Effects of shortening the lateral canes on yield components in ‘Triple Crown’ blackberry trained to the rotating cross-arm trellis system

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Effects of shortening the lateral canes on yield components in ‘Triple Crown’ blackberry trained to the rotating cross-arm trellis system

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Abstract. Three primocanes of mature ‘Triple Crown’ blackberry plants were trained on the rotating cross-arm trellis (RCA) trellis. By the end of the summer, as many as 30 lateral canes with lengths >3.5 m had developed on 3 primocanes that had been bent at a 0.50-m height and allowed to extend ~1.5 m in a horizontal orientation. In winter, the lateral canes were pruned back to 1.5 m lengths or left un-pruned. Data on cane length, percent budbreak, cluster numbers, fruit per cluster, fruit weight, and yield were collected in 2012 and 2013. Our findings showed that pruning of 3-m-long lateral canes to 1.5 m

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increased % budbreak, the number of clusters/m cane length and flower numbers/cluster,
but had no effect on fruit size or yield.

‘Triple Crown’ and other semi-erect and erect florican-fruiting (both thorny and
thornless) blackberries (*Rubus* subgenus *Rubus*) are productive and vigorous. The yield of
blackberries is dependent on the number of nodes (buds) left on the floricanes after winter
pruning. Reducing the florican number and shortening the lateral canes by summer or winter
pruning has been shown to decrease yields (Moore and Skirvin, 1990; Swartz et al., 1984).
Much of the commercial acreage of erect and semi-erect blackberries is on “T”-shaped
hedgerows and on divided canopy trellis systems (Swartz et al., 1984) in which the primocanes
are generally trained upright and later tipped or pruned to a height of 1.2- to 1.8-m tall with a few
lateral canes on each primocanes pruned back to 0.30- to 0.50-m lengths. Takeda (2002) trained
3 primocanes of mature ‘Black Satin’ blackberry plants on a wide “V” trellis, in which the posts
were set at 45° from the horizontal and the canes were topped at a 2.8-m height in summer to
promote lateral cane development. In winter, the lateral canes were pruned leaving 3 to 12 12-
ode lateral canes which resulted in plants with the total bud numbers ranging from less than 100
to about 500 buds. In that range of buds per plant, the yield increased linearly ~0.5 kg/lateral
cane or with increasing numbers of lateral canes from 10 kg/plant for plants with 3 lateral
canes/florican to 21 kg/plant for floricanes with 12 lateral canes. Pruning level did not affect
fruit weight, or TSS, but fruit number/cluster and fruit weight/cluster decreased with increasing
numbers of lateral canes on the florican. The results indicated that pruning can affect the
fruitfulness of nodes and raceme size (number of flowers or fruit).
In the Midwest, more than 100 ha of new blackberry plantings have been established since 2010 with the rotating cross-arm (RCA) trellis and cane training system (Fig. 1). The RCA trellis system is a modified “Y”-shaped trellis in which both the long and short arms can be rotated independently (Takeda and Peterson, 1999; Takeda et. al., 2003a; 2003b; Takeda and Phillips, 2011) and the blackberry plants can be trained to form a narrow or curtain-like canopy. Once the curtain of lateral canes is formed, the hinged cross-arms can be rotated to alter the orientation of lateral canes from more or less vertical in the summer to horizontal in winter. When the canopy is close to the ground, a rowcover can be applied over the plants to provide winter protection (Takeda et al., 2008; Takeda and Phillips, 2011). In spring, >95% of flowering shoots develop upward so that when the cross arms are again rotated up beyond vertical the fruiting shoots are positioned on one side of the canopy which contributes to increased harvest efficiency and protection from intense sunlight (Takeda et al., 2013). The rotation of long cross-arms beyond vertical also allows workers access to the new primocanes that are emerging from the crown for tying them to the training wire under the short cross arm.

The design features of the RCA trellis are similar to the shift trellis described by Stiles (1995). By securing the canes on the long, rotatable cross arms, the entire curtain of lateral canes can be easily rotated. The method of cane training for the shift trellis as described by Stiles (1995; 1999) has proven to be unsuitable for canopy rotation of erect and vigorous blackberry cultivars because their canes are large (> 2-cm diam.) and too stiff to bend once they become woody in late summer (Krewer et al., 2006), and it causes excessive cane breakage during trellis shifting in winter (Brubaker, 2014). In contrast, the cane training procedure for the RCA trellis system (Takeda and Peterson, 1999, Takeda and Philips, 2011; Takeda et. al., 2003a; 2003b) is unique in that the primocanes are trained to grow horizontally once they reach a height of 50 cm
(Fig. 2) when they are still flexible. The horizontally-growing primocanes are soft-tipped as they reach the adjacent plant ~1.5 m away, stimulating as many as 10 lateral canes to develop from the axillary buds along the horizontal portion of each primocane (Fig. 2). These lateral canes can be tied to one or more wires on the long cross arms to form a curtain of vegetative canes creating a canopy surface area > 6.5 m²/plant with a thickness of ≤ 0.2 m or less. Many of the lateral canes of ‘Triple Crown’ can grow beyond the top wire of the RCA trellis and extend downward reaching a length of > 3 m (Fig. 3) with >50 nodes. The recommendation to growers using the RCA trellis and cane training system has been to prune these long lateral canes at the top wire on the long cross-arm.

In the conventional hedge-row system (Demchak, 2013), winter pruning retains four to five floricanes/plant and topped at 1.8-m height, each having 5 ~0.50 m lateral canes. With this pruning/training technique, ~ 300 potential reproductive buds are present. In the RCA production system, three primocanes are secured to the training wire and 25 or more lateral canes are pruned to 1.5-m length, which results in ~1,000 potential reproductive buds on each plant. If the lateral canes are not pruned to 1.5 m length, each plant will have >1,500 buds without creating a shading problem. Although fewer primocanes per plant are retained and plants are established further apart in the row in the RCA system than in the conventional hedge row system, yields (kg/ha) of ‘Triple Crown’ and ‘Apache’ have been similar to the plants established in conventional planting systems (Takeda and Peterson, 1999). Understanding the effects of pruning on the fruitfulness of nodes is important in growing blackberries on the RCA trellis and cane training system (Takeda et al., 2003a; 2003b). The objective of this study was to determine the effects of not shortening the lateral canes to 1.5 m on budbreak, flower/fruit cluster
development, and productivity of ‘Triple Crown’ blackberry plants trained on the RCA trellis system.

**Materials and Methods**

Nursery-mature plants were established in Spring 2001 on raised beds covered with black landscape fabric at the Appalachian Fruit Research Station, WV (lat. 39.5° N, 177 m elevation, USDA Plant Hardiness Zone 6b). Plot maintenance and pest control followed the established bramble production guidelines for the region (Demchak, 2013). A RCA trellis was installed in Fall 2001. The description of the RCA trellis and the sequence of the primocane training and positioning of the cross arms are reported elsewhere (Takeda et al., 2003a; 2003b). In Summer 2011, eight plants ‘Triple Crown’ arranged in four blocks were selected to examine the comparative productivity of long lateral canes versus laterals canes pruned at the top wire on the RCA trellis (control) (Fig. 1). In 2012, each plant was hand harvested four times on Jul 12, 16, 19, and 26 to determine the total yield per plant, average number of berries harvested, and average berry weight. Following the final harvest, five laterals were removed from the first replication of plants to determine total nodes per cane, percent budbreak, percent nodes to become reproductive, flower numbers per cluster, and cluster length. The node of each cluster was recorded to be able to compare reproductive capacity between different areas of the lateral.

In Fall 2012, 30 plants of ‘Triple Crown’ blackberry were designated for yield determination in 2013. Plants were divided into 3 10-plant blocks where five consecutive plants were randomly assigned either as control plants in which all lateral canes were pruned to ~ 1.5 m length, or no pruning of lateral canes. Pruning treatment was a fixed effect and the 10-plant blocks were random effects. In July 2013, one plant in each replicate plot was randomly chosen and all lateral canes and spurred lateral canes were counted as well as all clusters. In addition,
the plant sampled in the first replicate was measured for length, along with any tertiary canes branching from them, in order to determine linear lateral cane length. The total node number, percent budbreak, and percent reproductive nodes was recorded for each spurred and lateral cane. The node location of every cluster on each of the lateral canes was recorded as well as the number of flowers on all the clusters to compare reproductive capacity between different sections (10-node increments) of the 1.5-m and ~ 3.0-m lateral canes. Also, four to eight lateral canes on each plant were spurred (e.g. pruned to 4 ~ 5 nodes in mid-October 2012). Data on bud break, flower shoots/spur, flower number/shoot, and flower shoot length from the spurred lateral canes were compared to those collected from the basal 5 nodes of 1.5-m-long and unpruned lateral canes. All data were subjected to analysis of variance, with all percentage values transformed by an arcsin square root transformation prior to analysis. All data were separated either by t-test or DIFF option using SAS PROC MIXED at P-value of 0.05 (SAS Institute, 2010).

**Results and Discussion**

Lateral cane length and reproductive development in response to pruning was measured in ‘Triple Crown’ blackberry trained on the RCA trellis system during the 2011-2012 and 2012-2013 growing cycles. In both years, lateral cane number per primocane averaged about 8. The lateral canes grew ~ 3 m, with 48 nodes in 2011 and 56 nodes in 2012 (Fig. 2 and Table 1), resulting in linear cane length of ~ 70 m from the three trained primocanes on each plant. Pruning the lateral canes to 1.5 m length removed the distal portion of each lateral cane with the 28 and 38 most proximal nodes of the lateral canes retained for fruit production in 2012 and 2013, respectively.
In 2012, pruned and unpruned plants averaged 70 m and 36 m of cane length, but produced an identical yield of 6.8 kg/plant ($P = 0.976$). They averaged 1,056 and 1032 berries per plant ($P = 0.877$), respectively. Mean single fruit weight was 5.8 g in pruned plants and 5.5 g in unpruned plants, but this difference was not significant ($P = 0.114$). Pruning lateral canes to ~1.5 m length decreased the total lateral cane length by about 40%, but increased the percentage of axillary shoots that developed a fruit cluster by 34% from 32% of nodes on unpruned lateral canes to 68% on pruned lateral canes (Table 1). Total clusters measured for control and long fruiting were 325 and 340, respectively. Pruning lateral canes to 1.5 m also increased the number of flowers on each inflorescence (Table 2). Flower number per inflorescence (cluster) was about 1 to 2 greater on pruned lateral canes (Table 3).

Flower shoots developed from <50% of axillary buds on lateral canes of ‘Triple Crown’ that were 1.5-m or longer, although budbreak (e.g. green shoots emerged from axillary bud) occurred on ~ 70% of axillary buds. In a study with ‘Black Satin’ blackberry (Takeda, 2002), in which as many as 12 lateral canes were pruned back to 12 nodes, flower shoots developed on >75% of axillary buds. A considerable decrease in flower shoot density (no. shoots/m lateral cane length) in longer lateral canes suggests that the pruning method described in this study may be leaving excessive numbers of lateral canes. The placement of as many as 25 lateral canes about 4 to 5 cm apart on the RCA trellis, oriented similarly to form a curtain, may be creating excessive shading of axillary buds (Fig. 2) and could prevent the axillary buds from transitioning into a reproductive bud, which occurs in fall and spring (Takeda et al., 2003c). Until the floricanes are removed after fruit harvest in August, the axillary buds are shaded by the dense canopy of leaves on primocanes on one side of the canopy and by the leaves subtending the fruit clusters on the other side.
Severe pruning had a profound effect on the fruitfulness of the remaining nodes (Table 4). When a few of lateral canes were shortened to 4- to 5-nodes-long, a higher percentage of buds broke (~80% vs. ~10%), the flower shoots were longer, and flower shoots had more flowers compared to the most proximal 5-node section of unpruned lateral canes. These findings agree with the results of a previous study in which pruning levels were established with a range of shortened lateral canes on floricanes trained on a V-shaped trellis (Takeda, 2002). Reducing the number of potential reproductive buds either by shortening the lateral canes or by the number of lateral canes clearly promotes the development of more vigorous flower shoots with a larger inflorescence.

The process of rotating the plant canopy developed by the cane training method (Takeda and Peterson, 1999) causes no cane breakage and can be achieved with little force applied on the trellis cross arms. In commercial fields with ~100-m-long rows (15 trellis posts), after all the detent pins are pulled from the trellis assembly and the first 2 cross-arms at one end of the row are pushed over vertical and toward the ground, the remaining cross arms can be pushed over one by one to lay horizontal in < 5 min (Trellis Growing Systems, personal communication). In spring, at least 3 cross arms must be lifted and rotated beyond vertical to rotate the remaining cross-arms in the row to harvest position. The rotation of a blackberry canopy on the RCA trellis is feasible, without much force or causing cane breakage, because it occurs at the bend points on the 3 main canes which are being twisted only slightly and shifted compared to other systems in which canopy rotation is only possible by a physical bending of the main canes with a wide arc or radius.

The cane-bending technique used for the RCA trellis system to promote lateral cane numbers and development has worked satisfactorily for trailing (‘Siskiyou’), semi-erect (‘Triple
Crown’ and ‘Chester Thornless’), and erect cultivars (‘Apache’, ‘Natchez’, and ‘Ouachita’). The first three primocanes to emerge from the crowns of these cultivars have the capacity to produce as many as 10 2.5-m-long lateral canes/m row length. This growth characteristic is highly desirable when adapting blackberries to the RCA trellis and cane training system. The exception are cultivars that have primocanes that are too stiff for bending (e.g. ‘Arapaho’) or those that do not develop lateral canes beyond the bend point (e.g. ‘Black Diamond’ and ‘Navaho’).

The ability to lay the canes close to the ground and apply rowcover to reduce winter injury in blackberries has stimulated the use of the RCA trellis to establish new, commercial plantings. The RCA system has been widely adopted in the Midwest, where this crop has not been grown extensively in the past, due to extreme winter conditions that either kill floricanes or cause significant loss in yield. When the canes are placed close to the ground and covered with a floating rowcover in winter, cane damage can be reduced significantly (Takeda and Phillips, 2011). In 2014, many parts of Ohio experienced a winter in which the temperatures dropped to as low as -28 °C on several days. Controlled laboratory freezing studies in January showed that many semi-erect and erect blackberry cultivars had LT50 values of -24 °C for canes and -20 °C for axillary buds (Hummer et al., 1995; Warmund et al., 1992). However, in Ohio, ‘Triple Crown’, ‘Apache’, and ‘Ouachita’ plants on the RCA trellis that had been covered with rowcover produced 50 to 80% of normal crop whereas the productivity of plants on the conventional hedge row system was only 10% (B. Bergefur, personal communication).

A number of growers using the RCA trellis system are leaving the long lateral canes unpruned with the expectation of increasing yield (Trellis Growing Systems, personal communication). The results of this study suggest that productivity cannot be increased by retaining lateral cane growth beyond the last training wire. This study as well as several
previous studies (Takeda, 2002) showed that with an increase in the number and length of lateral canes, there is a trend for a decrease in percentage of the axillary buds that develop into flower shoots and fewer flowers developing on the shoot. Training more primocanes is not recommended. Takeda et al. (2003a; 2003b) showed that retaining more than three primocanes increased yield little because additional primocanes produced few or no lateral canes. The present study provided additional information on the relationship of vegetative growth, pruning, and yield in blackberries trained to the RCA trellis system and possible mechanism of yield compensation at the whole plant level. These findings should be valuable to users of the RCA trellis and cane training system.
Literature Cited


Fig. 1. A schematic drawing of the commercial version of the rotating cross-arm (RCA) trellis. The trellis post and cross-arms are constructed of fiberglass reinforced plastic components manufactured by the pultrusion process (Trellis Growing Systems, Fort Wayne, IN). A) The RCA trellis consists of a post (~50 cm) (a) which has two plates (b) attached at the top. A long (c) and a short (d) cross-arm is secured between the two plates with detent pins. Two cane training wires (e1 and e2) are threaded through holes in the plates. Additional trellis wires (f) are threaded through both long and short cross-arms and secured to end trellis assembly arms. The wires in the foreground are connected to a wooden tie-back post (g). Three primocanes are placed on the training wire below the short cross-arm (e1). In winter these three canes are pushed over to the training wire under the long cross-arm (e2). The lateral canes that develop from the three bent primocanes are secured to wires (f) on the long cross-arm. The wire on the short arm (d) catches the lateral canes that extend away from the long arm.
Fig. 2. Primocane development on the Rotating Cross-Arm (RCA) trellis and cane training system in June. Left: Up to three primocanes are trained. Note the bending of primocanes (far left and right) and lateral canes emerging from the horizontal portion of bent primocanes. Right: An end view of blackberry plants trained on the RCA trellis in late August. Note the lateral canes have grown over the top wire on the long cross-arm and down toward the ground reaching lengths > 3 m.
Fig. 3. Percentage of nodes to be reproductive for a given linear section of nodes from proximal to most distal in relation to the horizontally-oriented primocane in 2012 (A) and 2013 (B) for pruned (■) and unpruned (□) lateral canes.
Table 1. The influence of pruning long canes of ‘Triple Crown’ blackberry on nodes per cane, percent budbreak, and the percent of nodes to become reproductive in 2012 and 2013.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Nodes per cane (no.)</th>
<th>Bud Break (%)&lt;sup&gt;z&lt;/sup&gt;</th>
<th>Reproductive Nodes (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pruned</td>
<td>29 b&lt;sup&gt;y&lt;/sup&gt;</td>
<td>38 b</td>
<td>86 a</td>
</tr>
<tr>
<td>Unpruned</td>
<td>48 a</td>
<td>56 a</td>
<td>90 a</td>
</tr>
</tbody>
</table>

P > F

<table>
<thead>
<tr>
<th>Treatment</th>
<th>2012</th>
<th>2013</th>
<th>2012</th>
<th>2013</th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>0.0030</td>
<td>0.0019</td>
<td>0.5342</td>
<td>0.1608</td>
<td>0.0104</td>
<td>0.0039</td>
</tr>
</tbody>
</table>

<sup>z</sup> Percentage values were transformed using ARSIN(SQRT(X)) transformation in PROC MIXED prior to analysis.

<sup>y</sup> Values in columns followed by the same letter are not significant at $P \leq 0.05$. 


Table 2. The influence of pruning long canes of ‘Triple Crown’ blackberry on the number of flowers per cluster and cluster length in 2012 and 2013.

<table>
<thead>
<tr>
<th></th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Flowers/cluster (no.)</td>
<td>Cluster Length (cm)</td>
</tr>
<tr>
<td>Pruned</td>
<td>8.1 a^2</td>
<td>38.3 a</td>
</tr>
<tr>
<td>Unpruned</td>
<td>7.1 a</td>
<td>38.4 a</td>
</tr>
</tbody>
</table>

P > F

Treatment 0.1266 0.9233 <0.0001 <0.0001

^Z Values in columns followed by the same letter are not significant at P ≤ 0.05.
Table 3. Number of flowers on inflorescence located along the length of lateral canes.

Inflorescences were grouped by an increment of 10 nodes from the most proximal to the most distal node.

<table>
<thead>
<tr>
<th>Node range (no.)</th>
<th>1 - 10</th>
<th>11 - 20</th>
<th>21 - 30</th>
<th>31 - 40</th>
<th>41 - 50</th>
<th>51 and beyond</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pruned</td>
<td>8.8 a$^z$</td>
<td>8.4 a</td>
<td>8.9 a</td>
<td>10.2 a</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Unpruned</td>
<td>8.4 a</td>
<td>7.0 b</td>
<td>7.0 b</td>
<td>6.2 b</td>
<td>7.3</td>
<td>8.7</td>
</tr>
</tbody>
</table>

P > F

| Treatment | 0.435 | 0.005 | 0.002 | 0.018 | _ | _ |

$^z$Values in columns followed by the same letter are not significant at $P \leq 0.05$. 


Table 4. The effect of pruning long lateral canes of ‘Triple Crown’ blackberry to four to five nodes (e.g. “spurred”) on percentage of nodes with flower shoots, and number of flowers and length of flower shoots. Data are comparisons of the development occurring on spurred lateral canes with 4 to 5 nodes and on the 5 proximal nodes on long laterals (either unpruned or pruned to 1.5 m) adjacent to the spurred canes.

<table>
<thead>
<tr>
<th>Nodes with fruit</th>
<th>(%)</th>
<th>No. flowers/cluster</th>
<th>Length (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-node-spur among 1.5-m-long laterals</td>
<td>76.0 a</td>
<td>18.2 a</td>
<td>54.2 a</td>
</tr>
<tr>
<td>Basal 5 nodes of 1.5-long laterals</td>
<td>11.1 b</td>
<td>9.9 b</td>
<td>41.4 b</td>
</tr>
<tr>
<td>4-node-spur among unpruned laterals</td>
<td>85.2 a</td>
<td>8.9 b</td>
<td>48.5 a</td>
</tr>
<tr>
<td>Basal 5 nodes of unpruned laterals</td>
<td>8.8 b</td>
<td>12.9 b</td>
<td>57.3 a</td>
</tr>
</tbody>
</table>

*Z* Means separated by DIFF option in SAS PROC MIXED. Values in columns followed by the same letter are not significant at $P \leq 0.05$. 