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Effects of Dormant Pruning, Summer Pruning, Scoring, and Growth Regulators on Growth, Yield, and Fruit Quality of 'Delicious' and 'Cortland' Apple Trees

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Abstract. **Summer pruning 6-year-old trees of 'Cortland' apple (*Malus domestica* Borkh.) for 3 consecutive years in either early July or early August reduced trunk circumference increase the year of pruning and increased terminal growth the following year. Terminal growth on 8-year-old 'Red Prince Delicious' trees summer-pruned in August for 3 consecutive years was similar to dormant-pruned trees, and trunk circumference increase was reduced the last 2 years. Fruit size and soluble solids were reduced the last 2 years. Fruit size and soluble solids were reduced by summer pruning 'Cortland' but not 'Red Prince'. Flowering, fruit set, yield, flesh firmness, flesh calcium, and storage disorders were not affected by summer pruning of either cultivar. Terminal growth of 'Cortland' trees was reduced the year of scoring and the following year. Bloom was increased the year following scoring. Scoring 'Red Prince' for 3 consecutive years consistently reduced terminal growth and increased yield the second and third years. Corrective dormant pruning (CDP) on 'Red Prince' reduced bloom but not yield the first year. In the 2 subsequent years, bloom, fruit set, and yield were not affected by CDP and the practice alleviated the problem of tree crowding. Summer pruning on 'Cortland' trees followed by a postbloom spray of butanedioic acid mono(2,2-dimethyl hydrazide) (daminozide) of 1500 ppm showed promise as a way to control tree growth, increase flower bud formation, and fruit set.**

The inflationary spiral has forced apple growers to plant trees more intensively to increase production per area and per worker-hour. As a consequence, tree crowding with a loss of productivity and fruit quality has occurred in some plantings. Dormant prunign restricts growth of roots and reduces the trunk circumference increase of a tree but growth is stimulated near the pruning cuts (5), which can confound the problems of tree crowding and reduced light penetration. In contrast, summer pruning may restrict tree growth more than an equivalent amount of dormant pruning while increasing flower bud formation (1, 6, 16) and red color development on fruit (18).

Reports of the influence of summer pruning on growth (1, 13, 16, 22), flowering (1, 6, 10, 13, 16), and fruit quality (10, 14, 17, 20, 22) have been conflicting, probably because responses to summer pruning may be dependent upon the time of year the pruning is done, the type of pruning cut, geographical location, and tree vigor.

Growth regulators (7, 11, 23, 26) and cultural techniques (7, 23) have also been used successfully to restrict apple tree growth and influence flower bud formation. This experiment was initiated to determine the most effective way to restrict the growth of bearing trees of 2 cultivars while maintaining or improving productivity and fruit quality.

Materials and Methods

'Cortland' and 'Red Prince Delicious,' a nonspur strain, were selected for the experiments due to their different bearing habits. 'Cortland' normally bears part of its crop terminally on 1-year-old wood, whereas 'Red Prince Delicious' produces most of its fruit on 2-year-old or older wood.

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'Cortland' experiment. A group of 42 trees in their 6th growing season on Malling (M)7a spaced 4.2 × 6.3 m was selected in a commercial orchard in Wilbraham, Mass. These trees were growing vigorously and at this spacing growth restriction will be required to maintain them within their allotted space. Prior to the initiation of treatments in 1978, the trees had been lightly dormant-pruned and trained as central leader trees. Six treatments were established in 1978 and continued in 1979 and 1980 with the exception of a scoring treatment which was performed only in 1978. Each treatment was replicated 7 times in a single-tree randomized block design. All trees received light dormant pruning regardless of treatment. Treatments were: 1) control, light dormant pruning; 2) scoring; 3) daminozide at 1500 ppm; 4) summer pruning in early July; 5) summer pruning in August; and 6) daminozide at 1500 ppm + summer pruning in August.

'Cortland' produces much of its fruit terminally on 1-year-old wood. The weight of the developing fruit causes the branch to droop or to be horizontally oriented and new upright shoots to develop near the base of the 1-year-old wood. After several years, the branches on 'Cortland' will have a profusion of thin, drooping wood. Light dormant pruning was similar for all trees in the experiment and consisted of cuts to maintain a conical tree shape and to allow better light penetration. Thinning cuts were made to: (a) direct growth in a different direction; (b) eliminate competition among branches and with the central leader; (c) remove vigorous upright growth on branches; (d) remove weak wood; and (e) space bearing wood evenly along the branch. Branches within 60 cm of the ground were removed.

Scoring (treatment 2) was performed 19 days after full bloom (FB) in 1978 by making a single circumscribing cut through the bark on the trunk. Daminozide at 1500 ppm dilute for treatments 3 and 6 was applied FB + 19 days, FB + 14 days, and FB + 12 days in 1978, 1979, and 1980, respectively. Summer pruning in early July or early August of 1978, 1979, and 1980 (treatments 4, 5, and 6) consisted of removing the current season's shoot originating from each terminal fruiting spur on 1-year-old wood.

The remainder of the current season's shoots on the tree were cut back to a lateral originating from 1- or 2-year-old wood. Watersprouts and vigorous upright shoots originating on scaffold branches were removed. These pruning procedures reduced branch spread, exposed apples on 1-year-old wood to direct sunlight, and removed all current season's shoots on the periphery of the tree except for those retained as the extension shoot of the scaffold branches.

Bloom and fruit set were determined on 2 tagged limbs per tree and trunk circumferences were recorded prior to budbreak in 1978 and after leaves had fallen in 1978, 1979, and 1980. Prior to summer pruning in July, the terminal growth on 20 randomly selected shoot was measured on the check and the July summer-pruned trees. Prior to August summer pruning, the terminal growth of 20 shoots was taken on all trees except those summer-pruned in July.

At commercial harvest time, 25 apples were taken from the periphery of each tree near the pruning cuts. The fruit were weighed and red color estimated to the nearest 10%. Flesh firmness was determined on 2 sides of 10 fruit using a Magness-Taylor penetrometer. Juice from the pressure test was collected and 2 soluble solid determinations were made with a hand-refractometer. Ten apples were mechanically peeled for Ca determinations following the procedures of Weis et al. (25). A 20-kg fruit sample was harvested and stored in 0°C air at 95% relative humidity for 17–18 weeks. Flesh firmness was determined on a 10-apple sample after 1 day at 20 to 25°. After 7–8 days at 20 to 25°, each box of apples was examined for bitter pit, cork spot, scald, and internal breakdown.

'Red Prince Delicious' experiment. These trees on Malling Merton (MM)106 in a commercial orchard in Wilbraham, Mass., but in a different block than the 'Cortland' trees were in their 8th growing season, spaced 4.2 m × 6.3 m, and growing very vigorously. Prior to initiation of treatments in 1978, in-row tree spread averaged about 6 m and branches projecting into the tree alleys had been reduced in length prior to harvest in 1977 to allow passage of equipment. A randomized block experiment was designed with single-tree plots and 6 replications of treatments. The treatments applied annually for 3 years, commencing in 1978, were as follows: 1) control, light dormant pruning; 2) corrective dormant pruning (CDP); 3) CDP + daminozide 1500 ppm + naphthaleneacetic acid (NAA) on dormant cuts; 4) CDP + daminozide 1500 ppm + NAA on dormant cuts + summer pruning; 5) CDP + summer pruning; and 6) CDP + scoring.

'Delicious' with a standard growth habit such as 'Red Prince Delicious' are prone to develop a whorl of upright branches which cause shading or competition with the leader. The severity of pruning on the control trees (treatment 1) was light to simulate grower practices. Tree height and spread was not reduced by pruning.

CDP for treatments 2–6, inclusive, consisted of containment pruning. In 1978, 1–2 large limbs per tree were removed at their point of origin on the central leader to reduce branch crowding or competition with the central leader. Only an occasional limb had to be removed for this purpose during the 1979 and 1980 pruning seasons. Trees were lowered in 1978 by 1–2 and maintained at 4-m height for the remainder of the study. A limb renewal program was initiated in 1978 in the top ⅓ of the trees. This consisted of annual removal of strong branches or cutting these back to a weak lateral branch. All water sprouts were removed except those that were in a favorable location to serve as replacement limbs. Each year branches that crowded those of an adjacent tree were removed or shortened by cutting back to a weaker side branch. Drooping ends of branches and those extending into the row received stubbing cuts to reduce length and to begin to stiffen them.

A 1% NAA solution was added to latex paint for treatments 3 and 4. This was applied annually with a paint brush following pruning but prior to bud swell. A 1500-ppm dilute spray of daminozide was applied 11–16 days after full bloom (FB) on the trees in treatments 3 and 4. Trees in treatments 4 and 5 were summer-pruned annually in early August using the following procedures. Limbs 2.5 cm circumference or less were removed throughout the tree where shading appeared to exist. Most watersprouts and vigorous upright shoots were removed. Drooping ends of branches were cut back to a weak lateral branch in a near-horizontal position to begin stiffening of the limbs. Scoring (treatment 6) was performed annually 11–16 days after FB by making a single circumscribing cut through the bark on the trunk.

Two limbs per tree ranging from 10–15 cm in circumference were tagged and measured for blossom cluster and fruit set counts and the trunk circumferences were recorded prior to bud swell in 1978 and again in Fall 1978, 1979, and 1980 after the completion of growth. Terminal growth of 20 shoots was taken at random around the periphery of each tree in August prior to summer pruning. At the normal harvest time, 20- and 30-apple samples and 20-kg sample were randomly harvested. The 20-apple sample was analyzed for flesh calcium by the method of Weis et al. (25). The 30-apple sample was weighed; the length and diameter were measured and 10 fruit were tested for flesh firmness and soluble solids as described for 'Cortland'. The 20-kg fruit sample was stored in 0°C air at 95% relative humidity for 24–25 weeks. After 1 day at 20 to 25° following removal from storage, a 10-apple sample was tested for flesh firmness. After 7–13 days at 20 to 25°C, a 50-fruit sample was examined for rots, bitter pit, and cork spot, internal breakdown, and internal browning.

Results

'Cortland'. Flower bud formation was increased by scoring only on 'Cortland' and only the year following scoring (Table 1). No summer-pruning treatment alone had a consistent influence on flowering or fruit set. Trees receiving both daminozide and summer pruning in August had greater bloom and fruit set the third year. Summer pruning reduced trunk circumference increase the year of pruning and increased terminal growth the following year. Scoring once in 1978 reduced trunk circumference increase for 3 years, whereas terminal growth was reduced in 1978 and 1979. Daminozide reduced terminal growth on the summer-pruned trees and caused additional growth suppression the year following scoring but had no effect on trunk circumference increase.

Summer pruning reduced average fruit weight in 2 of 3 years (Table 2). Trees scored in 1978 had smaller fruit than the controls in 1978 and 1979 but larger fruit in 1980. Daminozide caused further size reduction in 1979 and 1980 on scored and August-pruned trees. Only daminozide increased flesh firmness. Summer pruning in both July and August consistently reduced soluble solids. No treatment consistently influenced fruit color, flesh calcium, tree yield, flesh firmness, or the development of disorders following storage (Tables 2 and 3).

'Red Prince Delicious'. Summer pruning had no consistent influence on flowering or fruit set when compared with lightly pruned or CDP trees (Table 4). Terminal growth on CDP trees was greater than that on light, normally pruned trees. Summer

Table 1. Effects of summer pruning, scoring, and daminozide on flower bud formation, fruit set, and growth of 'Cortland' apple trees, 1978–1980.

Treatment	Blossom clusters/ cm limb circumf			Fruit/cm limb circumf			Fruit/100 blossom clusters			Terminal growth prior to summer pruning (cm)					Trunk circumf increase (cm)		
										1978	1979		1980		4/78–	10/78–	11/79–
	1978	1979	1980	1978	1979	1980	1978	1979	1980	Aug.	July	Aug.	July	Aug.	10/78	11/79	10/80
Check	4.8 ab[z]	4.0 cd	6.4 b	2.3 c	1.3 b	2.0 b	51 b	35 b	41 a	33 a	29 b	29 b	32 b	32 b	3.9 a	4.2 a	3.9 a
Scoring[y]	3.8 ab	7.7 a	6.4 b	3.9 ab	2.2 ab	2.2 ab	108 a	35 b	41 a	28 b	---	18 c	---	28 b	2.0 c	2.8 d	3.1 b
Scoring[y] + daminozide 1500 ppm	2.9 b	7.8 a	6.0 b	4.5 a	2.9 a	2.6 ab	129 a	36 b	54 a	25 b	---	9 d	---	22 c	2.2 c	2.9 cd	3.3 b
Summer pruning —July	4.4 ab	2.1 d	5.5 b	2.9 bc	1.2 b	2.2 ab	71 b	60 a	46 a	---	33 a	---	39 a		2.9 b	3.9 ab	3.0 b
Summer pruning —Aug.	5.1 a	3.6 cd	5.3 b	2.3 c	1.3 b	2.1 ab	47 b	39 b	47 a	---	---	32 a	---	36 a	3.0 b	3.1 cd	3.2 b
Summer pruning— Aug. + daminoz-ide 1500 ppm	3.8 ab	4.9 bc	8.7 a	2.3 c	2.6 a	3.4 a	61 b	49 ab	48 a	---	---	16 c	---	21 c	3.5 ab	3.4 bcd	3.1 b

[z]Mean separation within columns by Duncan's multiple range test, 5% level.
[y]Scoring done only in 1978.

Table 2. Effects of summer pruning, scoring, and daminozide on fruit quality, yield, and flesh calcium content of 'Cortland' apples at harvest, 1978–1980.

Treatment	Fruit wt (g)			Flesh firmness (N)			Soluble solids (%)			Red color (%)			Flesh Ca (ppm)			Yield (kg/tree)	
	1978	1979	1980	1978	1979	1980	1978	1979	1980	1978	1979	1980	1978	1979	1980	1978	1980
Check	223 a[z]	232 a	209 b	68.5 b	76.5 b	75.2 b	12.5 b	12.9 a	13.0 a	75 b	70 b	69 ab	101 abc	127 bcd	126 a	24 a	56 a
Scoring[y]	169 c	209 c	226 a	68.9 b	77.0 b	74.3 b	13.1 a	12.0 c	12.5 b	79 ab	73 b	66 b	90 c	119 d	132 a	28 a	46 a
Scoring[y] + daminozide 1500 ppm	165 c	173 d	183 c	72.9 a	84.5 a	83.2 a	12.9 ab	11.6 d	12.0 c	84 a	76 ab	75 a	95 bc	148 a	140 a	28 a	46 a
Summer pruning— July	202 b	226 b	224 ab	68.9 b	75.2 b	73.8 b	11.9 c	12.5 b	12.5 b	78 ab	70 b	74 a	102 abc	122 cd	129 a	22 a	42 a
Summer pruning— Aug.	190 b	223 b	224 ab	68.9 b	78.7 b	72.1 b	11.7 c	12.2 bc	12.4 bc	79 ab	77 ab	75 a	111 a	140 ab	126 a	20 a	44 a
Summer pruning — Aug. + damino-zide 1500 ppm	192 b	173 d	154 d	72.9 a	86.7 a	85.8 a	12.8 ab	11.6 d	12.0 c	85 a	83 a	74 a	108 ab	147 a	128 a	20 a	56 a

[z]Mean separation within columns by Duncan's multiple range test, 5% level.
[y]Scoring done only in 1978.

Table 3. Effects of summer pruning, scoring, and daminozide on fruit quality of 'Cortland' apples following 17–18 weeks of regular storage, 1978–1980.

Treatment	Flesh firmness (N)			Breakdown (%)			Bitter pit and cork (%)			Scald (%)		
	1978	1979	1980	1978	1979	1980	1978	1979	1980	1978	1979	1980
Check	55.2 a[z]	56.0 bc	46.3 b	15 abc	10 a	19 a	13 b	5 b	30 ab	23 bc	72 b	91 a
Scoring[y]	54.7 ab	56.0 bc	45.8 b	22 ab	13 a	22 a	30 a	5 b	20 bc	31 ab	95 a	95 a
Scoring[y] + daminozide 1500 ppm	55.2 a	58.7 a	50.7 a	26 a	12 a	15 a	30 a	4 b	15 c	41 a	90 ab	90 a
Summer pruning—July	52.0 c	55.2 c	45.4 b	11 bc	21 a	26 a	15 b	14 a	34 a	26 bc	95 a	91 a
Summer pruning—Aug.	52.5 bc	55.6 bc	45.4 b	11 bc	17 a	21 a	10 b	8 ab	33 a	19 c	88 ab	95 a
Summer pruning—Aug. + daminozide 1500 ppm	54.7 ab	57.8 ab	50.3 a	7 c	16 a	26 a	8 b	4 b	16 c	25 bc	86 ab	90 a

[z]Mean separation within columns by Duncan's multiple range test, 5% level.
[y]Scoring done only in 1978.

pruning CDP trees had no influence on subsequent terminal growth, whereas daminozide + NAA in the presence or absence of summer pruning reduced it.

Fruit weight on CDP trees was consistently reduced by daminozide, and in 1979 and 1980 it was also reduced by scoring (Table 5). Fruit size was increased in 1979 by CDP and in 1980 by CDP + summer pruning. Daminozide increased flesh firmness while the other treatments had no consistent effect. Soluble solids in fruit from CDP trees were reduced by daminozide but increased by scoring in 1979 and 1980. No treatment consistently influenced fruit shape or flesh calcium. Yield was not influenced the first year treatments were applied. CDP and CDP + summer pruning reduced yield the second year. This reduction was partially reversed by daminozide and completely eliminated by scor-

Table 4. Effects of summer pruning, corrective dormant pruning (CDP), scoring, and daminozide on bloom, fruit set, and growth of 'Red Prince Delicious' apples, 1978–80.

Treatment	Blossom clusters/ cm limb circumf			Fruit/cm limb circumf			Fruit/100 blossom clusters			Terminal growth prior to summer pruning (cm)			Trunk circumf. increase (cm)		
	1978	1979	1980	1978	1979	1980	1978	1979	1980	1978	1979	1980	4/78–10/78	10/78–11/79	11/79–10/80
Light normal pruning	8.2 a[z]	9.8 ab	6.9 c	7.0 ab	4.6 ab	4.0 ab	103 a	50 b	56 a	22 b	32 b	32 b	5.1 a	3.4 ab	3.6 a
CDP	4.5 b	8.0 abc	7.7 bc	4.5 b	5.3 ab	4.6 ab	118 a	72 ab	63 a	31 a	36 a	40 a	4.1 b	3.8 a	3.1 ab
CDP + daminozide 1500 ppm + NAA on dormant cuts	4.8 b	10.5 a	10.4 ab	5.8 ab	6.1 a	5.6 a	143 a	63 ab	61 a	20 b	26 c	30 b	3.9b	3.4 ab	3.2 ab
CDP + daminozide 1500 ppm + NAA on dormant cuts + summer pruning	5.8 ab	9.3 ab	11.2 a	7.2 a	5.8 ab	6.1 a	143 a	61 ab	56 a	---	25 c	29 b	3.5 b	3.0 bc	2.9 b
CDP + summer pruning	5.7 ab	5.8 c	7.7 bc	4.4 b	3.5 b	3.1 b	114 a	62 ab	42 a	---	39 a	42 a	3.7 b	3.2 b	2.9 b
CDP + scoring	3.3 b	8.9 abc	10.2 ab	4.8 b	6.6 a	5.9 a	161 a	79 a	68 a	30 a	32 b	27 b	4.2 b	2.6 c	2.1 c

[z]Mean separation in columns by Duncan's multiple range test, 5%.

Table 5. Effects of summer pruning, corrective dormant pruning (CDP), scoring, and daminozide on fruit quality, yield, and flesh calcium 'Red Prince Delicious' apples at harvest. 1978–80.

Treatment	Fruit wt (g)			Flesh firmness (N)			Soluble solids (%)			L/D ratio		Flesh Ca (ppm)			Yield kg/tree		
	1978	1979	1980	1978	1979	1980	1978	1979	1980	1979	1980	1978	1979	1980	1978	1979	1980
Light normal pruning	188 ab[z]	192 b	180 b	80.2 b	77.1 b	82.4 b	11.1 a	11.5 b	11.0 b	0.90 a	0.91 a	84 ab	138 bc	146 ab	80 a	166 a	166 ab
CDP	206 a	212 a	185 b	78.0 bc	75.3 b	82.4 b	10.9 a	11.8 b	10.7 b	0.90 a	0.91 a	79 b	127 c	126 c	84 a	76 cd	156 b
CDP + daminozide 1500 ppm + NAA on dormant cuts	178 b	174 cd	163 c	85.1 a	84.2 a	92.3 a	10.3 bc	10.9 c	9.9 c	0.87 b	0.90 a	90 ab	159 a	157 a	92 a	100 c	140 b
CDP + daminozide 1500 ppm + NAA on dormant cuts + summer pruning	173 b	167 d	162 c	84.7 a	85.6 a	90.5 a	10.0 c	10.6 c	9.8 c	0.87 b	0.90 a	98 a	156 ab	156 a	92 a	96 c	134 b
CDP + summer pruning	191 ab	210 a	200 a	77.9 bc	75.7 b	83.5 b	10.7 ab	11.8 b	10.6 b	0.90 a	0.91 a	88 ab	128 c	136 bc	76 a	64 d	136 b
CDP + scoring	200 a	189 bc	161 c	76.6 c	78.4 b	84.2 b	11.1 a	12.4 a	11.5 a	0.90 a	0.93 a	80 b	141 abc	137 bc	100 a	134 b	186 a

[z]Mean separation in columns by Duncan's multiple range test, 5% level.

ing. During the third year, yield on CDP trees and lightly pruned trees were comparable, whereas scoring further increased yield on CDP trees.

Fruit firmness from trees that received daminozide + NAA was increased following storage in both CDP and summer-pruned trees (Table 6). Scoring CDP trees reduced firmness the second and third years while summer pruning + CDP had no effect. No treatment consistently influenced the development of disorders following storage.

Discussion

Pruning in late June to early July increases flower bud formation more effectively than late pruning (4). In this investigation, August summer pruning had no influence on total flower bud formation. Summer pruning undoubtedly removed some of its potential flower buds because current season shoots were headed back to a fruit or eliminated when cutting to a weak lateral branch. On 'Cortland', summer pruning not only removed flower buds but probably stimulated their formation as found by Lord and Greene (10).

Unproductive blind wood behind the terminal bud characterizes the growth habit of 'Cortland' and other cultivars such as 'Tydeman's Red' and 'Rome Beauty'. The year following summer pruning of 'Cortland', 2 or 3 shoots grew behind the heading cut. Growth of these shoots was retarded when daminozide was applied after petal fall and flower bud formation for the following year (1980) was greatly increased (Table 1). The appearance of summer-pruned, daminozide-treated 'Cortland' trees was changed from trees with drooping branches and considerable blind wood to more compact trees having semispur-type growth habits.

Scored 'Cortland' trees had greater bloom and fruit set than the controls the year following treatment but not the second year. Batjer and Westwood (2) and Toenjes (21) have reported that the effects of scoring young trees on flower bud formation

Table 6. Effects of summer pruning, corrective dormant pruning (CDP), scoring, and daminozide on fruit quality of 'Red Prince Delicious' apples following 24–25 weeks in regular storage, 1978–80.

Treatment	Flesh firmness (N)			Breakdown (%)			Bitter pit and cork (%)			Rots (%)		
	1978	1979	1980	1978	1979	1980	1978	1979	1980	1978	1979	1980
Light normal pruning	64.5 ab	58.0 cd	57.8 b	3 a	6 b	2 a	28 abc	31 ab	15 ab	4.7 ab	5 ab	3 a
CDP	63.2 bc	59.1 bc	56.0 c	3 a	6 b	3 a	33 ab	49 a	10 b	5.5 ab	6 ab	4 a
CDP + daminozide 1500 ppm + NAA on dormant cuts	66.3 a	64.1 a	60.5 a	4 a	3 b	4 a	17 c	24 b	8 b	2.7 ab	1 b	4 a
CDP + daminozide 1500 ppm + NAA on dormant cuts + summer pruning	63.2 bc	66.3 a	60.0 a	4 a	4 b	1 a	20 bc	32 ab	12 ab	1.8 b	2 b	2 a
CDP + summer pruning	60.9 c	60.5 b	56.0 c	6 a	16 a	4 a	39 a	50 a	22 a	9.3 a	13 a	5 a
CDP + scoring	60.7 c	56.9 d	53.8 d	2 a	17 a	5 a	36 a	46 a	8 b	9.0 ab	9 ab	4 a

[z]Mean separation in columns by Duncan's multiple range test, 5% level.

are limtied to the year following scoring and bloom the second year may in fact be less than untreated trees (2). Although flowering was influenced only the year following scoring, terminal growth was reduced for 2 years and trunk circumference increase was reduced for 3 years. This emphasizes the fact that growth restriction is not a necessary prerequisite for enhanced flower bud formation (7).

The corrective dormant-pruning procedure was considered mainly responsible for confining the 'Red Prince' trees to their 4.2 × 6.3 m spacing. Either NAA or daminozide have been used to control growth on mechanically hedged apple trees (9). NAA application on dormant cuts followed by a postbloom daminozide treatment on CDP did control vegetative growth and partially overcame some of the loss in yield and second year. However, CDP 'Red Prince' trees that were scored maintained yields in the second and third years that were comparable to the larger, lightly pruned trees.

Summer pruning failed to restrict terminal growth on 'Red Prince' and increased it on 'Cortland' (Tables 1 and 2). These findings and those of others (13, 15, 17) are in conflict with the suggestion that a major benefit of summer pruning is supression of terminal growth (22). In contrast, summer pruning consistently reduced trunk circumference increase of 'Cortland' and of 'Red Prince' the last 2 years. This is in general agreement with Marini and Barden (13, 15) and Alderman and Auchter (1). Taylor and Ferree (19) reported that summer pruning most effectively reduced growth of the stem base and roots of pruned trees. Trunk circumference measurements reported herein were taken at the base of each tree, 50 cm above the soil line. Much of the photosynthate that is produced late in the season is translocated to the roots (8). Summer pruning can reduce root growth the year treated (15, 19), yet can be ineffective in retarding terminal shoot growth the following year (13, 15, 24). This raises questions about the relative importance of root-delivered photosynthate for shoot growth. Marini and Barden (15) have suggested that there may be a critical level of carbohydrate in the roots for spring shoot growth. Although summer pruning may reduce carbohydrate levels enough to restrict trunk circumference increase, they may still be above that critical level required to reduce terminal growth. Summer pruning can restrict growth (22); however, it should be emphasized that the major restriction is in trunk circumferenc increase and not in terminal growth.

Differences in the effects of summer pruning on fruit size and soluble solids can be explained in large part by the type and severity of the pruning procedures. Soluble solids were consistently reduced in 'Cortland' but not in 'Red Prince'. Current season shoots on 'Cortland' were cut to all fruits borne terminally on 1-year-old wood which generally left only 2–3 leaves to supply photosynthate, whereas larger cuts were made on 'Red Prince', rarely in the vicinity of fruit. Thus, the number of leaves in close proximity to fruit of 'Red Prince' was not reduced by summer pruning. Marini and Barden (14) reported a consistent decrease in soluble solids following summer pruning. Their data also emphasizes the importance of adjacent leaves as a major contributor to the soluble solids content of apples since regrowth following summer pruning resulted in higher soluble solids in 'Stayman' apples at harvest. Others (3, 14, 22) have reported a reduction in fruit size when summer pruning removed considerable leaf surface.

Ca moves to rapidly growing vegetative tissue at the expense of movement to fruit. No summer-pruning treatment influenced flesh Ca levels. This is in agreement with Lord and Greene (10) and Marini and Barden (14), but in conflict with other reports (12, 17). In this investigation the severity of summer pruning was only moderate and performed at a time when terminal growth had ceased. Therefore, at the time of pruning the competition between growing points and fruit had abated to the point where shoot removal probably had only a limited influence on Ca movement to the fruit.

In conclusion, summer pruning alone was ineffective at controlling terminal growth, increasing flower bud formation, improving fruit quality, or extending fruit storage life. However, summer pruning could provide work for employees during slack periods during the summer, reduce the need for dormant pruning, and improve light penetration and subsequent red color development on such cultivars as 'McIntosh' (10) and 'Delicious' (14) in warmer climates.

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Inflorescence and Floral Development in *Pelargonium* X *hortorum*

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Abstract. **Floral initiation and development in the hybrid geranium, *Pelargonium* X *hortorum* Bailey, were examined using scanning electron microscopy. Inflorescence initiation was marked by a raising of the apex followed by the formation of convex flower primordia. In floral development, 5 sepal primordia were delimited, closely followed by 5 petal primordia. Imbricate sepals enclosed the floral apex during later developmental stages. Five antesepalous, then 5 antepetalous stamen primordia were initiated. Five gynoecial primordia arose, forming a pentagonal ridge, carpellary lobes, and eventually an elongate style with stigma. Three of the antepetalous stamen primordia developed into filaform staminodia.**

The floral ontogeny of members of the Geraniaceae has been described (2, 3, 5, 7, 8) by light microscopic observations and line drawings or photographs. Miranda and Carlson (4) described early initiation and the finally differentiated inflorscence in the hybrid geranium; however, they did not show intermediate changes. It appears that there has not been a complete description of floral initiation and organogenesis of the hybrid geranium. This study describes the floral initiation and sequential development of the hybrid geranium using scanning electron microscopy (SEM).

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Materials and Methods

Hybrid geranium seeds, 'Sprinter Scarlet', were germinated under intermittent mist and grow in 10-cm pots in sphagnum peatmoss–vermiculite media amended with superphosphate and minor nutrients. Plants were fertilized at each irrigation with 200 ppm N using 15N–0P–12.5K. Every 4th irrigation was with