pletely understood. If one cannot provide suitable isolation (distance, low attractiveness to potential pollen vectors, etc.) to prevent undesirable outcrossing, then the rootstock cultivar needs to have some readily identifiable 'marker' to reveal outcrosses in the seedling row so that they may be discarded before the budding operation. At the present time the use of homozygous red-leaf rootstock lines may be the most practical option since the most likely unwanted pollen donors will be nearby commercial peach blocks which will invariably be green-leaf. The resulting heterozygous red-leaf outcrosses can be reliably identified in a careful inspection prior to budding.

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Variation in Drupelet Number and Weight in Pacific Northwest Red Raspberries

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Abstract

Fruit weight, drupelet number, drupelet weight and seed weight were measured for five fruit per plot for raspberries in plantings established at Puyallup, Wash. Primary fruit were harvested in the first and second harvest seasons for raspberries in three plantings established in 1990, 1991 and 1992. For pooled data from the 124 plots sampled in this study, mean fruit weight fruit and drupelet weight increased from the first to the second season, while there was no increase in drupelet number. The planting established in 1992 did not follow the same pattern as the pooled data. In the 1992 planting the drupelet number increased, but drupelet weight did not increase from the first to the second harvest season. This may be the result of weather conditions at the time of fruit initiation or fruit development.

The weight of a red raspberry (*Rubus idaeus* L.) fruit is dependent on the number and weight of drupelets. In addition to determining the weight of the fruit, the number and weight of drupelets affect the appearance and may impact fruit firmness (4, 5). Understanding the variation in these components of fruit weight is important when attempting to breed for these characters.

In a previous study (2), the number and weight of drupelets were determined for 124 raspberry genotypes grown in research plots at Washington State University Puyallup Research and Extension Center. There was significant variation among clones in the number and weight of drupelets. The number of drupelets per fruit varied from 38 to 145 and the weight of drupelets ranged from 18 to 76 mg. However, the study only sampled fruit from a single fruiting season. Drupelet number and weight could be affected by the weather conditions during flower initiation, fruit development or age of planting. Evaluation of raspberry harvest data from

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several years indicated that some traits, such as fruit rot, were highly variable from year to year (3).

The Washington State University breeding program has continued to collect information on the number and weight of drupelets. Data has been collected for the same plots in different years. The objective of this study is to report on the number and weight of drupelets of raspberry clones in different age plantings over several years.

Materials and Methods

Raspberry plantings were established at Washington State University Research and Extension Center, Puyallup, Wash. in 1990, 1991 and 1992. Five primary fruit from each plot were harvested at the peak of the season for the first and second harvest seasons (two and three years after planting establishment). The planting established in 1991 was also harvested in the third fruiting harvest season (four years after planting establishment). Fruit weight, number of drupelets, weight of drupelets and seed weight were determined for each fruit (2). Not all plots were sampled in both years, only those sampled both years were included in this study. One hundred twenty four plots were sampled for two years representing 8 raspberry cultivars and 43 selections. Each planting had three replications of each clone, however, only two replications were harvested for some clones.

The difference between the first and the second harvest season was calculated for each variable for a plot. The statistical significance of these differences were tested using the t test. Differences among cultivars within a planting for each year were analyzed using ANOVA and mean separation by Duncan's multiple range test.

Results and Discussion

For all three plantings the mean fruit weight of primary fruit increased from the first (4.35 g) to the second harvest season (4.93 g) (t = 7.45, p < 0.01). This is similar to the change in the seasonal mean of fruit weight from the first to the

second season where the fruit weight increased 9% from the first to second fruiting season (3). The increase in fruit weight from the first to second harvest season in this study was the result of an increase in drupelet weight. The number of drupelets did not change between the first (90.2) and second seasons (91.0) (t = 0.57, n.s.). The mean weight of the drupelets increased from the first (49.0 mg) to the second harvest season (54.9 mg) (t = 6.4, p < 0.01). The seed weight was determined for 87 of the samples. For these samples the seed weight increased from the first (1.81 mg) to the second harvest season (1.96 mg) (t = 7.12, p < 0.01). However, even though the seed weight increased from the first to the second season, the drupelet weight increased even more resulting in a decrease in the proportion of the fruit that was seed (3.85% to 3.57%, t = −3.88, p < 0.05).

The fruit weight, drupelet weight and drupelet number in the first and second harvest seasons were significantly correlated (r = 0.66, 0.57, 0.53 respectively; all p < 0.05). Although the fruit characteristics were significantly correlated, the values were small, $r^2 < 0.45$). When the three plantings were analyzed individually, fruit weight in the 1992 planting and drupelet number in the 1990 planting were not significantly correlated between the first and second harvest seasons.

The planting established in 1991 was harvested for three harvest seasons. The differences from the first to the second season for fruit weight, drupelet number and drupelet weight followed the same trends as for the mean of all plots in all three plantings. The means for the third harvest season differed from the first harvest season (greater fruit and drupelet weight but same drupelet number), but not from the second harvest season. This is consistent with other harvest data varying more from the first to the second harvest seasons, but little from the second to the third (3).

Although the differences from the first to the second harvest season for the pooled data were statistically significant, the three plantings did not behave the

Table 1. Measurements of fruit of red raspberry cultivars in three plantings at Puyallup, Wash.

Cultivar	Fruit weight (g)	Number of drupelets	Average weight of drupelets (mg)	Average weight of seed (mg)	Ration of seed wt to drupelet wt
1993 harvest season of 1990 planted raspberries[z]					
Chilcotin	4.1 ab[y]	91.8 a	44.7 a	1.8 a	4.1 b
Chilliwack	4.2 ab	89.5 a	47.4 a	1.9 a	4.0 b
Meeker	3.6 bc	99.6 a	36.2 a	1.8 a	4.9 a
Willamette	3.5 c	81.7 a	43.5 a	1.6 a	3.6 b
1994 harvest season of 1991 planted raspberries					
Qualicum	6.3 a	114.9 a	55.0 a	1.8 a	3.3 a
Willamette	4.6 b	84.4 b	55.0 a	1.7 a	3.1 a
1995 harvest season of 1992 planted raspberries					
Chilcotin	4.7 bc	97.0 a	47.7 cd	—[x]	—
Chilliwack	3.9 c	99.7 a	40.8 d	—	—
Comox	5.8 a	99.9 a	58.3 b	—	—
Glen Ample	6.0 a	81.8 a	72.8 a	—	—
Meeker	4.0 c	93.3 a	43.1 cd	—	—
Tulameen	5.1 ab	103.9 a	49.4 cd	—	—
Willamette	5.1 ab	100.6 a	51.0 bc	—	—

[z]Values from 1990 planting represent means of 2 replications, other plantings represent 3 replications. Each replication had 5 fruit harvested from it.
[y]Means within column, within each planting, followed by the same letter are not significantly different using Duncan's multiple range test, P = 0.05.
[x]Data not collected in 1995.

same. The plantings established in 1990 and 1991 followed the same pattern as the mean for all plots. The planting established in 1992 had a small increase in fruit weight from the first (4.48 g) to the second harvest season (4.84 g) (t = 2.09, p < 0.05) and an increase in drupelet number (91.4 to 96.8, t = 2.35, p < 0.05). However, there was no change in drupelet weight (50.4 to 50.9, t = 0.31, n.s.). It is not clear why this planting behaved differently from the other two plantings.

It is unclear when the number of drupelets per fruit is determined in the bud. In England, primary buds were present by 3 Dec. (1). The number of drupelets may have been determined by that time. The monthly temperatures and precipitation for August to December at Puyallup, Wash for the year prior to the harvest season were inspected. The number and weight of drupelets for the second harvest season (1995) of the 1992 planting was different from the other two plantings. The weather during August to December 1994 may have influenced drupelet development. In all four years (1991-1994) the precipitation in September was below the 30-year average and the temperature was above average. However, the temperature

in September 1994 was 1.9° C above average, while all other years were 1° C or less above average. Another difference in 1994 was above average rainfall in October 1994, while in the other 3 years the precipitation was below average. It is not clear if, or how, increased precipitation in October would affect drupelet numbers. A warm fall may allow flower bud differentiation to continue longer in the fall. Above average temperatures in September may have allowed more drupelets to be formed.

The drupelet weight in the second harvest season was the same as the first harvest season for the planting established in 1992. In the other two plantings there were significant increases in drupelet weight. In June 1994, precipitation was below average and temperatures were above average. Since this is the time when the drupelets were rapidly expanding, this may result in drupelets not attaining their full potential size.

The range in the average fruit weight was from 2.33 g (WSU 1018) to 7.73 g (WSU 1040 and WSU 1045). The number of drupelets ranged from 53.8 (WSU 1021) to 140.8 (WSU 1066). The drupelet weight ranged from 28.2 mg (WSU 1018) to 87.2 (WSU 1041). The seed weight ranged from 1.36 mg (WSU 1018) to 2.64 mg (WSU 1024). The ratio of seed weight to drupelet weight ranged from 2.53% (WSU 1013) to 5.63% (WSU 1021). Generally fruit with large drupelets had a small ratio of seed weight to drupelet weight and those with small drupelets had large ratios. Although seeds did not make up a large proportion of the drupelet weight, there were differences among clones. If the fruit is being used to produce juice, small increases in extraction efficiency may be achieved by proper clone selection.

The data for the second harvest season for eight cultivars are given in Table 1. There were differences among cultivars in at least one planting for each trait except for average seed weight. 'Glen Ample' had relatively few, large drupelets, although smaller fruited 'Meeker' had many

more, small drupelets. Although small seeded, the ratio of seed weight to drupelet weight was larger for 'Meeker' than for other cultivars.

This study confirms the previous study (2), demonstrating variation among clones in drupelet number and drupelet weight. It should be possible to select for fruit that is composed of many small drupelets or few large drupelets. However, values for fruit weight and drupelet number and weight were not strongly correlated for a clone from one year to the next. This suggests that the number and weight of drupelets are affected by environmental conditions differently for each clone.

The fruit weight was larger in the second fruiting season than in the first in all three plantings. Generally, this was a result of changes in drupelet weight and there were no changes in drupelet number. However, for one planting the drupelet number increased from the first harvest season to the second, but no changes in drupelet weight.

This study and a previous study on year-to-year variation (3) indicate harvest data in one year are significantly correlated with data from the same plots in the next harvest season. For many of the characteristics measured in both studies, the correlation coefficient (r^2) was less than 0.5. This indicates that there is considerable year-to-year variability.

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