Improving the Efficacy of Cytokinin Applications for Stimulation of Lateral Branch Development in Young Sweet Cherry Trees in the Orchard

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Abstract. Improving lateral branch development in young sweet cherry trees without reliance on pruning is a desirable component of tree training programs, especially for high-density systems. Applications of two proprietary formulations of 6-benzyladenine and gibberellins A₄ and A₇ (Promalin, Valent Biosciences, Walnut Creek, Calif.; and Perlan, Fine Americas, Walnut Creek, Calif.) to individual buds or intact bark of unpruned sweet cherry central leader shoots at green-tip had little effect on lateral shoot growth from buds or on distribution of new shoot growth along the treated leader shoots. Scoring, nicking, or notching cuts alone also had inconsistent effects on shoot development and distribution. In some trials, bud removal (or disbudding, removing every fourth bud on 1-year-old shoots) produced limited improvement of lateral shoot development and vertical distribution. Combining nicking, notching, scoring, or bark scraping with the application of cytokinin–gibberellic acid solution to the cut area greatly improved both number of shoots developed and the numbers originating from the lower portions of treated leader shoots. Removing the physical barrier to bioregulator product contact with active tissues was a primary factor in improving treatment efficacy.

Sweet cherry trees exhibit strong apical dominance, producing vigorous, upright shoot growth with limited lateral branching, particularly in young trees (Elfving and Visser, 2006; Jacyna, 2002; Jacyna and Puchala, 2004; Jacyna et al., 2005; Miller, 1983). The interaction of endogenous auxins and cytokinins is thought to play a role in the control by apical dominance of lateral bud activity in the spring and during shoot development (Sachs and Thimann, 1967; Theron et al., 1987; Wickson and Thimann, 1958). Pruning can interrupt the hormonally based apical dominance control system and encourage buds that otherwise might remain quiescent to form shoots. For this reason, commonly used training systems for sweet cherries rely on pruning as a principal means for stimulation of lateral branching during canopy development (Long, 2001, 2005; Long et al., 2005; Nugent et al., 2001).

However, pruning removes buds that might otherwise have developed into shoots or spurs and delays cropping (Elfving, 1990; Robinson et al., 2005). Therefore, alternative means for stimulation of bud growth have been examined in apple and, to a lesser extent, in sweet cherry. Scoring (a circumferential knife cut through the phloem tissue around a shoot or stem) and notching (removal of a small piece of phloem above a bud) have been used to interfere with hormone movement and to promote shoot development in apple (Cook and Strydom, 2000; Greene and Autio, 1994; Greene and Miller, 1988; Niu et al., 1998; Ouellette et al., 1996). Bud removal (disbudding) can affect and may improve shoot growth in apple and other tree fruit species (Mika et al., 1983; Peano et al., 2005), and may show promise for shoot growth stimulation in sweet cherry as well (Perry, 1999; Robinson et al., 2005). Very limited information suggests scoring or notching in the spring may positively affect lateral shoot development in sweet cherry (Long, 2005; Long et al., 2005).

Proprietary mixtures containing the cytokinin 6-benzyladenine (BA) and gibberellic acid isomers GA₄₊₇ [Promalin (PR) or Perlan (PER)] can induce sylleptic shoot formation on the current season's shoots when applied during active shoot growth in both apple and cherry (Cody et al., 1985a,b; Elfving and Visser, 2005, 2006; Hrotko et al., 1999; Jacyna, 2002; Neri et al., 2003; Wustenberg and Keulemans, 1999), but few

reports document the efficacy of such products for inducing shoot development from preexisting buds on 1-year-old or older wood in sweet cherry. Miller (1983) and Veinbrants and Miller (1981) reported that painting PR onto the entire surface of 1-year-old shoots of young sweet cherry trees produced some stimulation of branch development from lateral buds. Jacyna and Puchala (2004) and Jacyna et al. (1989) reported improvement in branch development and in shoot distribution when BA combined with GA₃ or GA₄₊₇ was painted on the lower two-thirds of 'Regina' sweet cherry branches or the central 30 cm of 'Bing' 1-year-old branches. Jacyna and Brown (1989a,b) briefly described the use of PR for one system of training young sweet cherry canopies.

Interrupting apical dominance by disrupting or altering hormonal movement to buds should lead to both increased number of lateral shoots as well as an improved spatial distribution of those shoots along the main stems or leaders on which they are borne (Jacyna and Puchala, 2004; Robinson et al., 2005). Sweet cherry growers in Washington state have reported variable results on branching from the application of cytokinin-containing products such as PR at high concentrations to individual buds at or near spring budbreak or the treatment of sweet cherry 1-year-old wood by scoring or notching above buds. The research described here was undertaken to explore in greater detail the shoot growth responses of young sweet cherry trees under Washington state conditions in terms of both shoot numbers and shoot distribution to alternative shoot-inducing treatments including scoring, nicking (a small cut with a sharp knife into the phloem without regard to location relative to a bud) or notching, or cytokinin applications for improvement of canopy development. Bud removal was also evaluated in some trials.

Materials and Methods

Seven experiments were conducted between 2003 and 2005. All trials used randomized complete block designs with five single-tree replications per treatment. Proprietary formulations of BA plus GA₄₊₇ [Promalin (or PR), Valent BioSciences, Walnut Creek, Calif.; or Perlan (or PER), Fine Americas, Inc., Walnut Creek, Calif.] were used in the trials. Bioregulator treatments were combined with 50% v/v interior white latex paint and applied by hand with a small paintbrush. Bioregulator concentrations are expressed in terms of the active ingredients.

Scoring cuts were made circumferentially around the 1-year-old wood to the cambium layer with a sharp knife. Notching cuts were made by hand directly above buds with a small jigsaw blade; nicking cuts were made with a small knife without regard to bud location, making a cut into the phloem tissue to or near the cambium. Bud removal was accomplished by removing every fourth bud by hand, counting from the terminal bud and proceeding to the point of junction of 1- and

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Fig. 1. Expt. 7, 2005. (A) Lateral shoot growth from unpruned leader shoot of second-leaf 'Skeena'/Mazzard sweet cherry tree. Note the strong apical dominance effect on lateral shoot location and development. (B, C) Sand epidermis plus paint PER (5000 mg-L⁻¹) on sanded area (spring, B); note absence of shoot growth response (C). (D, E) Scrape epidermis plus paint PER 5000 mg-L⁻¹ on scraped area (spring, D); note strong shoot growth and distribution response (E). (F, G) Nicking cuts plus paint PER 5000 mg-L⁻¹ on nicking cuts (spring, F); note strong shoot growth and distribution response (G).

2-year-old wood. Treatments were made at green-tip each year (with green-tip defined as when a majority of the buds on 1-year-old wood was showing a point of green tissue at the distal end of the bud).

Expt. 1, 2003, Chelan Falls, Washington. Scoring cuts (a cut every 30 cm starting 30 cm below the terminal bud and repeated to the base of the 1-year-old shoot), notching cuts (cut a slot to the cambium above every fifth bud with a 0.8-mm-thick jigsaw blade, count-

ing from the terminal bud to the base of the 1-year-old shoot), or bud removal were applied to a single, vertical, unpruned 1-year-old leader shoot per tree in separate second-leaf 'Bing'/Mazzard sweet cherry trees. Control trees were untreated (four treatments in total). Treatments were made at green-tip (21 Mar. 2003). After shoot growth was completed, the now second-leaf vertical leader shoot from which new lateral shoots developed was divided into 30-cm sections in

nonscored treatments or the ≈30-cm sections in scoring treatments. The length of each leader shoot section was measured and all lateral shoots (≥10 cm in length) in each section that developed in 2003 were counted and their lengths and crotch angles determined.

Expt. 2, 2003, Bray's Landing, Washington. Scoring cuts, notching cuts, or bud removal were applied as described in Expt. 1 to a single, vertical, unpruned 1-year-old

leader shoot per tree in five replicate, second-leaf 'Rainier'/Mazzard sweet cherry trees per treatment. Treatments were made at green-tip (21 Mar. 2003). Control trees were untreated (four treatments in total). Shoot growth measurements were carried out as described for Expt. 1.

Expt. 3, 2003, Bray's Landing, Washington. The following treatments were applied at green-tip (24 Mar. 2003) to a single, vertical, unpruned 1-year-old leader shoot in each of five replicate second-leaf 'Skeena'/Mazzard sweet cherry trees: 1) scoring cuts, notching cuts, or bud removal as described for Expt. 1; 2) PR 5000 mg·L⁻¹ in latex paint painted individually on every fourth bud, counting from the terminal bud in the same manner as for notching cuts as described in Expt. 1; 3) PR 5000 mg·L⁻¹ in latex paint applied as a ring around the leader shoot every 30 cm below the terminal bud to the base; or 4) scoring cuts as described earlier plus painting PR 5000 mg·L⁻¹ in latex paint onto the scoring cut immediately after making the cut. Control trees were untreated (seven treatments in total). Shoot growth measurements were carried out as described for Expt. 1.

Expt. 4, 2003, Chelan Falls, Washington. The same treatments were applied in the same manner as described in Expt. 3 at green-tip (24 Mar. 2003) to each of five replicate second-leaf 'Bing'/Mazzard sweet cherry trees. Control trees were untreated (seven treatments in total). Shoot growth measurements were carried out as described for Expt. 1.

Expt. 5, 2004, Bray's Landing, Washington. All treatments were applied at green-tip (23 Mar. 2004) to three vertical, unpruned 1-year-old shoots per single-tree plot in third-leaf 'Rainier'/Mazzard sweet cherry trees. Bud removal was applied as described in Expt. 1 to one single-tree plot per block. Three single-tree plots per block were treated with notching cuts as described in Expt. 1. Three different single-tree plots per block were treated with scoring cuts, applied as two cuts, one located approximately one-third of the distance from the terminal bud to the base of the 1-year-old shoot and the second at approximately two-thirds of that distance, thus dividing the treated 1-year-old shoot into thirds. In each block, one single-tree plot each of the notching cut treatments and of the scoring treatments was then painted on the cuts with PR at either 5000 mg·L⁻¹ in latex paint or 10,000 mg·L⁻¹ in latex paint, whereas the third single-tree plot for the notching and for the scoring treatment groups received no bioregulator. Control trees were untreated (eight treatments in total). When shoot growth was completed, the length of each of the three treated sections of each of the three vertical leader shoots in each plot was measured and the total number of lateral shoots in each of the three treated sections was determined. Plot means were calculated for statistical analysis of treatment effects.

Expt. 6, 2004, Chelan Falls, Washington. Scoring cuts as described in Expt. 1 were applied at green-tip plus 1 week (31 Mar.

Table 1. Effects of bud removal, notching, or scoring on lateral shoot number, mean length, crotch angle, and vertical distribution in second-leaf 'Bing'/Mazzard sweet cherry trees (Expt. 1, 2003, Chelan Falls, Wash.).

Treatment ^{a,y}	Lateral shoots			Lateral shoots in leader shoot section (% of total lateral shoots) ^x				
	No./100 cm limb length	Mean length (cm)	Crotch angle (°)	1	2	3	4	5
Control (untreated)	6.4 a	90 a	65 b	100 a	0 b	0 b	0 a	0 a
Bud removal	8.2 a	94 a	69 ab	48 c	37 a	13 a	2 a	0 a
Notching cuts	6.7 a	111 a	71 a	80 bc	13 b	8 a	0 a	0 a
Scoring cuts	7.8 a	98 a	65 b	55 bc	21 b	18 a	4 a	2 a

^aTreatments by hand to 1-year-old vertical, unpruned central leader shoots at green-tip (21 Mar. 2003).

^yMean separation in columns by Waller–Duncan Bayesian k-ratio test following significant F test ($P \leq 0.05$).

^xMean leader shoot length was 113 cm. Leader shoot sections 30 cm in length; 1 = terminal 30-cm section. Sections 4 and 5 (basal) may have been less than 30 cm.

Table 2. Effects of bud removal, notching, or scoring on lateral shoot number, mean length, crotch angle, and vertical distribution in second-leaf 'Rainier'/Mazzard sweet cherry trees (Expt. 2, 2003, Bray's Landing, Wash.).

Treatment ^{a,y}	Lateral shoots			Lateral shoots in leader shoot section (% of total lateral shoots) ^x					
	No./100 cm leader length	Mean length (cm)	Crotch angle (°)	1	2	3	4	5	6
Control (untreated)	4.6 bc	111 a	64 a	100 a	0 b	0 b	0 b	0 b	0 b
Bud removal	8.5 a	93 a	61 a	37 c	25 a	20 a	10 a	5 b	2 b
Notching cuts	4.0 c	123 a	61 a	74 b	13 ab	6 b	7 a	0 b	0 b
Scoring cuts	7.1 ab	109 a	59 a	28 c	6 b	9 ab	10 a	29 a	18 a

^aTreatments by hand to 1-year-old vertical, unpruned central leader shoots at green-tip (21 Mar. 2003).

^yMean separation in columns by Waller–Duncan Bayesian k-ratio test following significant F test ($P \leq 0.05$).

^xMean leader shoot length was 170 cm. Leader shoot sections 30 cm in length; 1 = terminal 30-cm section. Section 6 (basal) may have been less than or greater than 30 cm.

Table 3. Effects of bud removal, notching, scoring, painting Promalin (PR) on buds or in rings or scoring plus PR on lateral shoot number, mean length, crotch angle, and vertical distribution in second-leaf 'Skeena'/Mazzard sweet cherry trees (Expt. 3, 2003, Bray's Landing, Wash.).

Treatment (mg·L ⁻¹) ^{a,y}	Lateral shoots			Lateral shoots in leader shoot section (% of total lateral shoots) ^x				
	No./100 cm leader length	Mean length (cm)	Crotch angle (°)	1	2	3	4	5
Control (untreated)	3.7 c	122 a	53 ab	100 a	0 b	0 b	0 b	0 a
Paint PR (5000) on buds	3.0 c	120 a	42 b	93 a	7 bc	0 b	0 b	0 a
Paint PR (5000) rings	2.4 c	126 a	44 b	100 a	0 c	0 b	0 b	0 a
Bud removal	7.7 b	78 cd	55 ab	45 c	30 a	15 a	5 ab	5 a
Notching cuts	4.3 c	107 ab	42 b	97 a	3 bc	0 b	0 b	0 a
Scoring cuts	2.9 c	92 bc	46 b	74 b	13 bc	3 b	11 a	0 a
Scoring + paint PR (5000) on cut	15.9 a	57 d	67 a	49 c	19 ab	11 a	13 a	6 a

^aTreatments by hand to 1-year-old vertical, unpruned central leader shoots at green-tip (24 Mar. 2003).

^yMean separation in columns by Waller–Duncan Bayesian k-ratio test following significant F test ($P \leq 0.05$).

^xMean leader shoot length was 129 cm. Leader shoot sections 30 cm in length; 1 = terminal 30-cm section. Section 5 (basal) may have been less than or greater than 30 cm.

Table 4. Effects of bud removal, notching, scoring, painting Promalin (PR) on buds or in rings, or scoring plus PR on lateral shoot number, mean length, crotch angle, and vertical distribution in second-leaf 'Bing'/Mazzard sweet cherry trees (Expt. 4, 2003, Chelan Falls, Wash.).

Treatment (mg·L ⁻¹) ^{a,y}	Lateral shoots			Lateral shoots in leader shoot section (% of total lateral shoots) ^x				
	No./100 cm leader length	Mean length (cm)	Crotch angle (°)	1	2	3	4	5
Control (untreated)	4.5 b	123 a	66 a	100 a	0 d	0 b	0 b	0 b
Paint PR (5000) on buds	6.3 b	120 a	69 a	100 a	0 d	0 b	0 b	0 b
Paint PR (5000) rings	6.5 b	99 a	69 a	100 a	0 d	0 b	0 b	0 b
Bud removal	7.6 b	98 a	68 a	43 b	39 ab	16 a	2 b	0 b
Notching cuts	6.3 b	113 a	73 a	45 b	42 a	12 ab	0 b	0 b
Scoring cuts	6.2 b	100 a	72 a	51 b	15 c	10 ab	22 a	3 b
Scoring + paint PR (5000) on cut	19.2 a	63 b	72 a	28 c	26 b	22 a	15 a	9 a

^aTreatments by hand to 1-year-old vertical, unpruned central leader shoots at green-tip (24 Mar. 2003).

^yMean separation in columns by Waller–Duncan Bayesian k-ratio test following significant F test ($P \leq 0.05$).

^xMean leader shoot length was 121 cm. Leader shoot sections 30 cm in length; 1 = terminal 30-cm section. Section 5 (basal) may have been less than or greater than 30 cm.

2004) to three vertical, unpruned 1-year-old leader shoots on each of three sets of five replicate third-leaf 'Bing'/Mazzard sweet cherry trees. One set each of the scoring

treatment was then painted with PR at either 5000 mg·L⁻¹ in latex paint or 10,000 mg·L⁻¹ in latex paint; the third set was not painted. Control trees were untreated (four treatments

in total). Shoot growth measurements were carried out as described for Expt. 1 and plot means were determined for statistical analysis.

Expt. 7, 2005, Malott, Washington. The following treatments were applied at green-tip (14 Mar. 2005) to a single, vertical, unpruned 1-year-old leader shoot in single-tree plots of second-leaf 'Skeena'/Mazzard sweet cherry trees: 1) lightly sand a ring of epidermis between two adjacent buds, starting 30 cm below the terminal bud and repeated at 30-cm intervals to the base of the 1-year-old wood, with 220-grit sandpaper, avoiding physically breaking the layer, followed by painting the sanded area with 50% v/v latex paint; 2) sand as described plus paint sanded area with PER 5000 mg·L⁻¹ in latex paint (Fig. 1B); 3) scrape an area of epidermis between two adjacent buds, starting 30 cm below the terminal bud and repeated at 30-cm intervals to the base of the 1-year-old shoot to break the brown epidermal layer visibly but disturb underlying tissues minimally, followed by painting the scraped area with 50% v/v latex paint; 4) scrape as described plus paint scraped area with PER 5000 mg·L⁻¹ in latex paint (Fig. 1D); 5) make nicking cuts about every 10 cm down the 1-year-old shoot with a small knife, making sure the cuts penetrate into the phloem and also distributing the cuts around the axis of the 1-year-old shoot but without regard to locating nicking cuts above buds, followed by painting each nicking cut with 50% v/v latex paint; 6) nick as described plus paint each nicking cut with PER 5000 mg·L⁻¹ in latex paint (Fig. 1F). Control trees were untreated (seven treatments in total). When growth was completed, the length of the treated leader shoot on each tree was measured and lateral shoots originating from the distalmost 10 cm of the treated leader shoot and from the remainder of the length of that shoot were counted separately.

One-way analyses of variance were used to assess the significance of treatments. All percentage values were transformed using the arcsine transformation before analysis. Mean values were separated with the Waller-Duncan Bayesian k-ratio test ($P \leq 0.05$) after a significant F test. Statistical analyses were performed using the general linear models procedure of the Statistical Analysis System program package (SAS Institute, Cary, N.C.).

Results

Expts. 1 and 2. Bud removal, notching, and scoring treatments had no effect on total number of lateral shoots per 100 cm limb length developed in 'Bing' trees (Table 1), but bud removal increased the total number of lateral shoots per 100 cm in 'Rainier' trees (Table 2). Mean lateral shoot lengths were unaffected by treatment in either cultivar. The typically strong controlling effect of apical dominance over lateral shoot distribution in sweet cherry was clearly demonstrated by untreated trees of both cultivars; all lateral shoot growth in controls was limited to the uppermost 30-cm section of the 1-year-old

leader shoot. Bud removal and scoring were most effective for inducing lateral shoot development from lower portions of the treated shoots. Notching produced a smaller influence on shoot development in lower portions of the treated shoots.

Expts. 3 and 4. Notching alone, scoring alone, painting PR directly on individual buds and painting rings of PR on the stem between two adjacent buds had no effect on lateral shoot development or crotch angles in either cultivar, and only a very minor effect on mean lateral shoot length in 'Skeena' (Tables 3 and 4). Bud removal increased lateral shoot development in 'Skeena' only. Scoring followed by application of PR to the scoring cut was very effective in inducing an approximate fourfold increase in lateral shoot development in both cultivars, accompanied by a decrease in overall mean lateral shoot length (Fig. 2). Painting PR on buds or intact bark had no effect on lateral shoot distribution. Bud removal and notching improved the vertical distribution of lateral shoots in 'Bing', but only bud removal affected vertical shoot distribution in 'Skeena'. Scoring plus PR had the strongest effect on improving vertical lateral shoot distribution in 'Bing' and an equivalent effect to bud removal in 'Skeena'.

Expt. 5. Bud removal, notching, or scoring alone did not improve lateral shoot development in 'Rainier' trees, although some improvement in lateral shoot distribution was observed (Table 5). Painting PR on scoring or notching cuts greatly improved the lateral shoot development response and also increased the proportion of lateral shoots in the basal third of the treated leader. PR concentration did not appear to have a significant effect on lateral shoot development or vertical distribution.

Expt. 6. Scoring alone substantially increased the number of lateral shoots produced and improved their vertical distribution, but did not affect mean shoot length or crotch angle (Table 6). Painting PR on the scoring cuts about doubled the number of actively developing lateral shoots over scoring cuts alone, depending on PR concentration, while decreasing the mean lengths of the induced shoots. Painting PR on the cuts also improved shoot distribution compared with untreated controls, but not compared with scoring alone.

Expt. 7. Lateral shoot number originating from the terminal 10 cm of the treated leader shoot was not altered by any treatment (Table 7, Fig. 1A). Lateral shoot development in unpruned, vertical, 1-year-old cherry branches is frequently limited to this region of the branch (Fig. 2A). Shoot growth from the remainder of the length of the vertical leaders was not altered by bark injury-alone treatments. When PER was painted on either scraped epidermis or nicking cuts, lateral shoot development was increased by at least 10-fold, but PER painted on lightly sanded epidermis was not effective (Fig. 1B–G). Vertical shoot distribution was not determined in this trial.

Discussion

Interfering with auxin or other hormone movement in sweet cherry shoots during budbreak by cutting into the phloem via notching or scoring may improve lateral shoot development (Long, 2005; Long et al., 2005; Niu et al., 1998), but the results can be inconsistent, as shown in the trials reported here. Painting a concentrated solution of 6-benzyladenine plus GA₄₊₇ on individual buds or as rings on the intact bark of

Fig. 2. Expt. 3, 2003. (A) Lateral shoot growth from unpruned leader shoot of second-leaf 'Skeena'/Mazzard sweet cherry tree. Note the strong apical dominance effect on lateral shoot location and development. (B) Lateral shoot growth from unpruned leader shoot of similar tree receiving combination treatment of scoring every 30 cm plus painting PR 5000 mg·L⁻¹ on scoring cuts at green-tip. Note more shoots, shorter mean lengths, and much better vertical shoot distribution.

Table 5. Effects of bud removal alone or notching or scoring with or without Promalin (PR) treatment on lateral shoot number and vertical distribution in third-leaf 'Rainier'/Mazzard sweet cherry trees (Expt. 5, 2004, Bray's Landing, Wash.).

Treatment (mg·L ⁻¹) ^{z,y}	No. lateral shoots/100 cm branch length	Lateral shoots in leader shoot section (% of total lateral shoots) ^x		
		1	2	3
Control (untreated)	1.5 e	100 a	0 b	0 c
Bud removal	3.9 e	95 ab	5 cd	0 c
Scoring cuts	3.4 e	29 d	30 abc	40 a
Scoring + paint PR (5000) on cut	11.9 cd	49 cd	30 abc	21 b
Scoring + paint PR (10,000) on cut	18.7 bc	54 cd	28 abc	19 b
Notching cuts	4.9 de	73 bc	15 bcd	12 b
Notching + paint PR (5000) on notch	24.5 ab	40 d	43 a	17 b
Notching + paint PR (10,000) on notch	27.4 a	46 d	39 ab	15 b

^zTreatments by hand to 1-year-old vertical, unpruned central leader shoots at green-tip (23 Mar. 2004).

^yMean separation in columns by Waller–Duncan Bayesian k-ratio test following significant F test ($P \leq 0.05$).

^xMean leader shoot length was 156 cm. Leader shoot sections roughly one-third the total length of the leader shoot; 1 = terminal, 3 = basal.

Table 6. Effects of scoring cuts or scoring plus Promalin (PR) application to the scoring cuts on lateral shoot number, mean length, crotch angle, and vertical distribution in third-leaf 'Bing'/Mazzard sweet cherry trees (Expt. 6, 2004, Chelan Falls, Wash.).

Treatment (mg·L ⁻¹) ^{z,y}	Lateral shoots			Lateral shoots in leader shoot section (% of total lateral shoots) ^x					
	No./100 cm leader length	Mean length (cm)	Crotch angle (°)						
				1	2	3	4	5	6
Control (untreated)	2.2 d	83 a	54 a	93 a	0 b	0 b	0 b	7 b	0 b
Scoring cuts	9.8 c	64 a	58 a	8 b	13 a	14 b	25 a	27 a	12 a
Scoring + paint PR (5000) on cuts	17.8 b	39 b	59 a	20 b	18 a	18 ab	21 a	17 a	5 b
Scoring + paint PR (10,000) on cuts	21.6 a	34 b	55 a	15 b	17 a	26 a	24 a	14 ab	4 b

^zTreatments by hand to 1-year-old vertical, unpruned central leader shoots at green-tip (24 Mar. 2003).

^yMean separation in columns by Waller–Duncan Bayesian k-ratio test following significant F test ($P \leq 0.05$).

^xMean leader shoot length was 187 cm. Leader shoot sections 30 cm in length; 1 = terminal 30-cm section. Section 6 (basal) may have been less than or greater than 30 cm.

Table 7. Effects of breaking the epidermal layer alone or breaking that layer plus Perlan (PER) application to the sanded, scraped, or nicked areas on lateral shoot number originating from the terminal 10 cm of the treated branch and from the remainder of the branch in second-leaf 'Skeena'/Mazzard sweet cherry trees (Expt. 7, 2005, Malott, Wash.).

Treatment (mg·L ⁻¹) ^{z,y}	Lateral shoots originating from terminal 10 cm of 1-year-old leader branch (n)	Lateral shoots on remainder of 1-year-old leader branch (no./100 cm of branch) ^x
Control (untreated)	6.2 a	0.1 b
Lightly sand epidermis + paint only	6.4 a	0.0 b
Sand + paint PER (5000) on sanded area	7.2 a	1.4 b
Scrape epidermis + paint only	7.4 a	1.8 b
Scrape epidermis + paint PER (5000) on scraped area	7.6 a	10.6 a
Nicking cuts + paint only	8.0 a	0.1 b
Nicking + paint PER (5000) on nicking cuts	7.8 a	10.0 a

^zTreatments by hand to 1-year-old vertical, unpruned central leader shoots at green-tip (14 Mar. 2005).

^yMean separation in columns by Waller–Duncan Bayesian k-ratio test following significant F test ($P \leq 0.05$).

^xMean leader shoot length was 116 cm.

1-year-old shoots was completely ineffective for induction of lateral shoot development, even though the treated buds had some green tissue exposed at the time of treatment. Results from other studies indicate that cytokinin–GA products are effective for inducing sweet cherry buds to grow into shoots (Elfvig and Visser, 2006; Jacyna and Puchala, 2004; Miller, 1983; Veinbrants and Miller, 1981). Results of the trials reported here

show that a principal limiting factor in the effectiveness of such treatments for induction of shoot development in 1-year-old sweet cherry shoots is the penetration of sufficient bioregulator product into the active tissues of the plant. As long as the barrier represented by the outermost protective layer of tissue on 1-year-old sweet cherry shoots is interrupted or removed before application of a cytokinin–GA preparation, even if underlying

tissues are minimally disturbed, substantial lateral shoot growth is promoted and new shoots are produced from buds located on the lower portions of 1-year-old shoots, improving shoot distribution. Entire shoots or branches do not require complete coverage with cytokinin-containing bioregulators as described by Jacyna and Puchala (2004), Miller (1983) and Veinbrants and Miller (1981). When combined with nicking, notching, scoring, or scraping, spot treatment with cytokinin–GA mixtures at intervals down a 1-year-old shoot is sufficient to produce substantial new and well-distributed shoot development. The shoot development response to these treatments is somewhat localized. Cuts plus bioregulators need to be applied at intervals on 1-year-old shoots to ensure good distribution of the induced lateral shoots along the treated 1-year-old shoots.

When bioregulator treatments were effective at overcoming apical dominance, new shoot growth was increased severalfold in some trials reported here. Although some of these shoots might subsequently be removed, this large increase in lateral shoots and the consequent increase in lateral buds should result in greater productivity when the trees begin to flower. Combining whole-tree treatments for improved lateral shoot development with reduced pruning and the use of precocious, size-controlling rootstocks should further improve early productivity. Further tests are necessary to verify this hypothesis.

When sweet cherry bark is injured, infection by the bacterial canker pathogen [*Pseudomonas syringae* pv. *syringae* van Hall or *P. s.* pv. *morsprunorum* (Wormald) Young et al.] may occur (Ogawa et al., 1995). However, during 4 years of branching trials involving scoring and notching cuts made on several cultivars in numerous locations under both dry and wet conditions in the early spring around green-tip, we have never observed an infection by this pathogen under central Washington state conditions. Combining cytokinin–GA treatments with bark scraping, nicking, notching, or scoring may offer a less labor-intensive, practical alternative to heavy pruning or painting entire shoots or limbs with bioregulator products for stimulation of lateral shoot and canopy development, especially in higher density sweet cherry plantings.

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