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Differences in Regrowth and Terminal Flower Bud Formation of 'Fuji' and 'Jonagold' Apple Trees in Response to Summer Heading Back Pruning of Current Season's Shoots

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ABSTRACT Current season's shoots on 2-year-old branches of 'Fuji' and 'Jonagold' apple trees were heading back pruned to 5 leaves from early May to mid July at about 12-day intervals. The summer heading back pruning induced regrowth on the pruned shoots with different responses between the two cultivars. Generally, greater regrowth occurred on the pruned shoots of 'Fuji' trees than on those of 'Jonagold', irrespective of the time of the heading cut. The shoots of 'Fuji' trees pruned in late May or in June exhibited greater regrowth compared with those pruned in early May or in July, whereas the summer heading back pruning in June resulted in the greatest regrowth for 'Jonagold'. The heading cut induced terminal flower bud formation on the pruned shoots, the percentage of which was higher in 'Fuji' than in 'Jonagold'. The highest percentages of terminal flower bud formation for 'Fuji' and 'Jonagold' were obtained with the heading cut in late May and in mid June, respectively. Percent flowering of the buds was similar in both cultivars, but percent fruit set was slightly higher in 'Fuji' than in 'Jonagold'. The time of the heading cut did not affect percent fruit set in both cultivars. Our results demonstrate that summer heading back pruning of current season's shoots induces regrowth and terminal flower bud formation therefrom when done at appropriate time, but the specific responses to the heading cut are cultivar-dependent.

Additional key words: flowering, fruit setting, terminal flower bud

Introduction

High density systems have increasingly been practiced for intensive apple production (Forshey et al., 1992). However, excess tree crowding caused by vigorous vegetative growth has often occurred and consequently reduced productivity and fruit quality (Greene and Lord, 1983; Wagenmakers, 1988). Since summer pruning is known to reduce the foliage area, suppress the growth of trunk and roots, and induce branching and flowering (Lord et al., 1979; Marini and Barden, 1982; Mika et al., 1983; Miller, 1982; Utermark, 1977), summer pruning may be needed to encourage fruiting and balance growth of apple trees in high density systems. Especially for vigorous apple trees such as 'Delicious' and 'Fuji' cultivars, summer pruning is more required to control their vegetative growth (Miller, 1982; Myers and Ferree, 1983a, b).

Many apple cultivars are known to produce most of their fruits on 2-year-old or older branches, not on current season's shoots (Westwood, 1993). However, it has been reported that summer heading back pruning of current season's shoots could induce flower bud formation on the pruned shoots (Forshey et al., 1992; Miller, 1982; Myers and Ferree, 1983a). The heading cut of leafy shoots removes actively growing shoot apices which are strong sinks for photosynthates and rich sources of auxins. As a results, the heading cut results in the accumulation of photosynthates in the remaining shoots and leaves, and the disappearance of apical dominance, and thereby stimulates axillary buds to develop (Forshey et al., 1992; Marini and Barden, 1987; Mika, 1986; Saure, 1987). Thus, summer heading back pruning may help to facilitate the flower bud formation and subsequently to ensure the following year's fruiting.

In the present study, the effects of summer heading back pruning of current season's shoots of vigorous 'Fuji' apple trees were examined with respect to their regrowth and the results were compared with those of less vigorous 'Jonagold' apple trees. The effects of the summer heading back pruning were also investigated to determine whether the heading cut induces terminal flower bud formation and subsequent flowering and fruiting on the pruned shoots in the following year and whether the responses of both cultivars to the heading cut are different.

Materials and Methods

Tree culture

Eight-year-old 'Fuji' and 'Jonagold' apple trees (*Malus domestica* Borkh.), both grafted on Malling 26 rootstocks/Chinese crab apple (*Malus prunifolia* Borkh.) seedlings, grown in a commercial orchard in Chonbuk provincial area in Korea, were used for the study. The trees trained to a modified leader type were spaced 3 × 5 m in distances and the rows oriented east to west. All trees received recommended cultural practices including dormant pruning, pest management, and fruit thinning. However, the trees were not fertilized from the time of the summer heading back pruning to that of fruit setting on the pruned shoots in the following year.

Pruning treatments

Current season's shoots, longer than 10 cm with a crotch angle of 30 to 60°, on 2-year-old branches were selected at random and heading back pruned to 5 leaves. Twenty of the current season's shoots of each tree were heading back pruned on each pruning date starting from May 3, 1997 to July 12, 1997 at about 12-day intervals. The summer heading back pruning at the designated date was separately practiced on the respective tree. Shoots grown northward and those on control trees remained unpruned. However, vigorous upright shoots originating on main branches were all removed as soon as they had developed except those intended to serve as fruiting branches in the future. A randomized complete block experiment was designed with a single-tree plot and three replications for each treatment.

Measurements for regrowth and terminal flower bud formation

Shoot regrowth from axillary buds as well as termial flower bud formation were determined after the end of leaf fall. When more than 2 shoots were developed on the pruned shoot, the regrowth was expressed as the sum of the shoot lengths. Percentages of flowering and fruit setting were recorded in the spring of the following

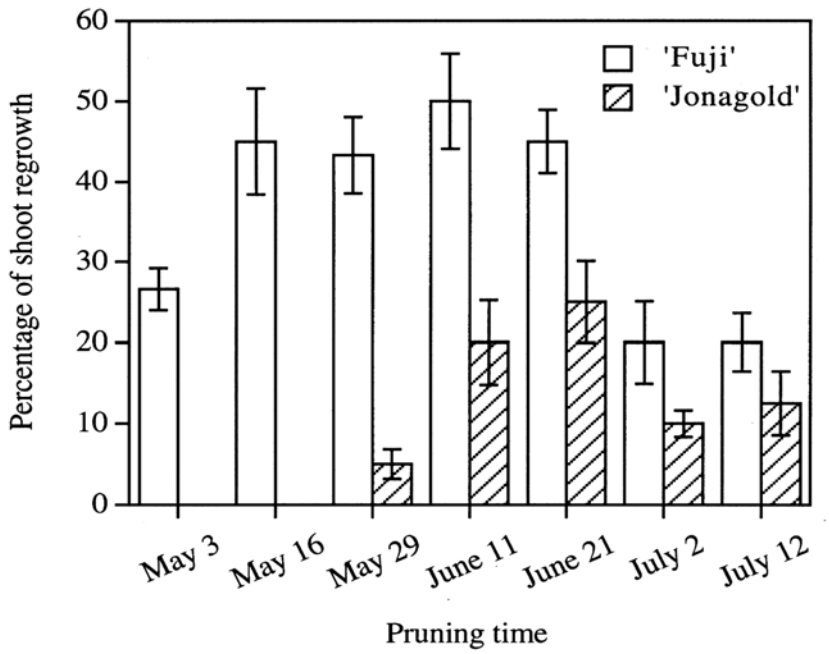

Fig. 1. Effect of time of summer heading back pruning of current season's shoots on the percentage of shoot regrowth on the pruned shoots of 'Fuji' and 'Jonagold' apple trees. Error bars are ± 1 SE of the means from three replications.

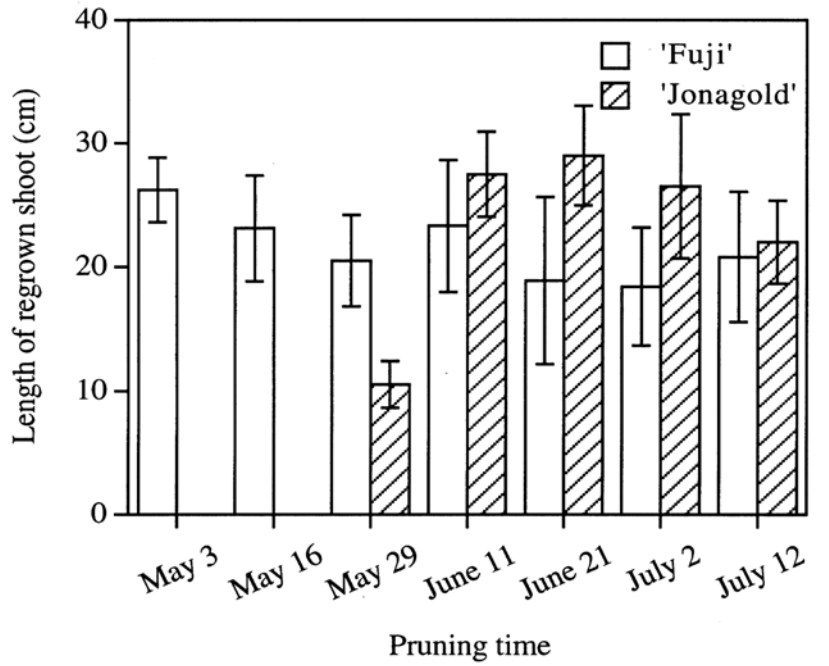

Fig. 2. Effect of time of summer heading back pruning of current season's shoots on the length of regrown shoots on the pruned shoots of 'Fuji' and 'Jonagold' apple trees. Error bars are ± 1 SE of the means from three replications.

Table 1. Effect of summer heading back pruning time on flowering and fruit setting in the following year of 'Fuji' and 'Jonagold' apple trees.

Pruning time	Flowering of terminal flower buds (%)		Fruit setting of flowered terminal buds (%)	
	Fuji	Jonagold	Fuji	Jonagold
May 3	13.2 c[z]	18.3 bcd	82.2 a	72.3 a
May 16	17.7 bc	20.7 abc	86.8 a	76.2 a
May 29	23.4 ab	22.8 ab	88.2 a	81.4 a
June 11	28.2 a	25.8 a	88.5 a	78.2 a
June 21	24.8 a	26.6 a	92.6 a	84.0 a
July 2	16.2 c	15.0 cd	83.1 a	70.0 a
July 12	16.5 c	13.0 d	84.8 a	69.5 a

[z]Mean separation within columns by Duncan's multiple-range test at $P<0.05$.

year.

Results and Discussion

Summer heading back pruning of current season's shoots on 'Fuji' and 'Jonagold' apple trees caused regrowth on the pruned shoots (Figs. 1 and 2) as observed in other cultivars (Lord et al., 1979; Marini and Barden, 1982). Two cultivars responded differently to the summer heading cut. Greater shoot regrowth occurred in 'Fuji' than in 'Jonagold' trees, irrespective of the time of the heading cut (Fig. 1). In each cultivar, however, the percentage of shoot regrowth was dependent on the time of the heading cut (Fig. 1). 'Fuji' shoots pruned from May 16 to June 21 exhibited greater shoot regrowth compared with those pruned in early May or in July. Generally, the shoot regrowth of 'Fuji' apple trees was reduced as the heading cut was delayed, as reported (Lord et al., 1979; Marini and Barden, 1982; Miller, 1982; Myers and Ferree, 1983a). On the other hand, the heading cut of 'Jonagold' shoots in May had little or no effect on regrowth, but that in June resulted in the greatest shoot regrowth (Fig. 1). Once the shoot regrowth occurred, however, there were no significant differences in their length of 'Fuji' apple trees pruned at different times (Fig. 2). Similar tendency was observed in 'Jonagold', except the trees pruned in late May. In addition, the heading cut practiced in June caused greater shoot regrowth in 'Jonagold' than in 'Fuji' (Fig. 2).

Both cultivars produce most of their fruits on 2-year-old or older shoots, not on current season's shoots as described earlier (Westwood, 1993). The percentages of spur bud formation on 2-year-old branches of the control trees were found to be 53 and 88% in 'Fuji' and 'Jonagold' apple trees, respectively. Spurs were not normally formed on current season's shoots of both cultivars. However, the summer heading back pruning of current season's shoots induced terminal flower bud formation on the regrown part of the pruned shoots (Fig. 3) and resulted in the subsequent flowering and fruit setting in the following year (Table 1). In response to the heading cut, the percentage of terminal flower bud formation was much higher in 'Fuji' than in 'Jonagold' (Fig. 3). Similarly, Miller (1982) and Myers and Ferree (1983a) reported that flower bud formation was

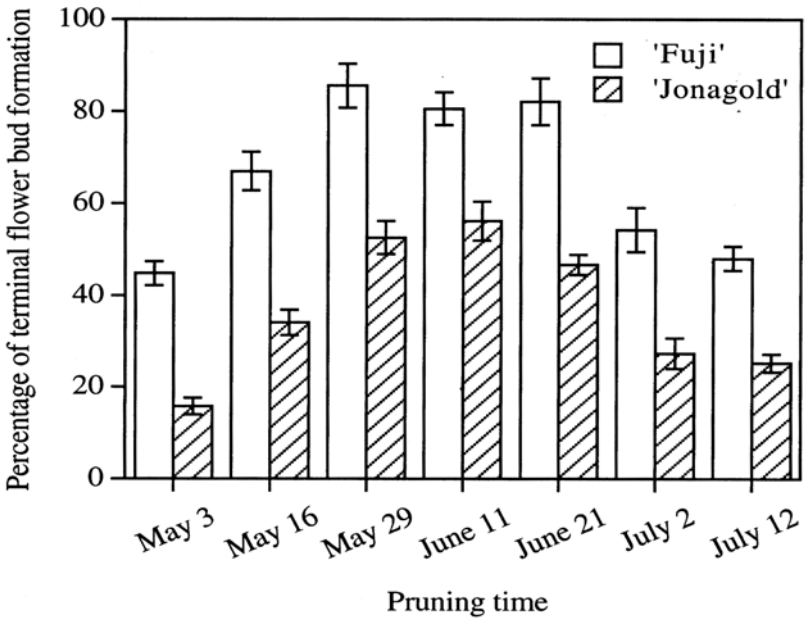

Fig. 3. Effect of time of summer heading back pruning of current season's shoots on the percentage of terminal flower bud formation on the pruned shoots of 'Fuji' and 'Jonagold' apple trees. Error bars are ± 1 SE of the means from three replications.

induced on summer pruned current season's shoots of 'Delicious' trees which do not normally produce spurs on the shoots. However, summer pruning of current season's shoots of 'Red Prince Delicious' and 'Cortland' trees to 0.5 to 1.0 cm stubs failed to induce flower bud formation (Lord et al., 1979). The conflicting reports of summer pruning on flower bud formation may be explained by the fact that the methods of summer pruning employed were different. Heading back pruning of current season's shoots can stimulate termial flower bud formation as shown in Figure 3, whereas thinning-out pruning, i.e., removing the whole shoot, definitely removes their potential flower buds. The terminal flower bud formation on current season's shoots following the summer heading cut might be due to the changes in nutritional status and redistribution of growth regulators caused by the heading cut (Taylor and Ferree, 1986; Utermark, 1977). To determine how nitrogen and carbohydrate status relates to the regrowth and terminal flower bud formation induced by the summer heading cut is objective of our further research.

There were significant effects of the time of the summer heading cut on terminal flower bud formation. The highest percentages of terminal flower bud formation for 'Fuji' and 'Jonagold' were obtained with the heading cut in May 29 and in June 11, respectively (Fig. 3). The results from Figures 1, 2, and 3 suggest that the time of the summer heading back pruning favorable for the regrowth is also advantageous to induce terminal flower bud formation.

Some terminal flower buds that developed directly behind the heading cuts on the current season's shoots developed subsequently into flowers and fruits in the following year. However, the maximum flowering percentage of the terminal flower buds was found to be less than 29% (Table 1). Marini and Barden (1982) also observed that terminal flower buds were developed below the pruning cuts, but most of the buds did not bloom. However, summer pruning effects on flowering have not been consistent (Greene and Lord, 1983; Mika et al., 1983; Morgan et al., 1984).

The two cultivars responded differently to the summer heading cut with respect to flowering percentage of terminal flower buds on the pruned shoots and fruit setting percentage of the flowered terminal buds (Table 1). Generally, the percentages of fruit setting on the pruned shoots were found to be slightly higher in 'Fuji' than in 'Jonagold', but the flowering percentages were almost the same in both cultivars. In both cultivars, however, the flowering percentages of the terminal flower buds appeared to be dependent on the time of the heading cut (Table 1). The terminal flower buds on the shoots pruned in late May or in June exhibited higher flowering percentages compared with those on the shoots pruned in early May or in July. For each cultivar, however, the percentages of fruit setting from the flowers were not significantly different among the shoots pruned at different times. Considering that competition between vegetative growth and reproductive organs is particularly severe during the periods of blossoming and the following 3 to 4 weeks (Mika et al., 1983), practicing heading cut during this period can increase both flowering and fruit setting, but late summer heading cut would have less effect on the reproductive process.

In conclusion, the summer heading back pruning of current season's shoots was effective to induce regrowth and terminal flower bud formation on the pruned shoots when it was done at appropriate time, but the responses to the heading cut were significantly different in 'Fuji' and 'Jonagold' apple trees. Thus, the heading cut could be used as a mean of encouraging reproductive growth especially for vigorous apple trees in high density systems. Additionally, the heading cut could reduce the need for dormant pruning, facilitate light penetration into the tree canopy, and improve fruit quality as reported by others (Forshey et al., 1992; Marini and Barden, 1987; Mika, 1986; Taylor and Ferree, 1984). However, it is considered necessary that the summer heading back pruning should be adjusted according to cultivar, rootstock, tree vigor, tree age, and weather, and need to be coordinated with other cultural practices, such as dormant pruning, fertilization, fruit thinning, and pest management.

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신초의 하계 절단전정에 의한 사과 품종 '후지' 및 '조나골드'의 2차 생장과 정화아 형성의 차이

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초 록

사과 품종 '후지'와 '조나골드'의 2년생 가지상에 발생한 신초에 대하여 5월 초순부터 7월 중순까지 약 12일 간격으로 기부에 5엽을 남기고 각각 절단전정을 실시한 결과, 절단한 가지상에 2차 생장이 이루어졌으며 절단전정의 시기와 관계없이 '후지'가 '조나골드'에 비하여 더 왕성한 2차 생장을 나타내었다. 그러나 각 품종에서의 2차 생장은 절단전정의 시기에 따라 다르게 나타나 '후지'의 경우 5월 초순이나 7월에 실시하였을 때보다 5월 중순 또는 6월에 실시하였을 때 더 왕성하였으며 '조나골드'의 경우에는 5월 중순까지의 전정에서는 2차 생장이 전혀 일어나지 않았으며 5월 하순 이후의 전정에 의해 2차 생장을 나타내었다. 하계 절단전정에 의하여 형성된 정화아로부터 이듬해에 개화와 착과도 이루어졌다. 대체적으로 '조나골드'에 비하여 '후지'가 절단전정에 의한 정화아 형성률이 높은 경향이었으며 '후지'는 5월 하순, '조나골드'는 6월 중순에 절단전정을 실시하였을 때 가장 높은 정화아 형성률을 나타내었다. 형성된 단과지로부터의 개화는 두 품종 모두 비슷하였으나 착과율은 '조나골드'보다 '후지'에서 다소 높게 나타났으며 각 품종에서의 착과율은 하계 절단전정의 시기에 따라 달라지지 않는 경향이었다. 따라서 하계 절단전정은 품종에 따라 그 생장 특성에 맞게 시기를 달리하여야 효과적임이 구명되었다.

추가 주요어 : 개화, 착과, 정화아