

Effect of Pruning System on Yield Components of Two Summer-bearing Raspberry Cultivars

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Abstract. Effects of annual pruning, alternate-year mowing, and primocane suppression on yield and its components for 'Titan' and 'Royalty' summer-bearing raspberries (Rubus idaeus and R. neglectus) were measured for 2 consecutive years. Cumulative yield was highest for primocane suppression and lowest for alternate-year mowing. Path analysis revealed that cane number per plant and number of fruitful laterals per cane were the most important yield components for both cultivars. Alternate-year mowing plots had higher cane numbers per plant than other treatments, but fewer fruitful laterals in the bottom and middle thirds of the canes. Annual primocane suppression increased numbers of fruitful laterals in the bottom and middle thirds of canes, resulting in increased yield compared to other treatments. Productivity was related to the amount of photosynthetically active radiation entering the canopy.

Pruning is one of the most important operations involved with raspberry culture, yet few studies have examined its effect on plant performance. As a result, raspberries are pruned without knowledge of the long-term yield response of a particular cultivar or the effect on plant vigor (3, 23). Identifying the effects of pruning on yield and its components should contribute to a basis upon which pruning recommendations can be rationalized. Light penetration, primocane interference with floricanes, labor costs, cane diseases, and long-term yield also should be considered in the development of any recommendation.

Raspberry pruning methods are being used in the Pacific Northwest and Scotland that show economic and cultural management benefits. These methods have not been examined to determine their adaptability to northeastern conditions and cultivars. One system involves alternate-year mowing. It is used currently in ~20% of the blackberry acreage in Oregon and is effective in reducing spraying and pruning costs (13). A second system, primocane suppression, is used widely in both Scotland and the Pacific Northwest to control excessive cane vigor (12), and its use is accompanied by increases in yield and berry size (3, 11, 23, 25). Neither system has been widely used in the eastern United States because of the short growing season and the lack of vigor in many cultivars.

We examined four different pruning systems under northeastern conditions over a 2-year period using two new and vigorous cultivars—Titan, a red raspberry, and Royalty, a purple raspberry. The objectives were to: a) determine the effect of cane manipulation on cane growth, yield, and its components, and b) identify relationships between raspberry primocanes and floricanes.

Materials and Methods

Description of cultivars. 'Titan' was released in 1985 from the Geneva Experiment Station breeding program, Geneva, N.Y. It is the largest-fruited red raspberry in the Northeast, with berries averaging 4 to 6 g. (20). 'Titan' has average vigor, and plants are easily maintained as stools because root suckering tends to be sparse. 'Royalty' is a hybrid purple raspberry released in 1982 and is considered one of the best purple raspberries for eastern conditions (19). In Geneva, fruit size of 'Royalty' rivals that of 'Titan', and is larger than the other commercially grown purple cultivars. Plants tend to have excessive vigor typically associated with such hybrid cultivars; however, suckering tends to be sparse.

Description of treatments. In all treatments, retained floricanes were topped at 1.1 m for 'Titan' and 1.2 m for 'Royalty' during the dormant season.

1) Conventional. The seven largest floricanes per plant were retained; all others were removed before budbreak. Canes were fruited annually, and primocane numbers were not controlled. Expended floricanes were removed shortly after harvest. This treatment was applied to the same plots in 1985 and 1986.

2) Primocane suppression. The seven largest floricanes per plant were retained; all others were removed before budbreak. When the first of the emerging primocanes reached a height of 15 cm, all primocanes were cut to the ground using hand shears. A second flush of primocane growth emerged and was allowed to fruit the following year. Expended floricanes were removed shortly after harvest. This treatment was applied to the same plots in 1985 and 1986.

3) Alternate-year-mowing. In early spring, all floricanes were mowed to the ground, thereby inducing a flush of primocane growth. The following year, all floricanes were allowed to fruit.

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Mowing treatments were applied in 1984 and 1985, and harvesting occurred in 1985 and 1986. Mowing treatments were applied to different plots in the 2 years.

4) Alternate-year mowing plus primocane suppression. Floricanes were mowed to the ground the first year and, in the second year, all floricanes were retained and the primocanes were suppressed when the tallest reached a height of = 15 cm. The mowing treatment was applied in 1985, and suppression occurred in 1986.

Experimental design. The factors in the split-block factorial design were primocane suppression and alternate-year mowing. The conventional pruning method and the primocane suppression treatment each had two replications of 10 plants per plot for both cultivars. The alternate-year mowing treatment had four replications of 10 plants per plot, two of which were applied in 1984 and the other two in 1985. The mowing treatment, which was coupled with primocane suppression, had three replications consisting of 10 plants each and was only applied to 'Royalty'.

The number of floricanes was recorded for each plant in each treatment for both cultivars in 1985 and 1986. Seven random canes per plant were taken and the number of laterals per cane counted. Five random canes were taken from each plant, and the number of flowers was determined on each of four random fruiting laterals per cane. In 1986, the canes were divided into lower, middle, and upper thirds, and the number of fruitful laterals in each third was counted on 10 random canes per plot. Flower number on each of five random fruiting laterals per third of cane was determined. The plots were harvested every 3 days, and cumulative yield and weight per 50 berries were recorded at each picking date in both 1985 and 1986. Twice during the season, plants were harvested individually, and the raspberries were counted and weighed to evaluate the variability between plants in a given plot.

Primocane height was monitored for the different pruning treatments by measuring five random primocanes per plot at several times during both growing seasons. Photosynthetically active radiation in the canopy was measured in conjunction with height determinations using a LI-COR light meter (model LI-185-B) equipped with a quantum sensor. These light readings were taken at 40, 80, and 120 cm above ground level at five random locations in each plot on 15 July 1985. The sensor was placed in a vertical orientation prior to each reading. In Sept. 1986, basal diameters of 15 random primocanes per plot were recorded. Leaf samples were taken from primocanes in all the plots on 11 Aug. 1986 and were analyzed for mineral nutrient concentrations.

Statistical analysis. Analysis of variance techniques appropriate for the split-block and factorial designs were used to test for differences among factors. Path analysis was used to determine both direct and indirect relationships among yield components and was used to rank the relative importance of the components in determining yield (27). Overall yield component compensation was measured with the "W" statistic, which can have a value between 0 and 1 (9). A system with W = 1.0 exhibits additivity among components, W = 0.5 indicates overall independence among the components of yield, while W = 0.0 shows complete compensation.

Results

Two-year cumulative yields were highest for both 'Titan' and 'Royalty' with primocane suppression (Fig. 1 and Table 1). The control treatment was more productive over the 2-year period than was the mowed treatment for both cultivars. Mowing coupled with primocane suppression resulted in the highest single season yield on 'Royalty', but 2-year cumulative yields were similar to those of the annually fruiting conventional system.

![Fig. 1](cumulative_2_year_yield_response_of_titan_and_royalty_raspberries_subjected_to_conventional_mowing_and_primocane-suppression_treatments.png)

Cane number per plant was highest for mowed treatments. Mowing reduced, while suppression increased, the number of fruitful laterals per cane. Flower number per fruitful lateral was reduced for mowed treatments and increased for primocane suppression treatments. Mowing reduced berry size, whereas suppression increased it for 'Titan'. No significant differences were found for maximum berry weight or the date of maximum harvest.

Mowing reduced the number of fruitful laterals in the bottom and middle thirds of the canes (Fig. 2). Suppression increased the number of laterals in the bottom and middle thirds, but reduced the number of laterals in the top third (Fig. 2 and Table 2).

Pruning treatments did not affect flower number per lateral on the bottom third of the canes (Fig. 3), but mowing tended to decrease the number of flowers per lateral in the middle third of the canes and increase the number of flowers per lateral in the top third, relative to controls. Suppression increased the number of flowers per lateral in the middle third on those plots that were not mowed (Table 2).

With both cultivars, path analysis revealed that cane number per plant had a positive direct effect on yield but had a negative effect on all other yield components (Figs. 4 and 5). Lateral number per cane and flower number per lateral were positively related to yield. With 'Titan', the number of flowers per lateral was positively related to berry weight. Berry weight for both cultivars had a positive direct effect on yield.

Primocanes emerging in plots that had been mowed generally grew more quickly than those emerging from other plots in the early season (Figs. 6 and 7). Plots that had been mowed the previous year (and therefore contained both fruiting and vege-
tative canes) appeared to have slow primocane growth initially, but had the tallest primocanes by the end of the growing season. Primocanes from the second flush of growth after suppression were shorter than those in other treatments, but appeared to have growth rates at least as high.

With both 'Royalty' and 'Titan', the percent of full sun entering the plots at three heights within the plant canopy on 15 July 1985 was highest with primocane suppression, whereas mowed plots allowed the lowest percentage of potential photosynthetically active radiation to enter (Figs. 8 and 9).

There were no significant differences in basal diameters of primocanes among the treatments. Tissue analysis did not reveal
Fig. 5. Diagrammatic representation of the interrelationships among yield components for 'Royalty' raspberry as determined from path analysis. Asterisk indicates significance at $\alpha = 0.05$; W indicates degree of independence among components.

Fig. 6. Growth of 'Titan' primocanes in 1986 under conventional, mowing, and suppression pruning treatments.

Discussion

Primocane emergence and growth occur simultaneously with floricane lateral elongation, anthesis, and fruit development. Because developmental processes of the vegetative and fruiting phases are not temporally separated, the possibility of competition within or among these phases exists. There is much evidence that suggests that competition occurs among yield components of fruit crops because of limiting resources; this results in negative relationships among components of yield (2, 7, 8, 15, 18). Resources that limit raspberry production have not been determined; however, several researchers have implicated light and assimilates as possible factors (21, 23, 26).
Fig. 7. Growth of 'Royalty' primocanes in 1986 under conventional, mowing, and suppression pruning treatments.

Fig. 8. Distribution of photosynthetically active radiation on 15 July 1986 within a 'Titan' raspberry canopy subjected to various pruning treatments.
The W values for both ‘Titan’ and ‘Royalty’ suggest that there was some degree of compensation among yield components, and a negative effect of cane number on all other yield components was observed. Primocane suppression may have reduced component compensation by increasing resource availability. This treatment resulted in significant yield enhancement through increases in number of fruitful laterals per cane and berry weight. In addition, primocane development was accelerated when fruiting canes were removed, and fruiting canes were more productive when primocanes were suppressed.

The penetration of light into the raspberry canopy was enhanced with primocane suppression and reduced with mowing relative to conventionally pruned plots. It is not known, however, if the associated yield response and primocane growth rates in our study were a direct result of light availability and interception. We have shown in another study (14), however, that a trellis design that improves canopy light interception is more productive than other systems.

Wright and Waister (26) noted that heavy self-shading with the conventional system is probably responsible for low yields, as primocane shading promotes leaf loss on the lower fruiting laterals, which then impedes flower and fruit development. A reduction in numbers of fruitful laterals toward the bottom of canes with the conventional system was observed in our study and has also been noted by other researchers (4, 6, 17). The distribution and numbers of flowers per lateral also could have been affected by shading and component compensation.

The various pruning treatments also could have influenced the distribution of assimilates between vegetative and fruiting phases or affected apical dominance. The removal of floricanes with the alternate-year mowing system may redirect resources so that primocane development is accelerated. Conversely, suppressing primocanes may divert more of the available resources to the floricanes. Brierley and Landon (1), however, suggested that little competition exists among primocanes and floricanes for photosynthate in raspberries. Whitney (24) proposed that competition for assimilates between phases is minimized by the spatial separation of their activities. Our study was not designed to measure competition between vegetative and fruiting canes directly, but does suggest that limited competition occurs among floricanes and components of yield.

The conventional system required selective removal of individual canes and annual disease and insect control measures while yields were moderate. Primocane suppression increased yields and berry size, consistent with the observations of other researchers using other cultivars at other locations (4, 10, 16). Primocane suppression still required the selective removal of individual canes, annual pest control, and the additional removal of young primocanes.

Alternate-year mowing did not require selective removal of canes, and pest control costs were reduced, since only half of the plots were fruiting in any given year. However, plots were only 89% as productive as the annual system with ‘Titan’ and 67% as productive with ‘Royalty’ over the 2-year period. Other studies have found cumulative yields with alternate-year mowing to be 85% of the annual system for blackberries and 70% for raspberries (13). Smith (unpublished data) compared alternate-year mowing to the conventional system for three raspberry cultivars over 2 years in New York State and found that mowing reduced yields 28%.

The increased yields observed with alternate-year mowing coupled with primocane suppression were probably the result of suppression offsetting some of the negative relationships among yield components that occurred when canes were mowed.
without suppression. Mowing plus suppression treatments had greater cane numbers than controls and an increase in the number of fruitful laterals in the bottom and middle thirds of the canes. These combined effects resulted in cumulative yields equal to those of annually pruned, conventionally pruned plots. Alternate-year mowing plus primocane suppression appears to be a feasible system, as it has the advantage of alternate-year mowing without the associated reduction in yield.

Several researchers have reported variable cultivar responses with vigor control treatments (4, 22), and others have observed that continuous primocane suppression will reduce the vigor of a planting (16). Significant genotype-environment interactions also have been measured (5). These observations provide researchers with additional questions to examine before an optimal system can be identified.

Literature Cited