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Leader Management and Soil Fumigation Affect Branching and Precocity of Young Apple Trees

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Abstract. **Apple (*Malus domestica* Borkh.) cultivars Spur Galagored (#42) ('Gala'), Jonagored ('Morren's'), and Red Fuji (B.C. #2) ('Fuji') on Mark rootstock and 'Gala' on Malling 26 EMLA (M.26) and Malling 9 EMLA (M.9) were planted in the four major apple-production regions of western North Carolina. Three leader management techniques, weak leader renewal, snaked leader, and heading with partial terminal leaf removal (H + PTLR), were applied to five-tree plots beginning the spring after planting. Leader management techniques, weak leader renewal or H + PTLR, which involved dormant pruning or vegetation removal and an interruption in vegetative vigor, reduced total branching and yield during the third year. Fumigation with methyl bromide increased lateral branching and yield in the third year. No significant yield differences were detected for 'Gala' grown on M.9, M.26, or Mark rootstocks. Trees grown in the most western region of the state, Haywood County, had smaller trees and reduced yields compared to the other three regions due to a shorter growing season.**

To obtain early yields in high-density apple orchards, stimulation of numerous lateral branches from the tree's central leader is necessary (Ferree and Schmid, 1994; Peterson, 1989). Early branching is essential for proper limb selection to encourage early production (Shepherd, 1979; Van Oosten, 1978). If a poorly branched tree is planted, a branching framework must be developed as soon as possible. Many techniques are available to achieve early branching. Traditionally, the central leader training system has been maintained by dormant pruning where typically one-third to one-half of the previous-season's growth is removed to stimulate branching near the cut. However, this procedure results in lateral branches with narrow crotch angles to the central leader, which cannot support a crop load and also reduces early fruit yield. Techniques to promote branching, other than pruning, are 1) changing the orientation of the leader (Mullins, 1965; Myers and Ferree, 1983), 2) removing immature apical leaves (Barlow and Hancock, 1960; Wertheim, 1978), 3) growth regulator applications (Greene and Miller, 1988), and 4) bagging of the dormant leader (Strydom, 1993). Also, cultivar and rootstock vigor may influence the effectiveness of branch-inducing techniques, because these are often most successful when shoot growth is rapid (Greene and Miller, 1988; Larsen, 1979; Sachs and Thimann, 1967).

Branch-inducing techniques, however, were developed in northern regions in North America and Europe where the growing season is short and leader growth rates are slower relative to southern regions (Hamzakheyl et al., 1976; Oberhofer, 1990; Tromp, 1970; Wertheim, 1978). Over 30 years, the average growing season length for New York, Michigan, and Washington apple production regions has ranged from 140 to 164 days, while western North Carolina averaged 175 days (personal communication, Regional Climate Centers). Also, the average cooling degree days (18.3C base) ranged from 390 to 614 in these northern states, but the mean was 890 for North Carolina (Gale Research Co., Detroit, 1984). These and other climatic factors can commonly result in 1.5 to 2.0 m of vigorous, unbranched leader growth on young, nonfruiting, unmanaged apple trees in southeastern orchards, even when planted on size-controlling rootstocks.

Most leader management techniques reported to stimulate branching have not been adequately tested under the vigorous growing conditions of the southeastern United States. The objective of the field trials reported here was to evaluate the effects of three leader management techniques on lateral branching with three cultivars and three rootstocks under southeastern climatic conditions. Also, the interaction of these treatments with preplant soil fumigation on replant sites and their influence on early bloom and production was investigated.

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Material and Methods

Four replicated trials were planted in Feb. 1991 in the four major apple-production regions in western North Carolina at elevations varying from ≈300 to 810 m (Table 1). The trials were all planted in apple replant sites in which the trees had been removed within the last 24 months. Unbranched trees of 'Spur Galagored' (#42) ('Gala'), 'Jonagored' ('Morren's'), and 'Red Fuji' (B.C. #2) ('Fuji') on Mark rootstock were planted in a split-split-plot design with four replications and five trees/plot. The main plot was cultivar, subplot was leader management technique, and sub-subplot was fumigation. Also, 'Gala' on M.26 EMLA and M.9 EMLA was planted in a split-plot design, with rootstock as main plot and leader management technique as the subplot. All trees on M.9 and M.26 were planted in fumigated soil, similar to the fumigated treatment for 'Gala' on Mark. Thus, two trials were combined, one comparing three cultivars on Mark, half fumigated, half nonfumigated, and the other comparing 'Gala' on three rootstocks, all fumigated. Fumigation was done in Oct. or Nov. 1990 by releasing a 0.45-kg can of methyl bromide (98%) in the bottom of an augured planting hole 45 cm wide and 45 cm deep. Holes were dug and the cans were placed in the bottom of the hole, buried, the soil was packed, and the cans were punctured with a three-pronged metal fork, with the outside prongs holding the can in place and the center prong puncturing the can. All trees were tied to 2.5-m stakes placed beside each tree at planting and trees were headed to 40 cm above the graft union in March. During the growing season, trees were irrigated when needed, and a 2-m vegetation-free strip was maintained in the tree row.

The three leader management techniques applied to the five-tree sub-subplots beginning the spring after planting (1991) were 1) weak leader renewal (WLR), where the current leader was removed during the dormant season, just above a weaker lateral; that lateral then was tied up to the stake to become the new leader; 2) snaked leader (SL), where, after each 45 cm of leader growth, the leader was bent across the vertical stake at a 60° angle and tied; this was repeated during the growing season in alternating directions as growth permitted; 3) heading and partial terminal leaf removal (H + PTLR), where the leader was headed, during dormancy, 15 to 20 cm above the uppermost usable lateral to encourage vigorous regrowth; then, during the growing season, the apical, nonexpanded leaves were removed by pinching without disturbing the apical meristem. Removal was repeated every 12 to 15 cm of leader growth, about three to four times per season. These three treatments were repeated each growing season on the same trees, and no other pruning or training was done to the leaders. Lateral limbs were spread outward to an 85° angle. Lateral limb removal and renewal was done in all trees to maintain a slender spindle-type tree form as outlined by Oberhofer (1990). In 1993 and 1994, the crop load was hand-thinned to one

Table 1. Elevation, cooling degree days (base 18.3C), and growing season length for the four major apple-production regions in North Carolina, where this study was conducted.

County	Elevation (m)	Cooling degree days	Growing season length (days)
Lincoln	299	1336	196
Wilkes	341	965	180
Henderson	656	743	169
Haywood	810	514	155

fruit/cluster with 10 to 15 cm between each fruit.

Data recorded during this study included total primary branches/tree after the third year, 1993 and 1994 trunk cross-sectional area (TCSA), number of flower clusters each spring, and total fruit yield in 1993 and 1994. Analysis of variance (ANOVA) was done on these data using SAS's (SAS Institute, Cary, N.C.) ANOVA procedure for factorial data sets. Means were separated using Waller–Duncan with $P \leq 0.01$ to provide a greater confidence in the differences obtained.

Results and Discussion

The total number of branches on 'Gala', 'Jonagored', and 'Fuji' on Mark was significantly affected by soil fumigation and leader management (Table 2). Snaking the leader (SL) in alternate directions resulted in the most branches. Leader management did not significantly affect TCSA of these cultivars, but there was a significant interaction affect between location and cultivar. In 1993, TCSA of trees grown in fumigated soil was larger than that of trees grown in nonfumigated soil. 'Fuji' in Wilkes County had the largest TCSA (16.6 cm^2) and 'Gala' in Haywood County the smallest (5.3 cm^2). The 'Gala' trees always had the smallest TCSA at all four locations and 'Fuji' trees generally had the largest. In 1994, the only significant differences in TCSA were by location, with trees grown in Henderson and Wilkes counties having larger TCSAs than trees grown in the other two locations.

Number of flower clusters on 'Gala', 'Jonagored', and 'Fuji' trees on Mark in 1992 was increased significantly only by fumigation (Table 2). However, number of flower clusters in 1993 showed significant main effects for all four variables, with no interactions (Table 2). In Henderson County, 'Jonagored', SL, and fumigation resulted in the highest flower cluster counts. This result suggests that location, cultivar, leader management, and preplant soil fumigation can each have a significant impact on third-year flowering independent of the other variables. Therefore, if any one of these is not optimum, the potential for early fruit production could be diminished.

Fruit yield of 'Gala', 'Jonagored', and 'Fuji' trees on Mark in 1993 followed a pattern of significance similar to 1993 flowering (Table 2), except that the cultivar main effect was nonsignificant. There was, however, a significant cultivar × location interaction. Not only did 'Jonagored' in Henderson County have the highest yield, with 8.8 kg/tree, but 'Jonagored' had the highest yield at all locations. In Henderson and Lincoln counties, 'Gala' had the lowest yield; in Haywood County, 'Fuji' had the lowest yield; and both cultivars had the same yield in Lincoln County. This relationship indicates that treatments that increase early flowering contribute to early fruit production. The SL technique resulted in the greatest yield. Thus, leader management techniques that required dormant pruning had less yield the first year of fruiting. In 1994, there were no significant treatment differences in fruit yield, although the trend was similar to that in 1993.

In 1992, one tree out of each plot was subjected to a leader management technique in which unbranched leaders were bent to horizontal during the dormant season and retied to vertical after lateral growth was ≈5 cm long. This management technique resulted in asymmetrical branching of the leader on the upward side of the bent leader and in death of all of the buds on the lower side. However, these trees averaged 22 branches/tree compared to 19 for the SL, and the 1993 yield was not significantly different from the SL, but was higher than that for the other two leader management techniques. In 1994, the trees with the leader bent to horizontal in 1992 had a significantly higher yield than those under WLR or H + PTLR and equal to the SL (data not shown). This finding agrees with those of Clayton-Greene (1989), who showed that early fruiting is increased with greater branching and that early fruit production is reduced when trees are pruned.

Total branching of 'Gala' trees on Mark, M.9 EMLA, and M.26 EMLA was affected significantly only by leader management, with SL resulting in the highest branch count (Table 3). In 1993, TCSA was affected only by location, with the trees in Henderson County significantly larger than at all other locations and the trees in Haywood County being the smallest. Neither TCSA in 1994 nor number of flower clusters in 1992 were significantly affected by any of the variables tested. However, number of flower clusters in 1993 was affected significantly by location. Trees in Henderson County produced the most flowers. Fruit yield in 1993 was significantly affected by location, but not by rootstock or leader treatment (Table 3). Henderson County had the highest yield of all locations, and the lowest yield in Wilkes was due to extremely low winter temperatures. Fruit yield in 1994 was significantly affected by location and leader management, but there was a significant three-way interaction of location, rootstock, and leader management. Yields were lowest in Haywood County, which was expected, because its growing season is significantly shorter and there are fewer cooling degree days than at the other locations.

Table 2. Branching, trunk cross-sectional area (TCSA), bloom, and yield of 3-year-old apple trees on Mark rootstock subjected to various branch-inducing treatments. Mean separations are not shown for main effects when there is a significant interaction with the main effect.

	Total branches/ tree	TCSA (cm^2)		Flower clusters/ tree		Fruit yield/ tree (kg)	
Variable	1993	1993	1994	1992	1993	1993	1994
Location (L)							
Henderson	16.7	12.4	17.0 a	5	252 a	6.8	10.6
Haywood	15.8	7.1	11.6 b	7	130 c	2.5	5.3
Lincoln	14.9	10.1	13.6 b	1	194 b	5.0	7.6
Wilkes	17.8	13.3	19.2 a	8	127 c	2.6	9.7
Cultivar (C)							
Gala	15.6	9.0	13.6	3	157 b	3.0	8.0
Jonagored	15.9	11.0	16.0	9	271 a	5.8	7.3
Fuji	17.3	12.2	16.5	4	114 b	4.1	9.5
Leader management (T)							
Snaking	19.4 a	10.7	15.4	6	210 a	4.9 a	9.3
H + PTLR	14.6 b	10.9	15.2	3	146 b	3.4 c	8.3
Weak leader	14.5 b	10.6	15.4	7	166 b	4.2 b	7.2
Fumigation (F)							
Control	15.3 b	10.1 b	14.8	3 b	140 b	3.6 b	7.8
Fumigated	17.2 a	11.3 a	15.8	7 a	207 a	4.8 a	8.7
F significance							
L	NS	**	**	NS	**	**	NS
C	NS	NS	NS	NS	**	NS	NS
L × C	NS	**	NS	NS	NS	**	**
T	**	NS	NS	NS	**	**	NS
C × T	NS	NS	NS	NS	NS	NS	NS
L × C × T	NS	NS	NS	NS	NS	NS	NS
F	**	**	NS	**	**	**	NS
C × F	NS	NS	NS	NS	NS	NS	NS
T × F	NS	NS	NS	NS	NS	NS	NS
C × T × F	NS	NS	NS	NS	NS	NS	NS
L × C × T × F	NS	NS	NS	NS	NS	NS	NS

NS, **Nonsignificant or significant at $P \leq 0.01$, respectively.

Table 3. Branching, trunk cross-sectional area (TCSA), bloom, and yield of 3-year-old 'Gala' apple trees on three rootstocks subjected to various leader management treatments. Mean separations are not shown for the main effect when there is a significant interaction with the main effect.

	Total branches/ tree	TCSA (cm^2)		Flower clusters/ tree		Fruit yield/ tree (kg)	
Variable	1993	1993	1994	1992	1993	1993	1994
Location (L)							
Henderson	17.0	13.1 a	19.3	22	279 a	5.5 a	17.5
Haywood	15.8	6.0 c	11.4	5	138 b	3.6 b	2.6
Lincoln	12.8	8.8 b	12.7	4	155 b	3.7 b	10.0
Wilkes	15.3	10.2 b	16.1	8	144 b	2.4 c	9.5
Rootstock (R)							
Mark	16.7	9.7	14.0	5	183	3.3	8.8
M.26 EMLA	14.3	9.6	15.4	6	163	3.7	10.4
M.9 EMLA	14.7	9.2	15.2	18	190	4.5	10.5
Leader management (T)							
Snaking	17.9 a	9.4	14.7	10	202	4.0	10.6
H + PTLR	14.3 b	9.7	15.0	11	185	4.0	10.5
Weak leader	13.5 b	9.5	14.9	8	150	3.5	8.5
F significance							
L	NS	**	NS	NS	**	**	**
R	NS	NS	NS	NS	NS	NS	NS
L × R	NS	NS	**	**	NS	NS	NS
T	**	NS	NS	NS	NS	NS	**
R × T	NS	NS	NS	NS	NS	NS	NS
L × T	NS	NS	NS	NS	NS	NS	NS
L × R × T	NS	NS	NS	NS	NS	NS	**

NS, **Nonsignificant or significant at $P \leq 0.01$, respectively.

In general, there were fewer significant effects within the 'Gala' trees on different rootstocks, compared to the three cultivars on Mark (Tables 2 and 3). This result suggests that cultivars are more variable in their response to leader management, fumigation, and location than is a single cultivar on different size-controlling rootstocks.

We conclude that young apple trees can vary in their early branching, flowering, and fruit yield depending on cultivar, rootstock, fumigation, leader management, and location, just as was described for more northern climates (Ferree, 1994). However, these factors may be more critical under southeastern growing conditions because vigorous leader growth tends to reduce branching, limiting early flowering and ultimately reducing early yield potential. Leader management techniques that appear to be most successful in the southeastern states are those that do not require dormant pruning, vegetation removal, or both, but those that involve bending or physical manipulation of the leader, which may be aided by growth regulator usage.

Literature Cited

Barlow, H.W.B. and C.R. Hancock. 1960. The experimental modification of branch form in an apple rootstock. Bot. Gaz. 121:208–215.

Clayton-Greene, K.A. 1989. Apple production and tree training. Compact Fruit Tree 22:8–11.

Ferree, D.C. 1994. Early performance of two apple cultivars in three training systems. HortScience 29:1004–1007.

Ferree, D.C. and J.C. Schmid. 1994. Influence of training stakes and various pruning and bending techniques on early performance of 'Fuji' apple trees. Fruit Crops 1993: A summary of research, Ohio Agr. Res. & Dev. Ctr. Res. Circ.

Gale Research Co. 1984. Climate normals for the U.S. (base 1951–1980). First ed. Detroit.

Greene, D.W. and P. Miller. 1988. Effects of growth regulator sprays and notching on growth and branching of 'Starkrimson Delicious' apple trees. J. Amer. Soc. Hort. Sci. 113:18–23.

Hamzakheyl, N., D.C. Ferree, and F.O. Hartman. 1976. Effect of lateral shoot orientation on growth and flowering of young apple trees. HortScience 11:393–395.

Larsen, F.E. 1979. Chemical stimulation of branching in deciduous tree fruit nursery stock with ethyl 5-(4-chlorophenyl)-2*H*-tetrazole-2-acetate. J. Amer. Soc. Hort. Sci. 104:770–773.

Mullins, M.G. 1965. The gravitational responses of young apple trees. J. Hort. Sci. 40:237–247.

Myers, S.C. and D.C. Ferree. 1983. Influence of summer pruning and tree orientation on net photosynthesis, transpiration, shoot growth, and dry weight distribution in young apple trees. J. Amer. Soc. Hort. Sci. 108:4–9.

Oberhofer, H. 1990. Pruning the slender spindle. British Columbia Ministry Agr. & Fisheries, Summerland, Canada.

Peterson, A.B. 1989. Intensive orcharding. Good Fruit Grower, Yakima, Wash.

Sachs, T. and K.V. Thimann. 1967. The role of auxins and cytokinins in the release of buds from apical dominance. Amer. J. Bot. 54:136–144.

Shepherd, U.M. 1979. Effect of tree quality at planting on orchard performance. E. Malling Res. Sta. Bul. 1978. p. 40.

Strydom, D.K. 1993. Young apple tree training through year three. Compact Fruit Tree 26:12–14.

Tromp, J. 1970. Shoot orientation effects on growth and flower bud formation in apple. Acta. Bot. Necrol. 19:535–538.

Van Oosten, H.J. 1978. Effect of initial tree quality on yield. Acta Hort. 65:123–125.

Wertheim, S.J. 1978. Manual and chemical induction of side-shoot formation in apple trees in the nursery. Scientia Hort. 9:337–346.