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Pruning and Deblossoming Effects on Shoot Growth and Leaf Area of 'McIntosh' Apple Trees

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Abstract. **Fourteen-year-old 'McIntosh'/M 26 apple trees (*Malus domestica* Borkh.) were deblossomed, pruned, or deblossomed and pruned, and separated into different shoot and leaf types after harvest. Both deblossoming and pruning increased shoot growth; the former by increasing shoot numbers and the latter by increasing mean shoot length. In spite of differences in total shoot growth, there were no differences in the relative proportions of the 3 shoot types. Treatment did not affect total leaf area, but both deblossoming and pruning increased the proportion of shoot leaves with corresponding decreases in spur leaves.**

When all the shoots on an apple tree are considered collectively, there is a preponderence of short shoots (4, 5, 7, 8, 11), producing a skewed shoot-size distribution curve. This deviation from normal distribution is caused partially by the fact that there are 3 different kinds of apple shoots: terminal, lateral, and bourse (1, 2, 5, 10, 11). (Terminal shoots develop from terminal buds, lateral shoots develop from lateral buds on the previous season's shoots, and bourse shoots develop from buds at the base of a flower cluster.) The lateral and bourse shoots tend to be significantly shorter than the terminal shoots, and their inclusion results in high percentages of short shoots. Since some cultural practices affect shoot growth (1, 2, 3, 5, 11, 14, 18, 20, 21), it would seem that they also might affect shoot-size distribution and the relationships among the 3 types of shoots. This study was conducted in an effort to evaluate the effects of fruiting and pruning on: 1) total shoot growth of 'McIntosh' apple trees, 2) the size distribution of that shoot growth, and 3) the leaf surface associated with the various types of shoots.

Materials and Methods

1982. In mid-August, six 13-year-old 'Imperial McIntosh'/M 26 apple trees in a 2.4 × 2.4 × 4.8 m offset double-row planting were selected for uniformity on the basis of trunk cross-sectional (CS) area. All shoots were removed from each tree and separated into terminal, lateral, and bourse shoots; the length of each shoot was measured to the nearest cm. Extension growth less than 3 cm in length was considered a spur. The leaves were collected from each type of shoot, and all spur leaves also were removed. One major scaffold branch from each tree (about 15% of the total bearing surface) was sampled separately. The leaves of each of the 4 types (terminal shoot, lateral shoot, bourse shoot, and spur) from this branch were counted. The area of all leaves from 10 representative shoots of each type and from 10 spurs was determined with an area planimeter. Then, all leaves and shoots were oven-dried and weighed. The total number of leaves/tree was estimated from mean leaf weights, which were derived from the sample branch and total leaf weights for the tree. Total leaf areas were estimated from mean leaf areas, derived from the sample branch and estimated total leaf numbers.

1983. In late winter, 20 trees from the same planting used in 1982 were selected for uniformity on the basis of trunk CS area. These trees received uniform pruning and fertilization (and produced comparable crops) in 1982. Four whole-tree treatments were assigned in a randomized block design with 5 replicates. The treatments included an untreated control, deblossoming, pruning, and deblossoming + pruning. The pruning was completed in late winter and was limited to a moderate thinning-out. In deblossoming, the blossom clusters were pinched out by hand at the pink stage of development. During the first week of September, the fruits were harvested, counted, and weighed. After harvest, all shoots and leaves were removed, separated, measured, dried, and weighed as described previously for 1982.

Results

1982. The distribution of shoot numbers among the 3 types was approximately 1 terminal: 1 lateral: 1 bourse. The terminal shoots were longest, laterals intermediate, and bourse shoots shortest. When all shoots were combined, shoot-size distribution was similar to that previously reported (11). When considered separately, however, the terminal shoots approached normal distribution, but both lateral and bourse shoots had relatively high percentages of short shoots (Fig. 1).

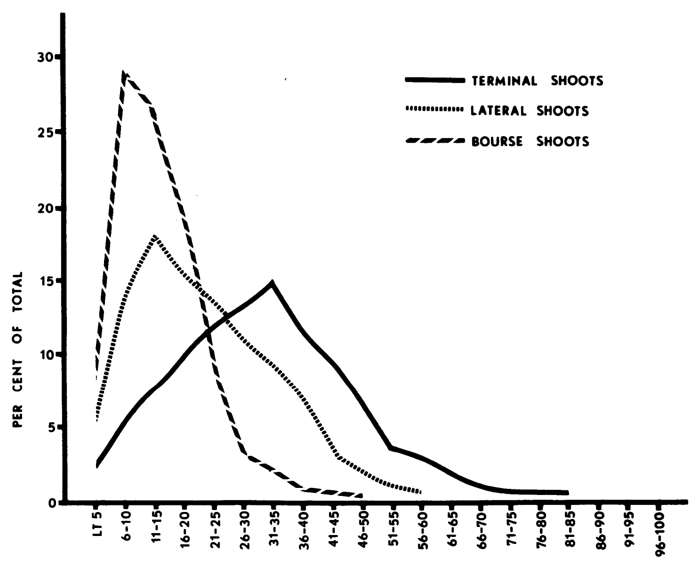

Fig. 1. Shoot-size distribution of terminal, lateral, and bourse shoots of 'McIntosh' apple trees.

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Table 1. Effects of pruning and deblossoming on shoot growth of 'McIntosh' apple trees.

Measurement	Unpruned		Pruned	
	Fruiting	Deblossomed	Fruiting	Deblossomed
Terminal shoots				
Number/tree	125 b[z]	255 a	179 ab	198 ab
Total growth/tree (m)	38.1 b	79.6 a	62.5 a	71.3 a
Mean length (cm)	30.4 b	31.2 ab	34.9 ab	36.1 a
Total dry wt./tree (g)	345 b	685 a	468 ab	719 a
Mean dry wt. (g)	2.75 a	2.69 a	2.62 a	3.64 a
Lateral shoots				
Number/tree	94 b	184 a	111 b	120 b
Total growth/tree (m)	20.3 b	46.0 a	31.5 ab	36.2 ab
Mean length (cm)	21.5 c	25.0 b	28.5 ab	30.3 a
Total dry wt./tree (g)	112 b	309 a		
Mean dry wt. (g)	1.19 c	1.68 b	1.70 b	2.64 a
Bourse shoots				
Number/tree	167 b	241 a	210 ab	165 b
Total growth/tree (m)	22.4 b	38.5 a	32.2 ab	36.5 a
Mean length (cm)	13.4 b	15.9 ab	15.3 ab	22.1 a
Total dry wt./tree (g)	97 b	208 ab	150 ab	253 a
Mean dry wt. (g)	0.58 c	0.86 b	0.71 ab	1.53 a
Total shoots				
Number/tree	386 b	680 a	500 b	483 b
Total growth/tree (m)	80.8 b	164.1 a	126.2 a	144.0 a
Total dry wt./tree (g)	554 b	1202 a	806 b	1287 a

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

Table 2. Effects of pruning and deblossoming on the relative proportions of terminal, lateral, and bourse shoots of 'McIntosh' apple trees.

Measurement and shoot type	Proportion in % of total[z]			
	Unpruned		Pruned	
	Fruiting	Deblossomed	Fruiting	Deblossomed
Shoot numbers				
Terminal shoots	32.4 a[y]	37.5 a	35.8 a	41.0 a
Lateral shoots	24.4 a	27.0 a	22.1 a	24.8 a
Bourse shoots	43.2 a	35.5 a	42.1 a	34.2 a
Shoot growth (length)				
Terminal shoots	47.1 a	48.5 a	49.5 a	49.5 a
Lateral shoots	25.1 a	28.1 a	24.9 a	25.1 a
Bourse shoots	27.8 a	23.4 a	25.6 a	25.4 a
Shoot dry wt				
Terminal shoots	62.2 a	57.0 a	58.0 a	55.9 a
Lateral shoots	20.3 a	25.7 a	23.3 a	24.5 a
Bourse shoots	17.5 a	17.3 a	18.7 a	19.6 a

[z]Transformed to arcsin for analysis.
[y]Mean separation within rows by Duncan's multiple range test, 5% level.

Shoot leaves comprised 46.9% of the total number, but since they were larger than the spur leaves (12), they accounted for 55.7% of the total leaf area.

1983. The fruiting trees produced a heavy crop. The average yield/tree was 70.7 kg, which is more than 4000 boxes/ha at this spacing. Pruning reduced fruit numbers by 25.9%, but increased fruit size by 9.7%. The net effect was a reduction in yield of 18.7%.

In comparison with fruiting-unpruned trees, deblossoming alone increased the numbers of all 3 types of shoots and increased total shoot growth in either length or weight (Table 1). Although there was little effect on mean shoot length, there were increases in mean dry weight of lateral and bourse shoots. Pruning alone, as compared with the untreated control, had no effect on shoot numbers. It did, however, increase terminal shoot and total shoot growth, mean length of lateral shoots, and mean weight of lateral and bourse shoots. Pruning + deblossoming, again in comparison with fruiting-unpruned trees, did not affect shoot numbers. Rather, it increased the growth of terminal, bourse, and total shoots, and total weight of all shoots. Pruning + deblossoming also increased mean length of all shoots and mean dry weight of lateral and bourse shoots.

There was some variability, but the relative proportions of the 3 types of shoots again approached a 1:1:1 distribution (Table 2). Treatment had no significant effect on this distribution. Even though the terminal shoots accounted for only about ⅓ of

Table 3. Effects of pruning and deblossoming on shoot size distribution of 'McIntosh' apple trees.

Shoot length categories	Size distribution in % of total[z]			
	Unpruned		Pruned	
	Fruiting	Deblossomed	Fruiting	Deblossomed
Terminal shoots				
<10 cm	6.1 a[y]	3.4 ab	1.1 b	2.1 b
10-30 cm	46.2 a	47.1 a	32.0 b	36.5 ab
>30 cm	47.7 b	49.5 b	66.9 a	61.4 ab
Lateral shoots				
<10 cm	19.1 a	11.6 ab	8.9 b	5.9 b
10-30 cm	58.1 a	54.4 ab	48.5 ab	43.8 b
>30 cm	22.8 c	34.0 b	42.6 ab	50.3 a
Bourse shoots				
<10 cm	38.5 a	30.0 ab	29.3 ab	14.6 b
10-30 cm	58.7 a	65.1 a	63.0 a	62.2 a
>30 cm	2.8 b	4.9 b	7.7 b	23.2 a
All shoots				
<10 cm	23.2 a	15.2 b	16.6 b	7.5 c
10-30 cm	54.5 a	55.5 a	50.8 a	47.5 a
>30 cm	22.3 b	29.3 b	32.6 ab	45.0 a

[z]Transformed to arcsin for analysis.
[y]Mean separation within rows by Duncan's multiple range test, 5% level.

Table 4. Effects of pruning and deblossoming on leaf numbers, leaf area, and leaf dry weight of 'McIntosh' apple trees.

Measurement	Unpruned		Pruned	
	Fruiting	Deblossomed	Fruiting	Deblossomed
Terminal shoot leaves				
Number/tree	2055 b[z]	3745 a	2944 ab	3512 a
Total area/tree (m^2)	5.61 b	9.96 a	8.42 ab	10.85 a
Mean area (cm^2)	27.3 a	26.6 a	28.6 a	30.9 a
Total dry wt./tree (g)	645 b	1289 a	900 ab	1174 a
Mean dry wt. (g)	0.32 a	0.34 a	0.31 a	0.33 a
Lateral shoot leaves				
Number/tree	1155 c	2167 ab	1665 bc	2786 a
Total area/tree (m^2)	2.37 c	4.18 b	3.51 bc	6.63 a
Mean area (cm^2)	20.5 ab	19.3 b	21.1 ab	23.8 a
Total dry wt./tree (g)	257 b	559 ab	374 b	695 a
Mean dry wt. (g)	0.22 a	0.26 a	0.23 a	0.25 a
Bourse shoot leaves				
Number/tree	1349 b	2142 ab	2053 ab	2574 a
Total area/tree (m^2)	2.72 b	4.56 ab	3.76 ab	5.43 a
Mean area (cm^2)	20.2 a	21.3 a	18.3 a	21.1 a
Total dry wt./tree (g)	309 b	495 ab	444 ab	566 a
Mean dry wt. (g)	0.23 a	0.23 a	0.22 a	0.22 a
Total shoot leaves				
Number/tree	4559 b	8054 a	6662 ab	8872 a
Total area/tree (m^2)	10.70 c	18.70 b	15.69 bc	22.91 a
Total dry wt./tree (g)	1220 b	2343 a	1718 ab	2435 a
Spur leaves				
Number/tree	12,782 a	7359 b	8490 ab	6261 b
Total area/tree (m^2)	16.23 a	12.88 ab	11.46 b	12.15 ab
Mean area (cm^2)	12.7 b	17.5 ab	13.5 b	19.4 a
Total dry wt./tree (g)	1998 a	1419 ab	1236 b	1211 b
Mean dry wt. (g)	0.16 ab	0.19 a	0.15 b	0.19 a
Total leaves				
Number/tree	17,341 a	15,413 a	15,152 a	15,133 a
Total area/tree (m^2)	26.93 b	31.58 ab	27.15 b	35.06 a
Total dry wt./tree (g)	3218 a	3762 a	2954 a	3646 a

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

Table 5. Effects of pruning and deblossoming on the relative proportions of shoot and spur leaves of 'McIntosh' apple trees.

Measurement	Proportion in % of total[z]			
	Unpruned		Pruned	
	Fruiting	Deblossomed	Fruiting	Deblossomed
Leaf numbers				
Terminal shoot leaves	11.8 b[y]	24.3 a	19.4 ab	23.2 a
Lateral shoot leaves	6.7 c	14.1 ab	11.06 b	18.4 a
Bourse shoot leaves	7.8 b	13.9 a	13.5 a	17.0 a
Total shoot leaves	26.3 b	52.3 a	43.9 a	58.6 a
Spur leaves	73.7 a	47.7 b	56.1 ab	41.4 b
Leaf area				
Terminal shoot leaves	20.8 a	31.5 a	31.0 a	30.9 a
Lateral shoot leaves	8.8 b	13.3 ab	13.0 ab	18.9 a
Bourse shoot leaves	10.1 b	14.4 ab	13.8 ab	15.5 a
Total shoot leaves	39.7 b	59.2 ab	57.8 ab	65.3 a
Spur leaves	60.3 a	40.8 ab	42.2 ab	34.7 b
Leaf dry weight				
Terminal shoot leaves	20.3 b	34.3 a	30.5 ab	32.2 ab
Lateral shoot leaves	8.0 b	14.9 ab	12.7 ab	19.1 a
Bourse shoot leaves	9.6 b	13.1 ab	15.0 a	15.5 a
Total shoot leaves	37.9 b	62.3 a	58.2 a	66.8 a
Spur leaves	62.1 a	37.7 b	41.8 ab	33.2 b

[z]Transformed to arcsin for analysis.
[y]Mean separation within rows by Duncan's multiple range test, 5% level.

the shoot numbers, terminal shoots contributed about ½ of the total growth in length and almost ⅔ of the total dry weight. Distribution was not affected by treatment in either area (length or weight).

In the untreated control, shoot size distribution approached that of 1982 (Fig. 1). As shoot growth increased in response to treatment, however, shoot size distribution was altered significantly. The percentage of short shoots (< 10 cm) decreased from 23.2% to 7.5%, and the percentage of long shoots (> 30 cm) increased from 22.3% to 45.0% (Table 3). The effect of treatment on mean shoot length was not uniform among the 3 shoot types (Tables 1, 3). The greatest difference in mean terminal shoot length was 5.7 cm (18.8%); corresponding differences for lateral and bourse shoots were 8.8 cm (40.9%) and 8.7 cm (64.9%), respectively.

Deblossoming alone had no effect on the total number of leaves/tree, but it increased the numbers of terminal, lateral, and bourse shoot leaves while reducing the number of spur leaves (Tables 4, 5). There were also increases in dry weight and area of terminal and total shoot leaves, but there was no effect on mean leaf weight or mean leaf area. As compared with the untreated control, pruning alone reduced the total weight and total area of spur leaves. Pruning + deblossoming, in comparison with fruiting-unpruned trees, increased the numbers of terminal, lateral, and bourse shoot leaves and reduced the number of spur leaves. There was no effect of pruning + deblossoming on the total number of leaves/tree, but both leaf weight and leaf area were increased for all 3 shoot types. Mean area of the spur leaves was increased by this treatment.

Discussion

It is well established that fruiting reduces shoot growth of apple trees. Nevertheless, the evaluation of this response sometimes is complicated by the effects of the previous crop (11, 16, 19, 23), as well as the current crop (2, 3, 4, 5, 14, 18). In this study, both deblossoming and pruning increased shoot growth, but not in the same manner. The elimination of the crop increased the number of shoots/tree, but had little effect on shoot length; in contrast, pruning had no effect on shoot numbers, but increased mean shoot length. There was a strong interaction between pruning and deblossoming. Pruning alone was relatively ineffective, and substantial differences in shoot growth were recorded only when pruning was combined with deblossoming. It must be emphasized, however, that this was a moderate pruning with the cuts limited to thinning-out. Severe pruning, or heading-back rather than thinning-out cuts, might have produced significantly different results. Some previously reported responses have been associated with rather severe pruning (4, 5).

Shoot-size distribution curves are dominated by high percentages of short shoots. In this study the terminal shoots consistently were about 50% longer than the lateral shoots, which, in turn, were about 50% longer than bourse shoots. Despite large differences in shoot numbers (75.9%) and total shoot growth (103.2%), there were no differences in the relative proportions of terminal, lateral, and bourse shoots (Table 2). Increased shoot growth changed shoot-size distribution significantly (Table 3), with decreases in the percentage of short shoots and increases in the long shoots. Nonetheless, these changes were due to increases in the mean length of all types of shoots, not to changes in their relative proportions.

In agreement with previous results (11), total shoot growth/tree was more closely related to shoot numbers than to mean shoot length. The coefficients of correlation between total shoot growth/tree and numbers of shoots/tree were 0.94, 0.93, 0.78, and 0.89 for terminal, lateral, bourse, and total shoots, respectively. Corresponding values for the relationship with mean shoot length were 0.27, 0.52, 0.34, and 0.20.

The differences in shoot growth associated with these treatments had little effect on total leaf canopy. There was no effect on total leaf numbers, and total leaf area was increased in the deblossomed + pruned treatment only. As previously reported, the spur leaves were smaller than the shoot leaves (12), and lateral and bourse shoot leaves were smaller than terminal shoot leaves. Others have reported reductions in leaf size associated with fruiting (2, 9, 13, 15, 22), but in this study, such reductions in leaf size were limited to spur leaves. Still other investigators have found wide ranges in the relative proportions of shoot and spur leaves (6, 17), and there were large differences between treatments in this relationship in this study (Table 5). Both deblossoming and pruning reduced the number of spur leaves while proportionately increasing the number of shoot leaves, undoubtedly reflecting the effect of treatment on shoot growth. Any growing point may elongate and become a shoot, or it may fail to elongate, remaining short with small leaves and being considered a spur (14, 18). Consequently, increases in the number of shoots invariably result in decreases in spur leaves.

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