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GROWTH ACTIVITY OF APPLE TREES DEPENDING ON THE METHOD AND TIMING OF CROWN PRUNING

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ABSTRACT

The apple tree is one of the most widespread fruit crops in the world. As the area of plantings increases and horticulture transitions to intensive technologies, the demand for skilled workers increases. The introduction of mechanization processes can solve this problem at all stages of fruit production. The aim of this study was to investigate the effect of contour pruning and its modification at different times on the growth of 'Jonaweld' apple trees grafted onto the dwarf rootstock M.9 T337. As a result of contour pruning, the trunk diameter increased by 61% and the number of shoots by 40%. Contour pruning with manual refinement produced intermediate results between manual and contour pruning. Furthermore, contour pruning produced the shortest shoots, only 22 cm, compared to 29 cm with manual pruning. There was also a general tendency to limit the growth activity of trees due to postponing pruning. The growth of trunk diameter slowed by 25%, the number of shoots decreased by 8%, and their length decreased by 20%. Specific productivity was highest when contouring with postharvest refinement and pruning.

Key words: contour pruning, mechanical pruning, manual pruning, growth

INTRODUCTION

Typically, mechanical pruning is used in plantations of several fruit crops such as bush berries, grapes, and citrus. Temperate fruit crops usually require detailed pruning in the middle of the crown, which can be achieved by manual pruning. Pruning fruit trees is complex and expensive, requiring approximately 80–120 hours of skilled labor per hectare. Manual pruning is a labor-intensive and expensive agricultural procedure in apple production that can be replaced, at least partially, by mechanical pruning (Zahid et al. 2020).

Since the 1960s, industrial horticulture has been developing technology for mechanized pruning of fruit crops. The first mechanisms for this purpose were reported by Childers (1983), marking a significant milestone in the evolution of agricultural practices. These mechanisms, which comprise a series of tractor-powered blades, remove part of the branches on the periphery of the crown, imitating traditional manual pruning. Citrus crops (lemon, orange, grapefruit) and olive trees, which do not require detailed pruning in the middle of the crown, are more adapted to this type of pruning (Peça et al. 2002; Bordas et al. 2012; Dias et al. 2012). The first studies on the effect of mechanical pruning on fruit trees showed positive results, with the exception of a deterioration in fruit quality due to crushing, which was particularly noticeable in the case of peaches (Loreti 1971). In the case of apple trees, mechanical pruning gave negative results due to excessive peripheral growth. However, as industrial horticulture shifted from vigorous trees to small-sized crowns and the number of agricultural workers decreased, researchers began to take a new look at mechanized processes in fruit production (Miranda Sazo & Robinson 2013).

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Current studies show that mechanical pruning significantly reduces production costs (Velázquez Martí & Fernández González 2010) and increases yields, especially of plums, even though the fruits are smaller (Krueger et al. 2013) and require thinning. This disadvantage can be corrected by combining mechanical and manual pruning, which in the case of citrus fruit provides an increase in yield of 30 kg per tree (Velázquez Martí & Fernández González 2010). However, the results of different researchers show contradictory data on the effects of mechanical pruning on different crops over several years of application (Yildirim et al. 2010; Martin-Gorriz et al. 2014).

The timing of pruning is a critical factor that can significantly affect plant growth and maturation. Research by Chaploutskyi et al. (2023a) highlights the importance of this issue. Pruning too early can affect carbon storage, while pruning too late can stimulate the growth of new shoots that will not mature before winter (Flore 1992). Depending on the region, the most optimal time for early summer pruning is when newly formed shoots have 8–12 leaves. As a result, short shoots are formed in summer, the growth of which is weakened after several years of summer pruning (Chaploutskyi et al. 2021). However, genetic characteristics and the level of agricultural technology in the orchard must be taken into account to avoid excessive growth (Stebbins 1992). According to research by Poldervaart (2011), after mechanical pruning of trees, fruits become 2–3 mm smaller in diameter over time. This, however, has a positive effect on large-fruited triploid cultivars, demonstrating the potential benefits of this technique. Pruning apple trees during the growing season significantly reduces growth activity, which results in a reduction in the crown size (Chaploutskyi et al. 2023b).

The latest research aims to develop technology that ensures speed of work and correct pruning (Al-Gezawe et al. 2023).

MATERIALS AND METHODS

The study of methods and dates of pruning small crowns of apple trees was conducted in 2014–2016 in the experimental orchard of the Uman National University of Horticulture (48°46′06″N, 30°14′27″E). The orchard was established in spring 1995 with annual 'Jonaweld' ('First Red') trees grafted onto the dwarf M.9 T337 rootstock. The planting scheme was 4 × 1 m and the soil type was black sod-podzolic. The soil maintenance system in the aisles included sod-humus. Herbicides and drip irrigation were applied to the tree rows. Weather and climatic conditions during the experiment were typical for the region (Table 1).

Table 1. Average monthly weather conditions during the experiment period (2014–2016)

Month	Precipitation			Temperature			Relative air humidity		
	2014	2015	2016	2014	2015	2016	2014	2015	2016
1	48.3	37.5	74	-3.9	-1.4	-5.6	85	89	85
2	5.3	20.2	59.5	-1.9	-1.1	2.4	87	81	82
3	15.7	54.7	26.9	6.6	4.1	4.5	65	72	74
4	100	69.2	31.8	9.7	8.7	12.3	72	63	64
5	125.5	40.3	114.4	16.1	15.6	14.7	73	66	72
6	73	114.1	73.7	17.5	19.3	20.1	72	64	73
7	52.9	47.9	15.8	21.5	21.3	21.6	70	68	67
8	15.6	17.3	27.9	20.8	21.2	20.7	65	60	68
9	82.6	37.6	6.7	14.8	17.7	15.7	68	71	65
10	35.7	22.9	87	6.4	6.9	6.5	74	70	78
11	29.7	47.2	49.2	1.8	4.6	1.7	85	84	85
12	23.2	7.9	33.2	-2	1.7	-1.9	89	83	85

Experimental design

The experiment studied the effect of two factors: three methods of crown pruning and five pruning times. The trees were pruned at different times: in winter (0 points on the BBCH scale – "Biologische Bundesanstalt, Bundessortenamt und CHemische Industrie"), at the pink bud phase (BBCH 57), flowering (BBCH 65), in the early summer when 10 leaves had formed on new shoots (BBCH 74) and after harvest (BBCH 93). Three types of pruning were used at each time: manual, contouring with the formation of a fruit wall 80 cm wide in the lower part and 50 cm in the upper part, and contouring the crown periphery with manual refinement (Fig. 1). Manual refinement consisted of cutting the space between trees in the row, removing too thick branches in the upper part of the crown, low branches, and branches in the trunk zone.

The imitation of machine contour pruning was performed manually, using specially developed templates to observe the given dimensions of the crown.

Phytometric parameters were recorded in accordance with the generally accepted recommendations and methodology of Kondratenko and Bublyk (1996). Growth parameters were recorded at the end of the growing season. The increase in trunk diameter was recorded as the difference of value between adjacent years, measured with a caliper at the height of the trunk 30 cm from the soil level in two perpendicular projections, and then determined as an average value. The length and number of annual shoots longer than 5 cm were measured after the end of growth from the beginning of the annual increment to the tip of the shoot cone. Total shoot length was calculated by multiplying the average shoot length by the total number of shoots on the tree.

Statistical analysis

Factors were three crown pruning methods and five pruning dates with three replications of 5 trees per replication. Data are presented in tables based on annual averages and standard deviations. All data were subjected to analysis of variance using Statistica 10. Values between pairs of options were compared using Tukey's test ($p = 0.05$). The graphs show the long-term mean values of the variables throughout the experiment and the standard deviations. Direct correlation throughout the experiment was determined by comparing annual mean values using the Pearson method with an error level of $p = 0.01$.

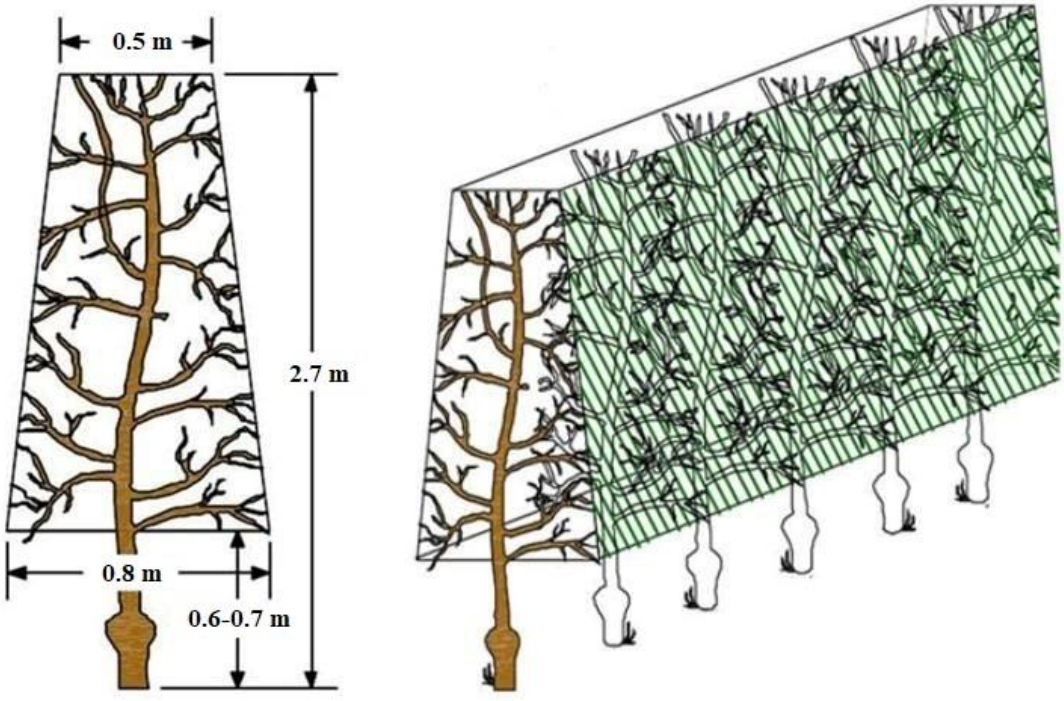

Figure 1. Formation of fruit walls as a result of contour pruning

RESULTS AND DISCUSSION

Crown pruning of 'Jonaweld' apple trees grafted onto the M.9 T337 dwarf rootstock affected growth activity depending on the method used. Contour pruning resulted in the highest number of shoots and trunk diameter, and a high total shoot length per tree compared with traditional manual pruning. Contour pruning with manual refinement also affected the above traits, but the values were lower than those of mechanical pruning. On average, shoots were longer after manual pruning, but the total shoot length per tree was the lowest due to the low number of shoots (Table 2, Fig. 2). Significantly fewer shoots were formed on trees that were pruned manually, forming a slender, spindle-shaped crown. However, the length of these increments is mutually inverse to their number. As the number of shoots increased with the contour pruning method and the contour pruning method with manual refinement, the increments were significantly shorter than with traditional manual pruning. A correlation was proven (Table 3) between the number of shoots and the increase in stem diameter. A reduction in shoot growth strength was also demonstrated in the studies by Masseron (2002) and Meekers (2010).

Table 2. Apple tree growth parameters depending on the method and timing of crown pruning (average value from 2014–2016)

Pruning method	Pruning time	Increase in trunk diameter (mm)	Number of shoots (pcs.)	Shoot length (cm)	Total shoot length (m per tree)
Manual	winter	3.8±0.2 cdef	47±1 de	32.4±1.5 a	15.1±0.3 abc
	pink bud	3.3±0.1 efgh	50±3 cde	29.6±0.6 b	14.9±0.6 abce
	flowering	3.1±0.3 fgh	47±3 def	29.1±0.4 b	13.6±0.5 cef
	early summer	2.5±0.2 h	40±1 f	27.7±0.5 bc	11.1±0.3 g
	after harvesting	2.7±0.3 gh	43±1 ef	26.0±0.6 cd	11.1±0.3 g
Contouring	winter	5.7±0.1 a	67±9 a	25.7±0.8 cde	17.1±1.8 a
	pink bud	5.5±0.5 a	65±4 a	23.7±0.6 efg	15.5±0.7 abc
	flowering	4.9±0.4 ab	62±6 ab	21.8±0.4 gh	13.6±1.3 cefg
	early summer	4.4±0.2 bc	60±3 abc	19.0±0.5 i	11.5±0.8 fg
	after harvesting	4.3±0.7 bcd	62±4 ab	20.4±0.9 hi	12.6±1.3 efg
Contouring with manual refinement	winter	4.6±0.3 bc	60±3 ab	27.7±0.8 bc	16.7±0.5 ab
	pink bud	3.9±0.2 cdef	62±2 ab	26.3±1.1 cd	16.3±1.0 ab
	flowering	3.9±0.2 cde	57±2 abcd	25.6±0.7 cde	14.5±0.3 bce
	early summer	3.5±0.4 defg	55±1 bcd	23.1±0.3 fg	12.6±0.1 efg
	after harvesting	3.5±0.2 defg	54±2 bcd	24.6±0.4 def	13.2±0.7 cefg

Mean values (mean ± SD) of indicators, the presence of the same letters in a pair of variants indicates no statistically significant difference according to Tukey's test ($p \geq 0.05$)

Table 3. Linear correlation coefficients between measured traits (n =15)

Trait	Number of shoots	Shoot length	Total shoot length	Increase in stem diameter	Specific productivity per trunk cross-section	Specific productivity per annual growth length
Number of shoots	1					
Shoot length	-0.56	1				
Total shoot length	0.55	0.38	1			
Increase in stem diameter	0.91*	-0.40	0.59*	1		
Specific productivity per trunk cross-section	-0.14	-0.66*	-0.79*	-0.36	1	
Specific productivity per annual growth length	0.01	-0.44	-0.37	-0.33	0.83*	1

*significant coefficients

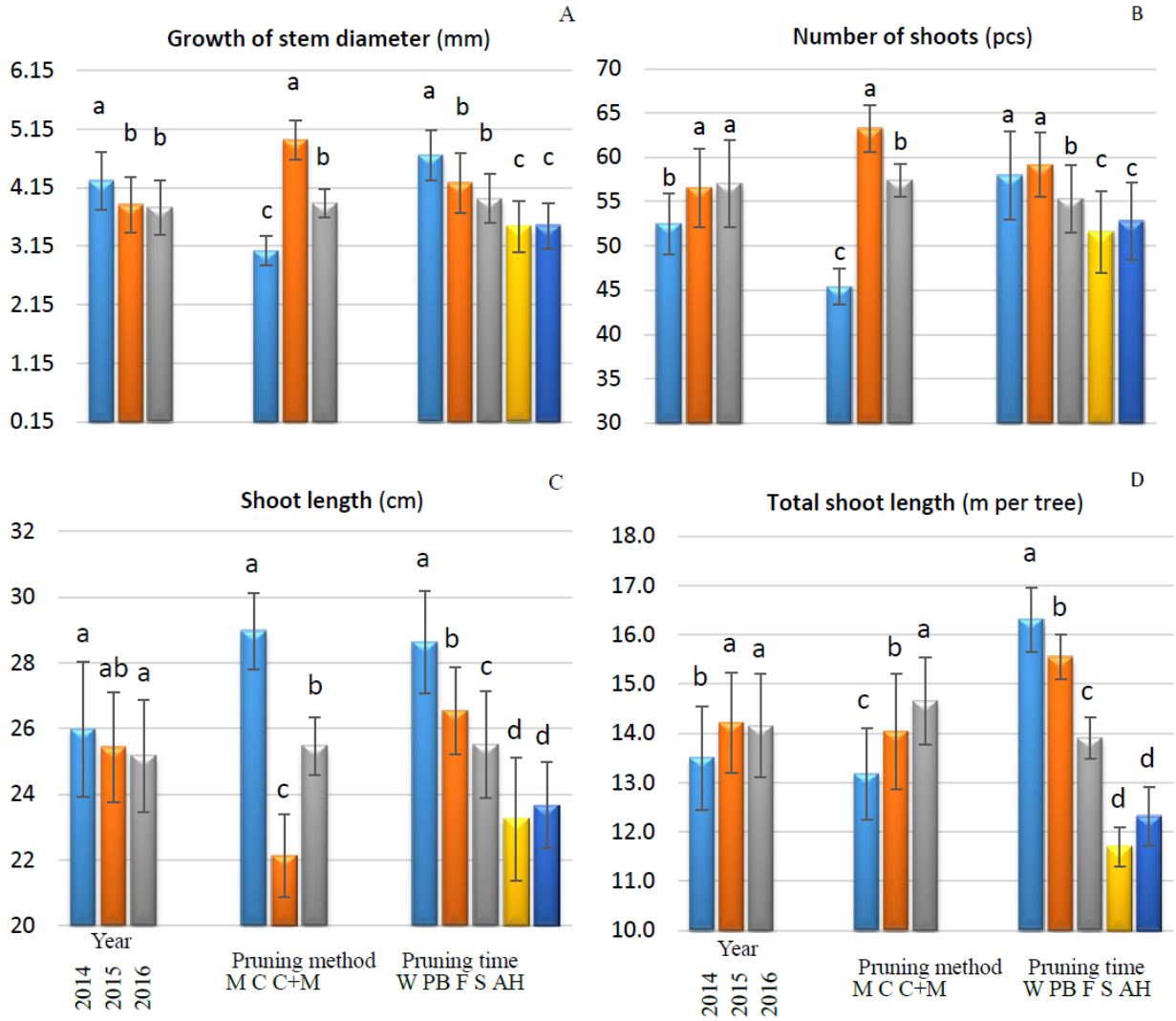

Figure 2. Productivity of 'Jonaweld' apple trees depending on the studied factors

Pruning method: M – manual, C – contour, C+M – contour with manual refinement; Pruning time: W – winter, PB – pink bud phase, F – flowering, S – early summer, AH – after harvest; Mean values (mean ± SD); The presence of the same letters in a pair of variants indicates no statistically significant difference according to Tukey's test ($p \geq 0.05$)

Despite the increase in shoot length with traditional manual pruning, their total length was significantly inferior to those with contour pruning and contour pruning with manual refinement. As a result of using contour pruning, the total shoot length increased by 7% compared to traditional manual pruning, and the implementation of manual contour pruning contributed to an increase in the total shoot length by 11%.

Our research has practical implications for plant cultivation. We found that the highest values of growth parameters were obtained during winter pruning, and these values decreased with the postponement of pruning from pink buds to after harvest. The timing of pruning had a decisive influence on shoot growth activity. Crown pruning in winter or at the beginning of the growing season increased the number and length of shoots. However, with the delay of crown pruning, the values of the indicators decreased. These findings can help horticulturists and plant cultivation professionals make informed decisions about the timing and method of pruning.

Understanding the effect of pruning time on plant growth is essential for effective agricultural practices. Late pruning limits the formation of strong growth processes, leads to the development of shorter shoots, and reduces overall growth activity. This knowledge can guide farmers and botanists in optimizing pruning schedules.

Due to the use of organic substances by plants for the formation of flowers, ovaries, and then

crops, plants have less opportunity to form vital growth processes in the second half of the growing season. Therefore, late pruning leads to shorter shoots and reduced overall growth activity. Miranda Sazo and Robinson (2013) tested summer mechanical pruning of several apple cultivars. According to their results, the light distribution in the lower part of the trees improved by 10% and the shoots were shorter with the formation of flower buds at the end, which contributed to higher yields the following year.

Contour pruning with manual refinement proved to be highly effective, leading to a considerable 25% increase in specific productivity per trunk cross-section (Table 4, Fig. 3). This significant increase in productivity is consistent with the findings of Mika et al. (2016), further confirming the potential of contour pruning to increase apple yields.

Table 4. Specific productivity of apple trees depending on the method and timing of crown pruning (average values from 2014–2016)

Pruning method	Pruning time	Specific productivity per trunk cross-section ($kg \cdot cm^{-2}$)	Specific productivity per annual growth length ($kg \cdot m^{-1}$)
Manual	winter	0.23±0.06 i	0.53±0.14 i
	pink bud	0.27±0.05 fghi	0.62±0.11 ghi
	flowering	0.26±0.05 ghi	0.67±0.11 fghi
	early summer	0.29±0.02 defgh	0.88±0.04 bcd
	after harvesting	0.32±0.02 bcde	0.98±0.08 ab
Contouring	winter	0.24±0.03 hi	0.57±0.04 hi
	pink bud	0.27±0.02 fghi	0.69±0.04 efgh
	flowering	0.28±0.03 efgh	0.79±0.02 def
	early summer	0.30±0.03 cdefg	0.98±0.01 ab
	after harvesting	0.32±0.03 bcdef	0.94±0.05 abc
Contouring with manual refinement	winter	0.28±0.02 defgh	0.63±0.04 ghi
	pink bud	0.34±0.04 abc	0.76±0.08 defg
	flowering	0.33±0.05 abcd	0.82±0.10 cde
	early summer	0.36±0.03 ab	1.02±0.04 a
	after harvesting	0.38±0.02 a	1.01±0.01ab

Note: see Table 2

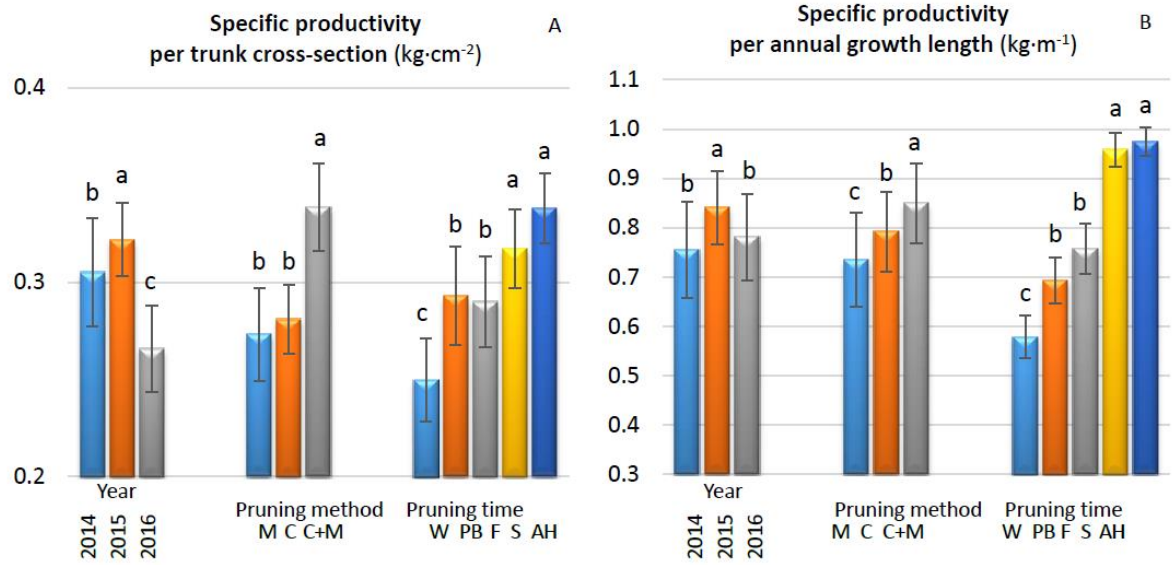

Figure 3. Specific productivity of 'Jonaweld' apple trees depending on the studied factors

Note: see Figure 2

Reduction in lateral trunk growth with increased productivity due to delayed pruning contributed to the increase in specific productivity values per trunk cross-section. The lowest value was found for winter pruning (0.25 kg·cm^{-2}). Pruning trees during the pink bud and flowering phases, as well as between early summer and postharvest prunings, was not significant.

The use of contour pruning with manual refinement increased yield by increasing the specific productivity index values for shoot length. Contour pruning increased by 6% and contour pruning with manual refinement by 15% compared to traditional manual pruning. Increased yields and reduced apical shoot growth also increased the specific productivity value per shoot length due to delayed pruning. There was also no significant difference in the indicator value when trees were pruned at the pink bud and flowering phase, in early summer and after harvest.

CONCLUSIONS

Pruning fruit trees is one of the main agrotechnical factors that can improve lighting and ventilation of the crown. Contour pruning produced more, but short shoots on the periphery of the crown (by 40%). A correlation has been proven between the number of shoots, total shoot length, and the increase in trunk diameter. By performing contour pruning with manual refinement and removing excess branches inside the crown, the illumination of the middle part of the crown is improved and the shortcomings of contour pruning can be corrected. Delayed pruning is a strategic approach that allows to influence the growth processes, enhance them or inhibit them, depending on the fruit load of the trees. It plays a crucial role in maintaining the balance between the growth and fruiting processes, emphasizing the importance of this equilibrium.

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