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Influence of Time of Thinning on Yield, Fruit Quality and Return Flowering of 'Fuji' Apple.

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Abstract

A study conducted over two growing seasons examined the effect of time of hand thinning of 6-year-old 'Fuji'/M.9Nagano apple trees on fruit quality and yield at harvest in 1999 and return flowering, yield and fruit quality in 2000. Primary thinning (PT) at 7, 17, or 28 days after full bloom (AFB), in combination with secondary thinning (ST) at 60 days AFB (when crop load was adjusted to a uniform level based on one fruit for every 55 leaves) proved effective for obtaining 300 g fruit at harvest. Trees receiving PT at 7, 17, 28 and 37 days AFB followed by ST at 60 days AFB showed at least 50 % of the fruits larger than 300 g at harvest in 1999. No thinning, primary thinning applied later than 37 days AFB, or ST only applied at 60, 74, or 94 days AFB failed to result in the 300 g average fruit weight standard. However, only the no thinning treatment resulted in reduced soluble solids levels at harvest. Flower buds as a percent of total terminal buds in 2000 ranged from 2 to 75% and was clearly related to time of primary thinning in 1999. Primary thinning as late as 28 days AFB resulted in adequate return flowering. All trees involved in the 1999 trial were thinned in 2000 with PT at 30 days AFB followed by ST at 60 days AFB. This resulted in 2000 yields ranging from 5 to 166% of those recorded in 1999, depending on the 1999 thinning regime. Only the trees receiving primary thinning by 28 days AFB exceeded yields obtained in 1999. In conclusion, this trial shows that PT within 28 days AFB in combination with ST for deciding crop load within 60 days AFB is the desirable practice for obtaining large size (around 300 g) quality fruits and enough return flowering for full cropping of 'Fuji' /M.9 apple trees at Nagano, Japan.

Introduction

The production of 'Fuji' apples is increasing dramatically in China and in many other countries (1, 3, 6, 8, 10). Although 'Fuji' has outstanding attributes including superb eating quality and storability, it has some weakness. A tendency toward alternate bearing has been observed wherever 'Fuji' is grown (4, 5, 9, 11, 12). Early thinning is thought to be important to prevent alternate bearing of 'Fuji' apples in Japan (5).

In Japan, primary thinning consists of removing all flowers and fruitlets arising from axillary buds on one-year wood and leaving only fruits in the king flower position on all other clusters. It is recommended that this be done within 30 days AFB by hand in conjunction with a chemical thinning regime. Lime-sulfur for flower thinning, and carbaryl, a chemical fruitlet thinner, have been used in combination with hand thinning. Secondary hand thinning involves thinning the remaining fruits to optimize the production of the desired 300-350 g fruits (6). It is based on a predetermined leaf-fruit ratio (5) and is normally accomplished about 60 days AFB.

Still, severe biennial bearing of 'Fuji' apples can be observed in commercial orchards in Japan. Therefore, to better establish the value of flower and fruitlet thinning on yield, fruit quality and the return flowering of 'Fuji' apple trees on M.9, the following trial was carried out at the Nagano Fruit Experiment Station in 1999 and 2000.

Materials and Methods

Twenty-seven 6-year-old 'Fuji'/M.9 Nagano (6) apple trees spaced at 2 x 4 m were used for this study. The thinning treatments applied in 1999 were as follows: 1) primary thinning 7 days AFB + secondary thinning at 60 days AFB (PT7AFB+ST60AFB); 2) PT17AFB +

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ST60AFB; 3) PT28AFB + ST60AFB; 4) PT37AFB + ST60AFB; 5) PT51AFB + ST60AFB; 6) ST60AFB; 7) ST74AFB; 8) ST94AFB; and 9) Control, trees left unthinned. These treatments were arranged in a randomized complete block with three single-tree replications. Primary thinning involved removing all flowers or fruits from flower clusters arising from axillary buds on one-year wood and leaving only the king fruit on all other clusters. Secondary thinning involved adjusting crop load to 55 leaves per fruit, considered the ideal leaf-fruit ratio for producing 300 to 350 g 'Fuji' apples (5). Flowers and fruits were thinned only by hand. Total leaf number per tree was estimated from the following leaf number and shoot length relationship following shoot length measurements made 60 days AFB: $Y = 8.9 + 0.176X - 0.001X^2$, where Y = number of leaves, X = shoot length, and an average of 5 leaves per spur (4).

The total number of flowers and fruits removed per tree was recorded in 1999. Yield per tree, average fruit size and fruit size distribution per tree were measured at harvest. Juice soluble solids content (degrees Brix) at harvest was determined by pooling individual measurements of 20 randomly harvested fruit per tree.

In 2000, all trees were thinned by PT at 30 days AFB and ST at 60 days AFB using the same procedure as in 1999. Return flowering was determined by counting total terminal buds and flowering terminal buds per tree at flowering time. Yield, average fruit weight and juice soluble solids were determined at harvest.

Results and Discussion

The number of flowers and fruitlets thinned from trees receiving primary thinning at 7 and 17 days AFB was significantly greater than on later-thinned trees (Table 1). Furthermore, primary thinning at 7 days resulted in the fewest fruits removed during secondary thinning. Natural fruit drop before and during the 'June Drop' period likely explains the decline in numbers of fruits removed.

Final fruit set on these 6-year-old trees in 1999 did not differ significantly among treatments except for the control (Table 1). This result shows that secondary thinning to determine crop load based on leaf/fruit ratio (55 leaves per fruit) was successful. Fruit set on control trees (288) was three to four times higher than on trees receiving the other 8 treatments. Furthermore, average yields, ranging from 21.2 - 24.9 kg did not differ among treatments except for the control (53.4 kg) which was at least double that of the other treatments (Table 1).

The trees receiving the earliest thinning treatment, PT7AFB+ST60AFB, showed the largest average fruit size (348 g) but all primary thinning treatments up to 37 days AFB resulted in average fruit weights exceeding 300 g (Table 1). As expected, fruit size on the unthinned trees (189 g) was the smallest. Measurements of fruit size distribution, i.e., the percentage of fruits falling into 5 weight categories (Fig. 1), revealed that primary thinning up to 37 days AFB resulted in very few fruits weighing less than 250 g.

All thinning treatments resulted in similar juice soluble solids at harvest (Table 1). All were significantly higher than on the unthinned trees.

Return flowering and cropping in 2000 was profoundly influenced by time of thinning in 1999 (Table 2). Only trees receiving primary thinning up to 28 days AFB produced a crop that exceeded that of the previous year. Primary thinning at 37 days AFB resulted in a 2000 crop that was 86% that of 1999. All other treatments resulted in very low return flowering and cropping.

The thinning treatments applied in 1999 did not influence average fruit weight in 2000 (Table 2). Only the very light crop control trees showed average fruit size values significantly higher than in 1999. Interestingly, despite the very low crop on many trees in 2000, juice soluble solids levels at harvest were not higher. The higher Brix levels in 1999 are likely explained by the hot and dry summer of that year (5).

It is believed that flowering on 20% of terminal buds (on either spurs or one-year shoots) is enough to gain the optimum crop load in Japan. Nevertheless, more than

Table 1. Influence of time of flower and fruit thinning on yield and fruit quality of 6-year-old 'Fuji' apple trees on M.9 in 1999.

Time of thinning	No flws and frts thinned/tree		No. frt set/tree	Yield (kg)	Av. frt wt (g)	Brix of frt (%)
	Primary	Secondary				
PT 7AFB+ST60AFB[z]	1203	14	68 a[w]	23.9 a	348 c	16.6 b
PT17AFB+ST60AFB	1046	68	77 a	24.0 a	311 bc	16.1 b
PT28AFB+ST60AFB	504	42	72 a	22.4 a	309 bc	16.0 b
PT37AFB+ST60AFB	283	58	77 a	24.0 a	311 bc	16.1 b
PT51AFB+ST60AFB	150	83	92 a	24.8 a	269 b	16.1 b
PT&ST60AFB[y]		196	86 a	24.9 a	290 b	16.4 b
PT&ST74AFB		213	84 a	23.7 a	281 b	16.5 b
PT&ST94AFB		478	76 a	21.2 a	280 b	16.7 b
Control[x]		0	288 b	53.4 b	189 a	13.8 a

[z]P: primary thinning, thinning flowers and fruitlets of axillary buds and lateral flowers or fruitlets of terminal buds. ST: secondary thinning, thinning for deciding crop load depend on 50 to 60 leaves per fruit. This thinning treatment was done 7 days and 60 days after full bloom (AFB).

[y]One time thinning for deciding crop load based on 50 to 60 leaves per fruit was done 60 days AFB.

[x]Trees were not thinned.

[w]Mean separation in columns by Tukey's LSD, p=0.05; means followed by the same letter are not significantly different.

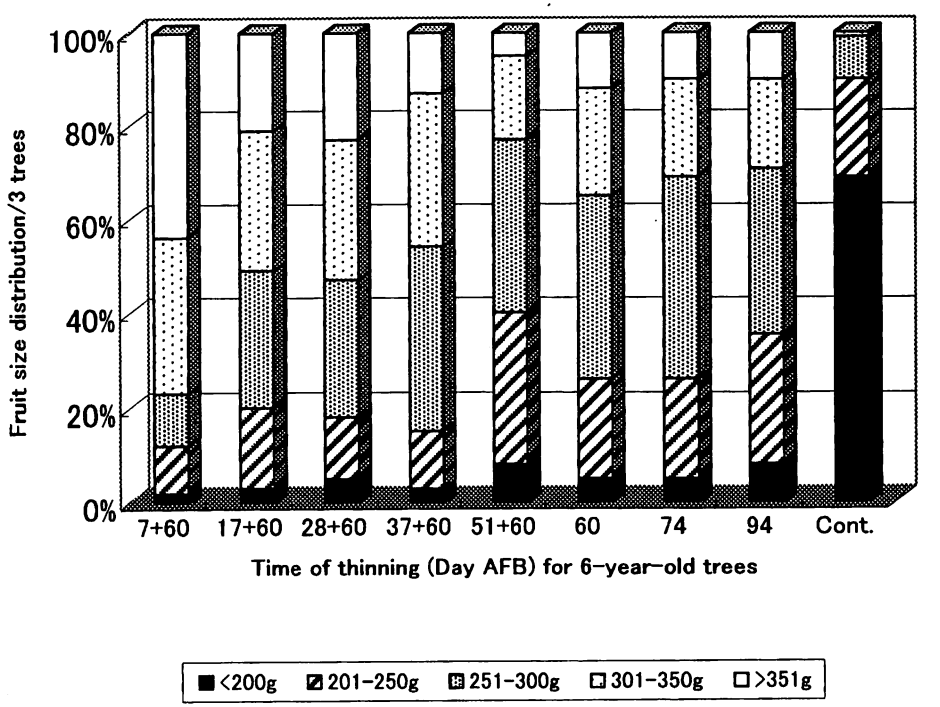

Figure 1. Influence of the time of thinning on fruit size distribution (% of total fruit number) of 6-year-old 'Fuji' apple trees.

Table 2. Influence of time of flower and fruit thinning in 1999 on return bloom, yield and fruit quality of 7-year-old 'Fuji' apple trees on M.9 in 2000[z].

Time of thinning in 1999	Return flowering[v] (%)	No. frt set/tree	Yield/tree (kg)	Av. frt wt (g)	Brix of fruit (%)
PT 7AFB+ST60AFB[y]	75 e[u]	119 c (174 c[t])	39.6 c (166 c)	327 a (93 a)	15.2 ab
PT17AFB+ST60AFB	59 de	98 bc (124 bc)	30.5 bc (121 bc)	305 a (98 a)	15.3 ab
PT28AFB+ST60AFB	44 cd	92 abc(123 bc)	24.1 abc (119 bc)	303 a (98 a)	15.3 ab
PT37AFB+ST60AFB	28 bc	62 abc(83 ab)	19.9 abc (86 abc)	318 a (102 a)	15.6 b
PT51AFB+STS60AFB	20 abc	42 abc(42 ab)	12.3 abc (46 ab)	299 a (111 a)	15.3 ab
PT&ST60AFB[x]	25 abc	46 abc(52 ab)	16.6 abc (64 ab)	329 a (113 a)	14.9 ab
PT&ST74AFB	4 ab	12 ab (15 a)	3.3 ab (15 a)	255 a (91 a)	14.7 a
PT&ST94AFB	2 a	8 a (5 a)	1.1 a (5 a)	297 a (106 a)	14.7 a
Control[w]	2 a	9 ab (4 a)	2.6 ab (5 a)	310 a (165 b)	14.8 a

[z]All trees were thinned by primary thinning 30 days AFB and thinned again by secondary thinning 60 days AFB in 2000.
[y]PT; primary thinning, thinning flowers and fruitlets of axillary buds and lateral flowers or fruitlets of terminal buds. ST; secondary thinning, thinning for deciding crop load depend on 50 to 60 leaves per fruit.
[x]One time thinning for deciding crop load based on 50 to 60 leaves per fruit was done 60 days AFB.
[w]Trees were not thinned.
[v]% of flower buds per total terminal buds in 2000.
[u]Mean separation in columns by Tukey's LSD, p=0.05; means followed by the same letter are not significantly different.
[t]Values in parenthesis are showing the per cent of the values of trees in 1999.

40% return flowering is desirable for selecting potential high quality fruit (5). The results of 44% or greater return flowering obtained by the earliest thinning treatments seem to show that thinning flowers and fruitlets as soon as feasible AFB is most desirable for flower bud differentiation.

According to Looney et al. (8), adequate return flowering of 'Fuji' requires the presence of a substantial number of resting spurs (spurs completely free of fruit at the time of normal flower induction, the first month or 6 weeks after flowering) in Canada. Lakso et al. (7), note that cell division occurring during the first month of fruit development is an important factor deciding apple fruit size potential. Thus thinning the flowers or fruits as early as feasible would have the benefit of allowing the most time for retained fruits to increase cell number. McArtney et al. (10), also demonstrated that early thinning resulted in maximum fruit size. The results of this present experiment are consistent with these earlier observations.

It is instructive to point out that the hormone type thinners such as NAA, NAD and ethephon used in many countries (2, 8, 9, 12) have not been used commercially in Japan because they cause small fruit and decrease the fruit length/diameter (L/D) ratio, resulting in flat-shaped fruits. Lime-sulfur spray (22%; 33 to 40 liters/400 liters of water/ha) has proven effective for flower thinning and is registered as the only bloom thinner in Japan.

In conclusion, these results show that adjusting crop load to 55 leaves per fruit, even as early as 60 days AFB, is not sufficient to insure the large fruit size demanded by the Japanese market on 'Fuji/M.9' apple trees. Primary thinning is required and should be performed within 28 days AFB if the goal is to ensure good fruit size and good return flowering.

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The Effect of Soluble Sugars, Total Flavan and Juglone Concentrations in Walnut Scions on Graft Survival

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Abstract

We examined the effects of soluble sugar, juglone and total flavan concentration of scionwood on graft success in walnut (*J. regia* L). According to simple regression analysis, graft success was linearly related to sugar and juglone concentrations, and quadratically related to flavan concentration. In addition, the best multiple regression model was constructed for graft success according to all possible regression approach. It was found that the best model included linear terms for flavan and sugar, quadratic term for flavan and the interaction term for flavan x sugar. The r square (R^2) for this model was 0.72, meaning that this model explained 72% of variation in graft success. The residual variation (28%) resulted from other factors.

Introduction

Many researchers involved in walnut grafting indicate two main causes of low graft survival percentage. The first is high phenol content of scionwood (5,6,13), and the second is juglone in xylem exudates (1,9,15,16,17). The oxidation of phenols and juglone during grafting may induce a necrotic layer at the graft interface. This layer negatively affects the differentiation of new vascular tissues at the graft union. In addition to these two factors, it has been reported that carbohydrate content of scion is also an important factor affecting graft survival of walnut (10,18).

Previous studies related to this subject were aimed primarily at determination of individual effects of factors that influence graft survival. The objective of this study was to determine individual and cumulative effects of three factors on graft success of walnut by regression analysis.

Materials and Methods

The experiment was carried out under uncontrolled field conditions. Whip and

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