May	3 June	17 June	17 June	26
Madawaska	20 April	3 May	19 May	28 May	3 June	17 June	29
Newburgh	23 April	3 May	22 May	3 June	6 June	24 June	33
Scepter	26 April	8 May	19 May	10 June	1 July	1 July	43
Sentry	20 April	3 May	28 May	10 June	24 June	1 July	34
Willamette	26 April	8 May	3 June	6 June	10 June	24 June	21

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Fruit Varieties Journal 46(3):137-140 1992

Response of Fruit Development Period to Temperature During Specific Periods After Full Bloom in Peach

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Abstract

Much research has been conducted to evaluate the relationship of temperature on growth and development. Models for predicting harvest time are generally based on temperature data for the entire period of growth and development. In peaches, fruit development period (FDP) is not associated well with temperature data for the entire period. Temperature of 30 to 45 days after full bloom serves as the best predictor for FDP in early ripening peaches under Texas conditions. The FDP of these peach cultivars is influenced by temperature differently. The reduction of FDP varies from about 2 to 6 days with one degree increase in temperature.

Introduction

Temperature's association with time required for growth and development has long been recognized and used for building models to predict harvest time for various crops (Dufault et al., 1989; Hoover, 1955; Madariaga and Knott, 1951). These models for predicting harvest time were based on the temperature throughout entire cropping cycle. However, in fruit crops, prevailing temperature throughout entire development (full bloom to harvest) may not yield an accurate prediction. Kronenberg's (1988) analysis of data from ten apple cultivars in four different locations in Europe indicated only temperature during the first month after the onset of flowering and the period immediately before harvesting influenced the length of fruit development. In apricots, the mean daily temperature during first six weeks after full bloom served as a good criteria for predicting harvest time (Baker and Brook, 1944; Brown, 1952). In peaches, the most critical time for FDP was the first two months after full bloom (Topp and Sherman, 1989; Weinberger, 1948). These studies have shown that temperatures during specific periods after full bloom have profound effects on FDP in fruit crops.

The objectives of this paper are to examine the specific time period that is the best predictor of FDP, and to interpret differences or similarities of selected peach cultivars' response to temperature during this period.

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