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Effect of Floricane Number in 'Marion' Trailing Blackberry. II. Yield Components and Dry Mass Partitioning

Jessica M. Cortell[1] and Bernadine C. Strik[2]
Department of Horticulture, Oregon State University, 4017 ALS, Corvallis, OR 97331-7304

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ABSTRACT. In Spring 1993 and 1994, mature trailing 'Marion' blackberry (*Rubus* L. subgenus *Rubus* Watson) plants were pruned to 0, 4, 8, and 12 floricanes. In 1994, yield per cane was higher for plants with 4 floricanes compared to plants with 8 or 12 floricanes. In Summer 1993, there was a trend for lower primocane dry mass with a higher floricane number and a significant reduction in primocane branch dry mass with an increase in floricane number. Total plant, fruit, floricane, and lateral dry mass increased linearly with floricane number. Results were similar for floricane components in Summer 1994; however, there were no treatment effects on primocane or branch dry mass and there was a significant linear increase in crown dry mass with floricane number. By Winter 1994–95, there were no treatment effects on primocane or crown dry mass. Plants without floricanes produced more primocanes per plant than plants with floricanes in 1993 but not in 1994. Plants without floricanes produced primocanes that had a significantly lower percent budbreak the following year (1994) than plants with floricanes. Primocanes produced by plants without floricanes had more nodes per branch and a greater average branch cane length than those from plants with floricanes the previous season. The number of nodes per primocane tended to decrease with an increase in floricane number per plant in 1994 and 1995. There was no significant effect of floricane number per plant the previous season on fruit per lateral, fruit mass, or yield per plant the following season in either treatment year (1993 + 1994). However, in 1994, plants without floricanes the previous year had the lowest yield per cane. Topping primocanes at 30 cm in 1993 and 1994 had few significant effects on yield components the following season. Thus, 'Marion' blackberry can compensate for reduced fruiting cane number through an increased percent budbreak on remaining canes. While there were differences in primocane dry mass among treatments after harvest in 1993, there were no differences by mid-winter in either 1993 or 1994. Although plants grown without floricanes in 1993 had more primocanes, these canes had a lower percent budbreak the following season. Consequently, in this study we did not see increased yield in plants grown without floricanes the previous season. This was perhaps because primocanes were not trained as they grew, a practice that improves light exposure to the canes and may increase flower bud initiation.

'Marion' trailing blackberry (*Rubus* sp.) is the most important trailing blackberry cultivar grown for processing in Oregon, accounting for 50% of the hectarage (Strik, 1992). Two of the major production problems for 'Marion' are a low percent budbreak and relatively poor cold hardiness. Poor budbreak may be a result of many factors including winter injury, disease problems, poor light exposure, and intracane competition for resources. Alternative production systems in 'Marion' blackberry may improve cold hardiness and budbreak (Bell et al., 1992, 1995).

The most common system for caneberries is annual or every year (EY) production, where vegetative and reproductive canes grow simultaneously in the same canopy. Another system used commercially for 'Marion' is biennial or alternate year (AY) production, where there is a complete separation of the vegetative and reproductive phases. Summer training has been found to stimulate cane growth, improve light exposure, and provide a less favorable environment for disease pathogens compared to winter training, which is often done in EY production (Bell et al., 1995; Sheets and Kangas, 1970). Primocanes produced in the AY system are also more cold hardy (Cortell and Strik, 1997; Sheets, 1987).

Competition between vegetative and fruiting canes in *Rubus* has been studied most extensively in red raspberry using annual and biennial systems (Clark, 1984; Dale, 1989; Nehrbas and Pritts, 1988; Waister et al., 1977; Wright and Waister, 1982a, 1982b). However, different factors may play a role in the success of biennial production in trailing blackberries because they differ from red raspberry in growth habit and in the training system used.

This research was undertaken to develop a better understanding of the physiology of vegetative and reproductive cane growth and carbohydrate partitioning in 'Marion' blackberry. Differing levels of the reproductive sink were established by manipulating the number of floricanes per plant. The specific objectives of this study were to determine the effect of floricane number and primocane pruning on yield components in the same season, yield components in the following year, and dry mass partitioning. The effect of floricane number and primocane pruning on primocane growth and subsequent cold hardiness are presented in Cortell and Strik, 1997.

Materials and Methods

An 8-year-old planting of 'Marion' blackberry on a latourell loam soil at the North Willamette Research and Extension Center, Aurora, Oreg., was used. Plants were spaced 2.4 m within rows spaced 3.1 m apart. The trellis consisted of two horizontal wires at 1.2 and 1.5 m. Weed management, irrigation, and fertilization followed standard commercial practice. No primocane suppression was done on any treatments. In February 1993 and 1994, plants were pruned to establish treatments of 0, 4, 8, and 12 floricanes per plant. Excess canes on each plant were counted and removed at ground level. An additional treatment was included with 0 floricanes and early primocane pruning at 30 cm. The plants studied in 1993 had fruited in 1992, while plants used in 1994 did not fruit in 1993. Canes used for primocane measurements in the

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[1]Graduate student.
[2]Professor.

first year were trained to the trellis in February for yield component analysis the following season. The experimental design was completely randomized with five replications of three plants per plot.

Yield component analysis. On plants with 4, 8, and 12 floricanes, fruit harvest was from 7 July to 2 Aug. 1993 and from 27 June to 21 July 1994. Total yield per plant was measured at each picking date. A randomly selected 25-fruit sample was used to obtain average fruit mass per treatment on each harvest date. A weighted average was then calculated for the season.

After fruit harvest, floricanes were carefully unwrapped from the training wires. In 1993 and 1994, the year of the floricane number treatment, four floricanes were randomly selected from one plant in each plot for yield component analysis. The canes were divided into basal and middle sections of 150 cm each and an apical section of the remaining cane length. Branch canes were separated from the main cane. Cane diameter was measured 30 cm from the base of the main cane and on each branch cane. Yield component data collected on each of the main cane sections and on each branch cane included number of nodes, nodes with a lateral, nodes with a fruitful lateral, number of fruiting sites, and fruiting lateral and cane length. Yield component data also were collected the year after treatment establishment (1994 and 1995) to follow the primocanes through their complete life cycle. Six canes per treatment plant, including the pruned and unpruned plants grown without floricanes the previous season (0 floricane treatment), were randomly selected for yield component analysis in the second year. Yield data were collected as described previously.

Dry mass partitioning. On a separate plant in each treatment plot, fruit were weighed to obtain yield and a subsample was dried to a constant mass at 40 °C to determine dry mass. Immediately following fruit harvest, on 5 Aug. 1993 and 16 Aug. 1994, one plant per plot was destructively sampled and partitioned into floricanes, laterals, primocanes, primocane branches, and crown tissues. Samples were dried to constant mass at 40 °C. The dry mass of primocane and crown tissues also was determined on 24 Jan. 1994 and 18 Jan. 1995 by destructive sampling.

Statistical analysis. Yield per plant, yield per cane, percent fruitful budbreak, number of fruit per lateral, average lateral length, and internode length were calculated. In the first season, yield per cane was calculated using yield data and cane number in the original treatment (i.e., 4, 8, or 12 floricanes per plant). Yield per meter of cane was calculated in the second season using the previous season's final primocane length. The effect of year on yield components was determined using analysis of variance (SAS, Cary, N.C.). Treatment effects were analyzed by linear regression with contrasts used for comparisons of treatment means (SAS). A *t* test comparison was performed on the 0-floricane pruned and unpruned treatments. Relationships among yield components were investigated by correlation analysis.

Results and Discussion

Effect of floricane number on yield components in the year of floricane pruning. There was a significant year effect ($P = 0.0001$) on the number of nodes per cane, average cane length, and percent budbreak. There was a year × treatment interaction for number of nodes per cane ($P = 0.05$).

In 1993, percent budbreak decreased linearly with floricane number (Table 1). This demonstrates the ability of 'Marion' to compensate for the removal of fruiting canes through increased budbreak and agrees with findings by Bell et al. (1995) that 'Marion' has the ability to compensate for lost buds by increasing production at remaining nodes. This potential for increased budbreak could be related to the normally low budbreak, ≈41%, typically found in 'Marion' (Bell et al., 1995). In another study, primary bud removal in 'Marion' had no significant effect on yield per cane, showing that 'Marion' can compensate for primary bud damage (Strik et al., 1996). In red raspberry, Waister and Barritt (1980) found that 'Meeker' produced 68% of a normal crop with 50% of the buds removed, while Moore (1994) found no significant difference in yield between disbudded (all primary buds removed) and nondisbudded red raspberry plants. Compensation for low budbreak can occur through increased fruit mass (Gundersheim and Pritts, 1991) and number of fruit per lateral (Waister and Barritt, 1980) in red raspberry. Fernandez and Pritts (1996) suggest that these "plastic responses" are due to the capacity of red raspberry to store large amounts of carbohydrates in the roots and to shift carbon partitioning to various plant parts depending on the current situation. In our study, compensation for low cane number per plant was solely through increased budbreak; there were no treatment effects on average fruit mass (Table 2) or number of fruit per lateral (Table 1).

In 1993, the number of nodes per cane and cane length increased linearly with floricane number. However, other than percent budbreak, there were no variables affected by floricane number per plant in 1994 (Table 1). In 1993 and 1994, plants with more floricanes produced a greater yield (Table 2). However, in 1994, yield per cane declined at high floricane numbers (Table 2), indicating that compensation occurred through increased percent budbreak at the lower floricane numbers (Table 1). This could explain why plants with

Table 1. Effect of floricane number on total (main plus branch canes) and branch yield components in the year of floricane pruning.

Floricanes (no.)	Nodes/ cane (no.)	Budbreak (%)	Fruit/ lateral (no.)	Avg. lateral length (cm)	Avg. cane length (m)	Branches/ cane (no.)	Avg. branch length (m)
				1993			
4	37.4	50	5.49	32.5	2.32	0.3	0.54
8	62.0	43	5.53	38.9	3.87	1.1	0.69
12	63.4	40	5.23	35.6	3.55	0.9	0.74
r^2	0.18	0.12	0.02	0.02	0.13	0.01	0.06
Significance	***	**	NS	NS	**	NS	NS
				1994			
4	226.6	24	7.21	38.3	14.61	2.8	3.61
8	158.9	19	6.98	33.9	10.49	1.5	3.40
12	242.8	17	7.43	37.4	15.90	2.9	3.40
r^2	0	0.20	0	0.02	0.01	0.05	0
Significance	NS	***	NS	NS	NS	NS	NS

NS,**,***Nonsignificant or significant at $P < 0.01$ or 0.001, respectively.

Table 2. Effect of floricane number on yield during the year of floricane pruning.

Floricanes (no.)	Yield/ plant (kg)	Yield/ cane (kg)	Fruit mass avg. (g)	Fruit mass above[z] (g)	Fruit mass below[z] (g)
			1993		
4	1.7	0.42	4.01	3.63	4.16
8	4.7	0.59	4.58	4.32	4.79
12	6.9	0.57	4.60	4.30	4.88
r^2	0.63	0.01	0	0	0.02
Significance	**	NS	NS	NS	NS
			1994		
4	7.48	1.87	5.08	---	---
8	7.82	0.98	4.96	---	---
12	11.08	0.92	5.19	---	---
r^2	0.29	0.49	0.03	---	---
Significance	*	**	NS	---	---

[z]Fruit mass data were collected separately from above and below the lower training wire in 1993 to assess possible cold injury effects.

NS,*,**Nonsignificant or significant at $P < 0.05$ or 0.01, respectively.

different numbers of floricanes did not have significant differences in primocane growth (Cortell and Strik, 1997).

In 1993, all plants were affected by winter injury as evidenced by low yield, cane dieback, stunted laterals, and reduced fruit mass in the terminal cane sections. There were no significant treatment effects on fruit mass in either year, although fruit from the tips of canes (above the trellis wire) were of lower mass than those from the basal portion of canes in 1993 (Table 2). This type of damage in 'Marion' has been reported previously by Bell et al. (1992), who observed reduced, erratic budbreak along the canes in addition to stunted laterals. This may be a result of damage to the phloem and cambial tissues at the bud base, causing laterals to emerge and extend, then later to collapse under the demands of flowering and fruiting, which overwhelms the vascular system (Moore and Brown, 1971).

Dry mass partitioning. There was a significant year effect on the dry mass components in summer: crown ($P = 0.0001$), primocane ($P = 0.001$), floricane ($P = 0.0001$), lateral ($P = 0.0001$), fruit ($P = 0.0001$), and total ($P = 0.0001$) tissues. There was also a significant year × floricane number interaction for crown ($P = 0.004$), primocane ($P = 0.01$), floricane ($P = 0.0001$), lateral ($P = 0.004$), and total ($P = 0.0001$) dry mass. In Winter 1994 and 1995, there was a significant year effect on crown dry mass ($P = 0.004$).

In Summer 1993, there was a trend for greater primocane and branch dry mass in plants without floricanes (Fig. 1). This is similar to findings in red raspberry, where primocane dry mass in biennial plots exceeded that of annual plots throughout the season because of a greater number of canes (Waister and Wright, 1989). Total plant, fruit, floricane, and lateral dry mass showed a significant linear increase (data not shown) with floricane number (Fig. 1). Results were similar in Summer 1994 for floricane components.

However, in 1994, there were no treatment effects on primocane or branch dry mass and there was a significant increase (data not shown) in crown dry mass with a higher floricane number (Fig. 2). The lack of significant differences in primocane dry mass might be explained by the high variability in original cane number (data not shown) in the planting before experiment establishment. The positive correlation between crown and total dry mass suggests that plants with healthy crowns can produce more primocane dry mass regardless of the number of floricanes. By Winter 1994 and 1995, there were no treatment differences in primocane or crown dry mass (data not shown). This suggests that plants with floricanes have the ability to catch up after harvest (Table 3) (Cortell and Strik, 1997). Waister and Wright (1989) found that postharvest primocane growth in red raspberry could account for as much as 25% of the total dry mass at the end of the season. We found that postharvest primocane growth in 'Marion' accounted for an average of 47% and 34% of the total end-of-season dry mass in 1994 and 1995, respectively.

In our research, there did not appear to be a limit on total biomass that could be produced with up to 12 floricanes. Thus, 'Marion' appears sufficiently vigorous to support >12 canes/plant (5 canes/m) without decreased yield. In red raspberry, the minimum cane density required for maximum yield was found to be ≈15 canes/m in North America and Tasmania (Buszard, 1986; Clark, 1984; Crandall, 1980; Fejer, 1979; Orkney and Martin, 1980), while in Europe the optimal number has been found to be 8 to 12 canes/m (Dale, 1989; Wood, 1960).

Effect of floricane number on the following year's yield components. There was a significant year effect on yield ($P = 0.0001$), number of nodes per cane ($P = 0.0001$), average cane

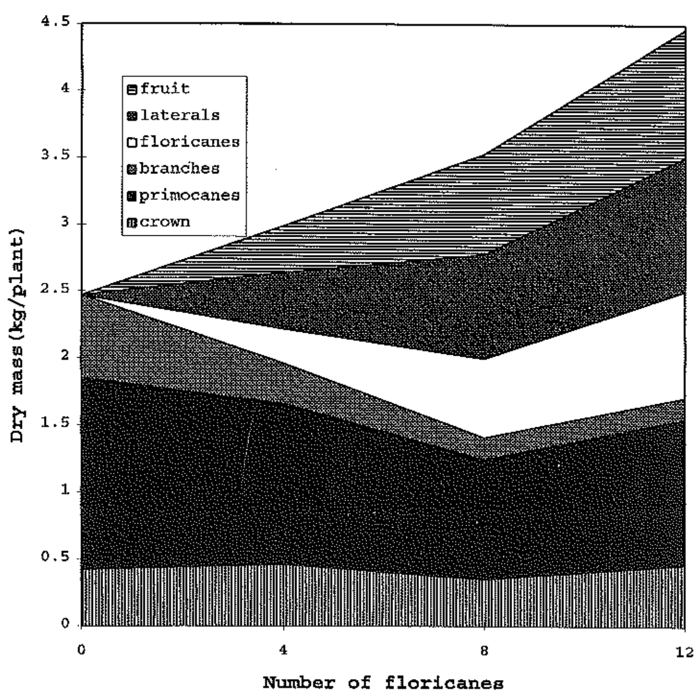

Fig. 1. Effect of floricane number on dry mass partitioning, 5 Aug. 1993.

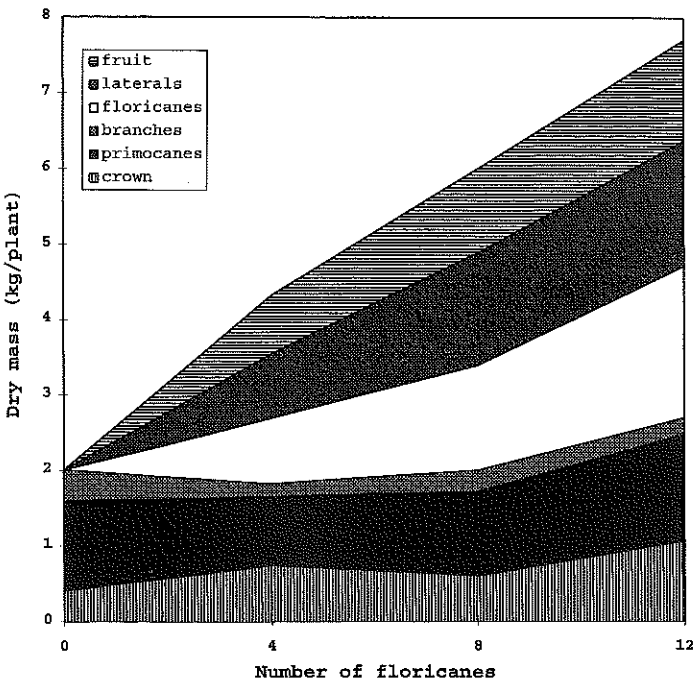

Fig. 2. Effect of floricane number on dry mass partitioning, 16 Aug. 1994.

length (P = 0.0002), and percent budbreak (P = 0.0001). There were significant year × treatment interactions for fruit mass (P = 0.02) and percent budbreak (P = 0.0002).

Plants without floricanes produced significantly more canes per plant than plants with floricanes in 1993, but not in 1994 (Table 3) (Cortell and Strik, 1997). Yield component data were collected on these canes during the season after treatment establishment to determine the effect of changing the reproductive sink in the previous season on subsequent yield. There was a significantly higher number of nodes per branch and a greater average branch cane length on plants without floricanes compared to plants with floricanes (Table 3). Primocanes produced by plants with 0 floricanes had a significantly lower percent budbreak the following year (1994) than those on plants with floricanes (Table 3) despite being more cold hardy (Cortell and Strik, 1997). There was a similar trend in 1995 (Table 3). A negative correlation was found between the number of nodes and budbreak in 1995 (r = –0.49; P = 0.03) and a similar trend in 1994 (r = –0.43; P = 0.06). As a result of this reduction in budbreak, there was no significant treatment effect on yield per plant in either 1994 or 1995 (Table 4). The low yield of the AY plants (0 floricanes the previous season) in this experiment was contrary to findings that 'Marion' generally produces 70% to 90% of the 2-year (EY) yield in the "on" year (Strik, 1992). In red raspberry, the biennial system was also found to produce a higher yield in the "on" year of AY production (Clark, 1984; Waister et al., 1977; Wright and Waister, 1982b). Wright and Waister (1982b) found an increase in the number of nodes as well as the number of nodes that produced fruitful laterals in biennial red raspberry production. In our study, plants without floricanes in 1993 had the lowest yield per cane in 1994 (Table 4). These results are in contrast to Wright and Waister's (1982b) findings of higher yield per cane with biennial production of red raspberry. In 1994–95, regression analysis showed no linear relationship between any yield components and the floricane number per plant the previous year.

In this study, the reduction in percent budbreak and low yield per cane in plants with no floricanes the previous year could have been from the poor light exposure and air flow resulting from February training. Plants are often February trained in EY production; however, in AY production, primocanes are generally trained onto the trellis as they grow, allowing for good light exposure to the buds. Sheets and Kangas (1970) found that canes trained by middle to late July had profuse lateral development resulting from stimulation of the axillary buds. Bell et al. (1995) found that August-trained plants had longer main canes, a higher percent budbreak, and a higher number of fruit per lateral than February-trained plants. This may explain why, in this study, AY production did not increase "on" year yield.

In relating the yield components to the previous season's

Table 3. Effect of floricane number on total (main cane plus branch) and branch cane yield components the following season.

Floricanes retained in 1993 or 1994 (no.)	Canes/ plant (no.)	Nodes/ cane (no.)	Budbreak (%)	Fruit/ lateral (no.)	Avg. cane length (m)	Branches/ cane (no.)	Nodes/ branch (no.)	Avg. branch cane length length (m)
				1994				
0	20.8	188.8	19	7.30	11.71	1.7	55.3	3.50
4	13.0	184.8	27	6.98	11.28	1.9	53.6	3.22
8	15.4	124.6	32	6.97	8.39	1.1	36.9	2.30
12	12.4	147.6	30	7.18	9.67	1.8	38.0	2.24
r^2	0.27	0.19	0.48	0	0	0	0.19	0.30
Significance	*	NS	***	NS	NS	NS	*	*
Contrast								
0 vs. others	**	NS	***	NS	NS	NS	*	*
				1995				
0	13.0	112.2	36	8.48	7.14	---	---	---
4	9.6	108.2	42	9.48	7.13	---	---	---
8	12.2	100.3	39	9.58	7.72	---	---	---
12	12.4	95.3	38	9.22	6.27	---	---	---
r^2	0.02	0.06	0.01	0.08	0.01	---	---	---
Significance	NS	NS	NS	NS	NS	---	---	---
Contrast								
0 vs. others	NS	NS	NS	NS	NS	---	---	---

NS,*,**,***Nonsignificant or significant at P < 0.05, 0.01, or 0.001, respectively.

Table 4. Effect of floricane number on the following season's yield.

Floricanes retained in 1993 or 1994 (no.)	Yield/plant (kg)	Yield/cane (kg)	Yield/meter (kg)	Fruit mass (g)
		1994		
0	17.08	0.84	0.13	5.44
4	15.09	1.19	0.12	5.10
8	18.16	1.18	0.11	5.31
12	14.52	1.27	0.08	5.27
r^2	0.05	0.29	0.29	0.02
Significance	NS	*	*	NS
Contrast				
0 vs. others	NS	**	**	NS
		1995		
0	9.17	0.70	0.10	4.18
4	10.28	1.10	0.16	4.65
8	11.93	1.08	0.14	4.44
12	9.97	0.89	0.14	4.59
r^2	0.04	0.04	0.12	0.11
Significance	NS	NS	NS	NS
Contrast				
0 vs. others	NS	NS	*	*

NS,*,**Nonsignificant or significant at $P < 0.05$ or 0.01, respectively.

primocane growth, there was a positive correlation between yield and primocane number ($r = 0.57$; $P = 0.008$) and length ($r = 0.56$; $P = 0.01$) in 1993–94. Percent budbreak was negatively correlated with number and length of primocanes ($r = -0.4$; $P = 0.03$ and $r = -0.68$; $P = 0.02$, respectively) and branches ($r = -0.68$; $P = 0.001$ and $r = -0.84$; $P = 0.0001$, respectively). In 1994–95, the number of nodes was positively correlated with primocane number ($r = 0.57$; $P = 0.008$), primocane length ($r = 0.56$; $P = 0.01$), branch length ($r = 0.53$; $P = 0.02$), and total length ($r = 0.80$; $P = 0.0001$). In our findings, there were no differences in primocane growth in 1994, possibly due to the existence of high variability in the planting prior to treatment establishment (Cortell and Strik, 1997). Thus, it is not surprising that there was no significant effect of floricane number on yield the following season (1995).

Some of the differences in response to biennial production in red raspberry and 'Marion' blackberry could be related to the trellis system used and the growth habit of the plants. For example, one of the benefits of biennial production in red raspberry is that the floricanes are not shaded by the primocanes, which has been shown to reduce yield in the basal cane section (Braun et al., 1989; Wright and Waister, 1984). However, in 'Marion', the primocanes grow along the ground and do not shade the floricanes. Consequently, any increases in yield occurring during the fruiting stage when plants are grown without primocanes would be more likely from reduced competition for resources rather than from shading. In 'Marion', the primocanes can benefit from the removal of floricanes because this reduces shading, thus creating a better light environment.

Effect of primocane pruning on yield components. Topping primocanes at 30 cm in 1993 had no significant effect on yield components the following season (data not shown). The only variable significantly affected by pruning in 1994 was fruit per lateral, with the primocane pruning treatment having fewer fruit per lateral. There were no significant treatment effects on yield or fruit mass in 1994 or 1995 (data not shown).

Primocane pruning had relatively little effect on yield components the following season because plants with no floricanes and without pruning also had increased branching over plants with floricanes. The improved light conditions or carbohydrate availability for primocane growth in the AY plants (0 floricanes, without pruning) may have stimulated branching. Sheets and Kangas (1970) observed that axillary branching increased with good light conditions from August primocane training. The lack of differences in the pruned and unpruned treatment suggest that 'Marion' blackberry can be stimulated to produce lateral branch canes in response to more than one factor. Although primocane pruning is a successful practice in erect and semi-erect blackberry cultivars (Moore and Skirvin, 1990), pruning 'Marion' to 30 cm in our study did not look promising.

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