Influence of Time of Summer Pruning and Limb Orientation on Growth and Flowering of Vigorous ‘Delicious’ Apple Trees

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Abstract. Trees of apple [Malus domestica Borkh. cv. Red Prince Delicious/Malling (M) 9] planted in 1974 on a 1.52 × 3.05 m spacing exceeded the allotted space by 40% at the initiation of the study in 1979. Trees were unpruned (control) and pruned on July 3, August 3, or September 3 in 1979 and 1980. Pruning decreased limb and trunk cross-sectional area. Horizontal limb cross-sectional area increase was less than that of vertical limbs. Pruning increased spur leaf numbers, area, and size on the 1978 limb section but only July and August pruning prevented the decline in spur numbers occurring on control limbs. July pruning increased bloom per cluster but decreased total bloom on the 1978 limb sections. August and September pruning were most efficient in maintaining tree height while all pruning treatments maintained tree spread.

‘Delicious’ apple is characterized by low fruitfulness, high vegetative vigor, and a very upright growth form (4). Pruning with heading cuts on ‘Delicious’ may be detrimental because of excessive invigoration (6, 10) and loss of fruitfulness (2). Normal dormant pruning using a combination of heading and thinning-out cuts on ‘Delicious’ may cause similar problems (4, 5, 6, 10). Since ‘Delicious’ is the major cultivar in the United States and is widely planted in all major producing areas, it is essential to develop techniques to balance vigor with productivity if it is to be utilized in more productive high density systems.

Summer pruning has been considered for controlling tree vigor (17). However, interpretation of summer-pruning studies is difficult due to differences in response due to cultivar (2, 10, 13, 14, 16), rootstock (14, 16), tree vigor (10), tree age (1) and whether the summer-pruned trees are compared to either dormant-pruned (1, 13) or unpruned trees (2, 7, 10, 18) or to both dormant-pruned and unpruned trees (8, 12, 14). Results indicate a suppression (2, 7, 14, 16, 17, 18), and an increase (8, 10, 12, 13) in vegetative growth, while others (1, 8) found little difference in tree size between dormant and summer pruning.

Limb orientation and spreading effects on apple tree growth are well-documented (4, 5, 9, 11), but few studies have investigated the interaction of summer pruning and limb orientation. This study examined the effect of time of summer pruning on vigorous ‘Delicious’ trees in a high-density system and the relationships of horizontal and vertical limbs to vegetative and reproductive responses.

Materials and Methods

Trees of ‘Red Prince Delicious’ on M 9 planted in 1974 at a spacing of 1.52 × 3.05 m were trained to a slender spindle. The trees exhibited excessive vegetative vigor, exceeding the allotted spacing by about 40% prior to initiation of the study in 1979. The following treatments were applied in 1979 and 1980 to trees grouped by vegetative vigor based on tree size: (a) control—no summer pruning; (b) July 3 pruning (56 days after full bloom); (c) August 3 pruning; and (d) September 3 pruning.

For each 1979 pruning treatment, terminal shoots were removed at a point 5 cm below the 1978 bud scale scar, and current season’s lateral shoots greater than 10 cm in length were removed at their point of origin. In 1980, current season’s growth as well as previous season’s regrowth greater than 10 cm in length were removed at their point of origin on about the same dates. All trees received light, uniform, dormant pruning consisting of thinning cuts in an effort to minimize crowding. However, limbs on which measurements were made were not pruned to prevent invigoration of shoot growth. The trees were not fertilized during the course of the study.

Sections originating in 1978 (1978 limb section) of 10 limbs in the following orientations were selected at random and tagged on each tree: (a) vertical to 45° from vertical (vertical) and (b) 45° from vertical to horizontal (horizontal). Attempts were made to tag only limbs on the exterior of the tree canopy to minimize differences in light exposure. Treatments were arranged in a split-plot design with summer pruning as the main plot and orientation as the subplot with 8 single tree replications for a total of 32 trees.

Shoot growth (shoots > 5 cm) was measured on all tagged limbs. Final growth, defined as the total current season’s shoot growth present on the tagged limbs in the dormant season, was measured in 1979 and 1980. Growth removed by pruning was measured in 1980. Final growth of control and summer-pruned trees was analyzed separately due to large differences in sample values.

The following were measured on each 1978 limb section: total length, circumference at the base, spurs (shoots < 5 cm), flower clusters, and flowers. During full bloom of 1981, 10 spurs/tree were sampled from 1978 limb sections and number of leaves, total leaf area, and average leaf size determined. Tree height, spread, and trunk circumference were also measured.

Results and Discussion

At the end of the 1979 season, July-pruned branches had greater final growth compared to August- or September-pruned
pruning, the August pruning resulted in the least regrowth. How­

delayed during the season is well-established (1, 2, 7, 10, 18).

branches (Table 1). The reduction in regrowth as pruning is
delayed during the season is well-established (1, 2, 7, 10, 18).

Norton (16) reported that with June, August, and late September

pruning, the August pruning resulted in the least regrowth. How­

ever, in our experiment there was no difference in regrowth
between August- and September-pruned trees.

Total length and number of shoots were greater on vertical

than horizontal limbs only on the control and July-pruned trees
(Table 1). This effect was probably due to a seasonal limitation

on regrowth in the August- and September-pruned trees. How­

ever, Norton (16) observed that summer pruning cuts on hori­

zontal limbs in August produced little or no regrowth whereas

similar pruning of vertical limbs did encourage regrowth.

In all pruning treatments, vertical limbs had greater shoot

growth and numbers removed by 1980 pruning than horizontal

limbs (Table 1). This was similar to a recent dormant-pruning

study where there was an alteration in the distribution of growth

in both horizontal and vertical branches, but only vertical limbs

had an increase in total growth (5). Pruning time in 1979 had

little effect on shoot growth that developed prior to pruning in
1980. However, 1979 summer pruning increased average shoot

length of growth removed by pruning compared to average 1980

length of unpruned limbs. Taylor (18) reported that August prun­

ing of ‘Jonathan’/M 26 caused a 59% increase in average ter­

minal shoot length in the following season compared to unpruned

trees; however, total shoot length and numbers were not re­

ported. Marini and Barden (13) found that, in most cases, August

pruning of ‘Delicious’/Malling Merton (MM) 111 and ‘Golden

Delicious’/MM 111 resulted in greater total shoot length but not

numbers or average lengths in the following season compared to

similar dormant pruning. Differences between these and our

results may result from their (13, 18) use of heading cuts, whereas

thinning cuts were used in this study. Current season’s shoots

were thinned at their point of origin, removing buds that will

likely develop into vigorous shoots. Mika (14) reported that

shoot heading or removal of 1/2 to 1/3 of current season’s growth

increased total shoot length, whereas shoot thinning decreased

shoot growth. In addition, rootstock vigor may have influenced
results. Norton (16) reported that summer pruning to spurs would

invigorate the spurs into vegetative shoots on vigorous scion/

rootstock combinations but not when more precocious rootstocks

were used, such as M 9.

The length of the 1978 limb section on control trees was

greater than on pruned trees because the pruning cuts were made

about 5 cm below the 1978 bud scale scar (Table 2). Cross­

sectional area of the 1978 limb was decreased by summer pruning
after one season, and 2 years of pruning reduced limb cross­

sectional area by more than 37%. The increase in limb cross­

sectional area between 1979 and 1980 was also reduced by

pruning compared to the control. However, Marini and Barden
(13) found that summer heading of current season’s growth of

‘Delicious’/MM 111 trees decreased branch circumference after

3 season’s summer pruning. Differences between these results

and ours may be due to the proximity of the measurements to

the pruning cut since Marini and Barden (13) measured circum­

ference at the base of 5-year-old wood and we measured at the

base of 2-year-old wood.

After 2 seasons of July or September pruning, trees exhibited

less increase in trunk cross-sectional area than control trees (Ta­

ble 2). Marini and Barden (13) found that 3 years of summer

pruning decreased trunk growth in ‘Golden Delicious’/MM 111

but not in ‘Delicious’ or ‘Stayman’ on MM 111. Lord et al.
(10) reported reduced trunk growth the year of summer pruning
in ‘Cortland’/M 7A, ‘Red Prince Delicious’/M 26, and ‘Red

Prince Delicious’/MM 106, but not on ‘Starkrimson Delicious’/

MM 106. However, the reduction in trunk growth did not persist
the year after summer pruning was discontinued (10). It appears
that the decrease in circumferential growth following summer

pruning begins near the site of the cut and develops basipetally

towards the trunk. This progression was demonstrated by de­

Table 1. Influence of limb orientation and time of summer pruning in 1979 and 1980 on total shoot length, shoot
numbers, and average shoot length on the 1978 limb section of ‘Red Prince Delicious’/M 9.

<table>
<thead>
<tr>
<th>Variable</th>
<th>1978 Final growth</th>
<th>1980 Final growth</th>
<th>Growth removed by pruning</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total shoot length (cm)</td>
<td>No. shoots</td>
<td>Avg shoot length (cm)</td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vertical</td>
<td>101.3 a</td>
<td>3.7 a</td>
<td>27.9 a</td>
</tr>
<tr>
<td>Horizontal</td>
<td>73.4 b</td>
<td>2.8 b</td>
<td>25.8 a</td>
</tr>
<tr>
<td>Summer-pruned</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>July</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vertical</td>
<td>30.9 a</td>
<td>1.8 a</td>
<td>17.2 a</td>
</tr>
<tr>
<td>Horizontal</td>
<td>18.6 b</td>
<td>1.2 b</td>
<td>15.5 a</td>
</tr>
<tr>
<td>August</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vertical</td>
<td>2.6 c</td>
<td>0.3 c</td>
<td>8.7 b</td>
</tr>
<tr>
<td>Horizontal</td>
<td>3.4 c</td>
<td>0.4 c</td>
<td>8.5 b</td>
</tr>
<tr>
<td>September</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vertical</td>
<td>1.3 c</td>
<td>0.2 c</td>
<td>6.5 b</td>
</tr>
<tr>
<td>Horizontal</td>
<td>1.5 c</td>
<td>0.2 c</td>
<td>7.5 b</td>
</tr>
</tbody>
</table>

*Compare means within columns of control or summer-pruned by Duncan’s multiple range test, 5% level.

*Compare interaction means within columns by Duncan’s multiple range test, 5% level.

increased growth of 2-year-old wood in the year of pruning and decreased trunk growth after 2 years of summer pruning (Table 2).

Summer pruning reduced both tree height and spread compared to the unpruned control, as shown in the 1980 measurements, and the effect persisted into 1981, even though the treatments were discontinued (Table 2). Vertical limbs which were pruned in July 1980 had more regrowth than horizontal limbs (Table 1). However, regrowth of 1980 July-pruned horizontal limbs were not greater than vertical or horizontal limbs pruned in August of 1980 (Table 1). Thus, height of July-pruned trees were greater than height of August-pruned trees but width was not affected (Table 2). Tree size measurements at the end of the growing season in 1981, during which no pruning treatments were applied, indicated August and September pruning was more effective than July pruning for maintaining tree height (Table 2). We observed that during the season following summer pruning, growth develops primarily near the end of previous season’s shoots. In this experiment, the amount of shoot growth developing prior to pruning in 1980 was not influenced by pruning time in 1979 (Table 1). However, more regrowth developed on July-pruned vertical limbs by the end of the 1980 season than on August and September-pruned limbs. Thus, the point at which 1981 shoot growth began on vertical limbs was relatively lower in August- and September-pruned trees than July-pruned trees.

Thus, tree height was more contained in 1981 on August- and September-pruned trees than July-pruned trees even though total current season’s shoot growth was similar. All pruning treatments maintained narrower trees, both in-row and across-row, than the control treatment. Taylor (18) reported that August summer pruning maintained canopy volume 43% below that of unpruned trees and, in addition, the canopy volume increase of August-pruned trees was some 75% less than unpruned trees. Marini and Barden (13) concluded that August heading of shoots showed little potential for controlling tree size compared to similar dormant pruning, although tree size measurements were not made. These results and those of Taylor (18) suggest that tree size measurements appear to be a more meaningful index of pruning effects on tree size control than shoot growth measurements.

Length and cross-sectional area were greater on vertical than on horizontal limbs (Table 2). In addition, horizontal limbs had less increase in cross-sectional area than vertical limbs, suggesting that the latter were inherently more vigorous. These differences in vigor were probably established in the first year of growth due to apical dominance (3).

Pruning in August 1979 increased spur number on the 1978 limb section the following year (Table 3). In addition, July pruning had a higher spur number than the control when compared on a limb length or cross-sectional area basis. July and

<table>
<thead>
<tr>
<th>Variable</th>
<th>1978 limb section</th>
<th>Change in trunk</th>
<th>1980 tree size</th>
<th>1981 tree size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cross-sectional area (cm²)</td>
<td>Cross-sectional area (cm²)</td>
<td>Height (m)</td>
<td>In-row spread (m)</td>
</tr>
<tr>
<td>July 3</td>
<td>33.8 b 0.75 c 1.00 b 0.25 b</td>
<td>5.55 a 4.53 b</td>
<td>2.74 b 1.92 b 2.00 b</td>
<td>3.16 a 2.03 b 2.65 b</td>
</tr>
<tr>
<td>Aug. 3</td>
<td>33.6 b 0.79 c 1.05 b 0.26 b</td>
<td>4.91 a 6.91 ab</td>
<td>2.29 c 1.94 b 1.92 b</td>
<td>2.88 b 2.21 b 2.54 b</td>
</tr>
<tr>
<td>Sept. 3</td>
<td>32.4 b 0.88 b 1.15 b 0.28 b</td>
<td>5.73 a 6.18 b</td>
<td>2.19 c 1.79 b 1.71 c</td>
<td>2.85 b 2.08 b 2.34 c</td>
</tr>
<tr>
<td>Control</td>
<td>39.7 a 0.98 a 1.69 a 0.71 a</td>
<td>7.87 a 9.37 a</td>
<td>3.03 a 2.32 a 2.63 a</td>
<td>3.19 a 2.69 a 3.24 a</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Limb orientation</th>
<th>Vertical</th>
<th>Hor. Horizontal</th>
<th>37.4 a 0.90 a 1.36 a 0.46 a</th>
<th>32.4 b 0.80 b 1.09 b 0.29 b</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3.74 a 0.90 a 1.36 a 0.46 a</td>
<td>3.74 a 0.90 a 1.36 a 0.46 a</td>
<td>3.74 a 0.90 a 1.36 a 0.46 a</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variable</th>
<th>1980</th>
<th>1981</th>
<th></th>
<th>Spurs/cm² limb cross-sectional area</th>
<th>Spur/cross-sectional area</th>
<th>Leaves/spur²</th>
<th>Avg leaf size (cm²)³</th>
<th>Total leaf area (cm²)/spur³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pruning time</td>
<td></td>
<td></td>
<td></td>
<td>6.1 b 0.18 b 8.1 a 6.1 a</td>
<td>6.3 a 7.6 a 5.4 a 41.1 a</td>
<td>5.6 b 7.0 b 4.5 b 31.7 b</td>
<td>3.6 c 6.8 b 4.5 b 30.7 b</td>
<td>3.5 e 5.9 c 3.2 c 18.9 c</td>
</tr>
<tr>
<td>July 3</td>
<td></td>
<td></td>
<td></td>
<td>6.8 a 0.21 a 8.7 a 6.2 b</td>
<td>5.6 b 7.0 b 4.5 b 31.7 b</td>
<td>3.6 c 6.8 b 4.5 b 30.7 b</td>
<td>3.5 e 5.9 c 3.2 c 18.9 c</td>
<td></td>
</tr>
<tr>
<td>Aug. 3</td>
<td></td>
<td></td>
<td></td>
<td>6.0 b 0.19 ab 6.2 b 6.0 b</td>
<td>3.5 e 5.9 c 3.2 c 18.9 c</td>
<td>3.6 c 6.8 b 4.5 b 30.7 b</td>
<td>3.5 e 5.9 c 3.2 c 18.9 c</td>
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<tr>
<td>Sept. 3</td>
<td></td>
<td></td>
<td></td>
<td>5.8 b 0.15 c 6.0 b 6.0 b</td>
<td>3.5 e 5.9 c 3.2 c 18.9 c</td>
<td>3.6 c 6.8 b 4.5 b 30.7 b</td>
<td>3.5 e 5.9 c 3.2 c 18.9 c</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td></td>
<td></td>
<td>5.7 b 0.18 a 7.1 a 7.1 a</td>
<td>5.1 a --- --- ---</td>
<td>4.4 b --- --- ---</td>
<td>--- --- --- ---</td>
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</table>

<table>
<thead>
<tr>
<th>Limb orientation</th>
<th>Vertical</th>
<th>Hor. Horizontal</th>
<th>6.7 a 0.18 a 7.4 a 5.1 a</th>
<th>5.7 b 0.18 a 7.1 a 4.4 b</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6.7 a 0.18 a 7.4 a 5.1 a</td>
<td>5.7 b 0.18 a 7.1 a 4.4 b</td>
<td>6.7 a 0.18 a 7.4 a 5.1 a</td>
<td>5.7 b 0.18 a 7.1 a 4.4 b</td>
</tr>
</tbody>
</table>

*Compare means within columns of pruning time or limb orientation by Duncan’s multiple range test, 5% level.

*Measured at full bloom in 1981.
August pruning for 2 years prevented a decline in spur numbers which occurred on limbs of both control and September-pruned trees (Table 3, Fig. 1). Summer pruning increased the number, total area, and average size of leaves measured in 1981 at full bloom (Table 3, Fig. 2). Vertical limbs had more spurs than horizontal limbs. However, orientation did not affect spur number when treatments were compared on a limb length or limb cross-sectional basis.

July pruning in 1979 decreased the number of flower clusters on the 1978 limb section in 1980 but due to increased flowers per cluster, total numbers of flowers per limb was not affected (Table 4). In addition, vertical limbs had more clusters and flowers than horizontal limbs. Fruit set in 1980 was not affected by orientation or pruning. July pruning of vertical and horizontal limbs for 2 seasons caused a decrease in the number of clusters and flowers per limb in 1981 (Table 4). However, July-pruned limbs again had a greater number of flowers per cluster. August pruning decreased cluster and flower numbers on vertical but not horizontal limbs. Neither in 1980 nor 1981 was there an effect of pruning or orientation on the total number of fruit borne on the 1978 limb sections (15). Taylor (18) found no effect of summer pruning on flowers per cluster or fruit set of 'Jonathan' but did increase the number of terminal clusters compared to light dormant pruning. Marini and Barden (13) found that 2 seasons of summer pruning 'Delicious' trees increased bloom on 2-year-old wood and decreased bloom on three-year-old wood, but did not affect total bloom per limb compared to dormant-pruned trees. Two seasons of summer pruning decreased flower density in 'Jersey Mac', which Ferree and Stang (7) explained by the loss of 1-year-old wood on which the cultivar normally produces flowers. In the present study, summer pruning decreased the number of clusters, flowers, and fruit occurring in 1-year shoots; however, 'Delicious' does not normally produce a major part of its crop on 1-year-old wood (data not presented).

Results of this study indicate that late summer heading into 2-year-old wood followed annually by thinning out of vigorous shoots can contain 'Delicious' trees in a high-density system. In addition, the decline in the amount of leaf area in the interior of unpruned trees was prevented by July and August pruning, thus increasing leaf area of interior spurs to provide future bearing sites. The development of spurs on July-pruned trees was apparently at the expense of flower density on the 1978 limb section. As previously mentioned, the reduction in flower density did not result in a decline in yield (15). The increase in spurs and flowers per cluster, and the decrease in total flower numbers following July pruning may be due to changes in nutritional status created by pruning. Elfving and Forshey (6) found that dormant heading of all 1-year-old wood resulted in higher N in bark and in spurs not in close proximity to the pruning

**Table 4. Influence of limb orientation and time of summer pruning in 1979 and 1980 on clusters, flowers, flowers/cluster, and fruit set on the 1978 limb section of 'Red Prince Delicious'/M 9 in 1980 and 1981.**

<table>
<thead>
<tr>
<th>Variable</th>
<th>1980 Clusters</th>
<th>Flowers/cluster</th>
<th>Flowers/clust</th>
<th>Set (%)</th>
<th>1981 Clusters</th>
<th>Flowers</th>
<th>Flowers/cluster</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pruning time</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>July 3</td>
<td>4.3 b</td>
<td>18.1 a</td>
<td>4.2 a</td>
<td>31 a</td>
<td>0.9 d</td>
<td>0.7 d</td>
<td>4.0 d</td>
</tr>
<tr>
<td>Aug. 3</td>
<td>4.7 ab</td>
<td>18.0 a</td>
<td>3.8 b</td>
<td>38 a</td>
<td>2.9 c</td>
<td>3.1 bc</td>
<td>12.8 bc</td>
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<tr>
<td>Sept. 3</td>
<td>5.1 a</td>
<td>19.0 a</td>
<td>3.7 b</td>
<td>36 a</td>
<td>3.5 ab</td>
<td>2.7 c</td>
<td>14.2 ab</td>
</tr>
<tr>
<td>Control</td>
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<td>18.4 a</td>
<td>3.5 c</td>
<td>44 a</td>
<td>3.9 a</td>
<td>2.9 c</td>
<td>16.1 a</td>
</tr>
<tr>
<td>Limb orientation</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vertical</td>
<td>5.2 a</td>
<td>19.9 a</td>
<td>3.8 a</td>
<td>35 a</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Horizontal</td>
<td>4.4 b</td>
<td>16.8 b</td>
<td>3.8 a</td>
<td>39 a</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
</tbody>
</table>

*Compare means within columns of pruning time or limb orientation by Duncan's multiple range test, 5% level.

*Compare interaction means within parameters by Duncan's multiple range test, 5% level.
Response of Young 'Topred Delicious' Apple Trees to Orchard Floor Management and Fertilization

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Additional index words. Malus domestica, nitrogen, cultivation, yield efficiency

Abstract. Growth of 'Topred Delicious' (Malus domestica Borkh)/Malling Merton (MM) 111 apple trees during the first 5 years in the orchard was significantly affected by the orchard floor management system. Trees grown in a mowed sod were smaller and had a significantly lower yield efficiency (kg/cm²) than those grown under cultivation or a herbicide strip system. N source or rate did not influence growth or average yield/tree; fruit size and bitter pit development were significantly greater where a complete fertilizer (10N-4P-8K) was applied. N increased tree growth under sod but not under a cultivated or herbicide strip management system. Growth response in the first year was increased when larger-sized trees were planted under a weed-free management system and trees were headed to 76 cm.

Today's high cost of developing an orchard requires greater attention to cultural management in order to obtain early returns on the investment. One of the primary objectives after planting is to quickly fill the allotted space with bearing wood. Applications of fertilizers can increase growth and yield of fruit trees (1, 5, 13, 23, 29). Management of the orchard ground cover can also influence growth and yield of deciduous fruit trees (2, 6, 7, 17, 20, 24, 28). Research dealing with the interaction of fertilization and ground cover management is limited, particularly with trees on clonal rootstocks in the United States.

The height at which trees are headed or the severity of pruning at planting affects growth and shoot development (11, 21). Osman (21) found a slight, nonsignificant reduction in trunk circumference when trees were severely pruned at planting, but ground cover condition was not specified. Ferree (11) found no difference in average or total shoot length on 9 apple cultivars when they were headed at 61, 68, or 76 cm. In the same study,