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Summer pruning effect on tree growth and fruit production of persimmon

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Abstract: This paper reviews the effect of summer pruning in persimmon (*Diospyros kaki* Thunb.) with regard to its positive and negative aspects on tree growth and fruit production. In order for this practice to be of a significant value, a clear understanding is needed to appreciate the fact that so many variables are involved and much remains to be substantiated. Major reasons for summer pruning of persimmon are to improve fruit quality by enhancing light penetration into the tree canopy and to restrict vegetative shoot growth. Summer pruning generally suppresses tree growth even though it elevates leaf activity. Positive effects of summer pruning on skin color, soluble solids, and appearance of fruits are observed mainly in those orchards where the trees are heavily dormant-pruned to lower tree height and to secure space in high density plantings. Secondary shoot pruning and topping could also improve fruit quality, increasing flower bud formation of remaining shoots. Summer-pruning effects are highly dependent on its severity and timing to affect tree growth, shoot regrowth, reserve accumulation, and fruit quality.

1. Introduction

Persimmon trees, having no dwarf rootstocks of commercial value, tend to grow high. Lowering tree height by heavy dormant pruning has been a routine practice for efficient management of many persimmon orchards. In densely planted orchards, heavy pruning is an inevitable practice to restrict tree size. This practice, in turn, causes vigorous shoot growth resulting in an excessive crowding of the canopy. Poor fruit set and excessive supply of nitrogen also stimulate the occurrence of vigorous shoots. Tree crowding not only hinders orchard operations, but deteriorates fruit quality as the tree interior becomes heavily shaded. Shoots of vigorous and succulent growth make the tree susceptible to anthracnose (*Colletorichum gloeosporioides*) when humidity within the canopy is high.

Summer pruning is one of many options to alleviate the problems of crowding, ensuring adequate light penetration into the canopy and controlling excessive shoot growth. However, removal of shoots during growing season involves the loss of functional leaf surface, which may lead to reduced tree development and fruit growth. Loss of leaf area may also reduce reserve accumulation for early growth the next season. The effect of summer pruning on physiological process and tree growth seems well documented in other deciduous fruit crops, but limited studies have been conducted in persimmon. In this paper we evaluate the effects of summer pruning on tree growth, fruit quality, and nutrient composition of perennial organs in persimmon.

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2. Tree response to summer pruning

Vegetative growth

Since removal of active leaf area reduces the production of dry matter during the growing season, summer pruning suppresses vegetative growth in other fruit crops, the effect of which is closely related to pruning severity, timing and cultivars (Taylor and Ferree, 1984; Rom and Ferree, 1985; Marini and Barden, 1987; Mediene *et al*., 2002; Zamani *et al*., 2006). In young 'Fuyu' and 'Nishimurawase' persimmons, thinning 26% of total shoot length in late July reduced dry weight of dormant one-year-old twigs, but it did not significantly affect total dry weights of aerial wood and the root (Choi *et al*., 2003 a). The result might be related in part to a high photosynthetic activity of remaining leaves until later in the season as shown in leaf chlorophyll concentrations (Fig. 1). Although not significant, negative relationships were observed between the increment of trunk cross-sectional area and pruning severity in the same experiment (Choi *et al*., 2003 a) and summer heading-back (Song *et al*., 2001).

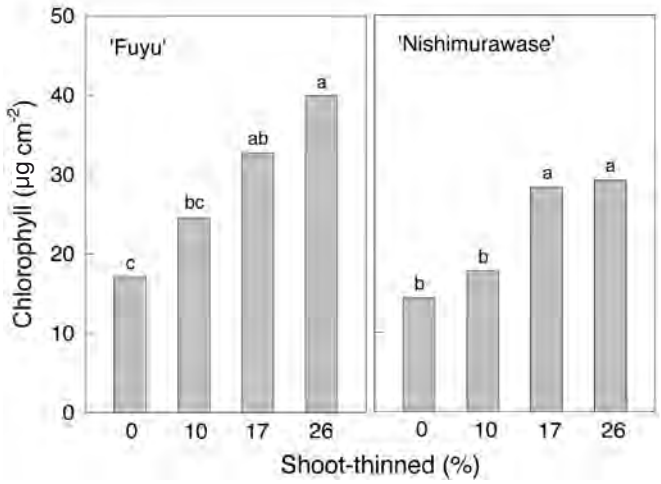

Fig. 1 - Effect of different severities of shoot thinning on 22 July on leaf chlorophyll of five-year-old 'Fuyu' and 'Nishimurawase' persimmon on 3 November. Chlorophyll content includes chlorophylls a and b. Values sharing the same letter are not significantly different from each other by Duncan's multiple range test at p≤ 0.05 (Choi *et al*., 2003 a).

Leaf activity

Summer pruning is known to increase photosynthesis, dark respiration, and transpiration of shoot leaves in other fruit crops (Taylor and Ferree, 1981; Marini and Barden, 1982; Myers and Ferree, 1983). As shoot thinning severity in late July increased in 'Nishimurawase' persimmon, specific leaf weight tended to become higher (Table 1). Chlorophyll content per unit area increased by 1.9-fold and 2.3-fold in 'Fuyu' and about 2-fold in 'Nishimurawase' trees that had been thinned 17% and 26% of their shoots, respectively (Fig. 1). Results indicated that photosynthesis can hardly compensate for the leaf area that has been removed, and there would be a sizable reduction in the production of photosynthates depending on pruning time

Regrowth

It is possible that shoot regrowth following summer pruning can have serious negative effects on the supply of photosynthates to fruit and shoot and resistance to diseases and pests (Forshey *et al*., 1992; Choi *et al*., 2003 b). In addition, excessive regrowth may reduce flower bud formation by gibberellins produced during shoot regrowth (Forshey *et al*., 1992). The extent of regrowth following summer pruning was influenced by the time and severity (Miller, 1982; Ferree *et al*., 1984). When 'Fuyu' persimmon was summer-pruned on 20 June or 4 July, the earlier pruning produced more secondary growth more than the later one (Fujimura, 1932). Summer pruning after late July, when buds enter physiological rest, did not result in a great problem of regrowth in persimmon trees, but heavy summer pruning may stimulate some buds to break into growth (Table 1). Heading-back cuts in vigorous shoots would easily induce regrowth more than thinning cuts. Late July through early August is the appropriate time for thinning out vigorous shoots to avoid regrowth in South Korea.

Reserve accumulation

Early loss of foliage from pruning may result in reduced carbohydrate levels of the tree, and that could adversely affect cold hardiness (Marini and Barden, 1987). When the current shoots were thinned up to 26% of their total length in late July in young 'Fuyu' and 'Nishimurawase' persimmon, the differences in non-structural carbohydrates and inorganic nutrients in four- to five-year-old wood of aboveground parts and the large root, measured on 2 April the following year, were not consistent with the pruning severity the previous summer (Choi *et al*., 2003 a). This result might be due to the increased activity of the leaves as presented in chlorophyll concentration in figure 1. However, thinning 50% of total shoots decreased carbohydrate concentration in one-year-old shoots of field-grown 'Nishimurawase' (Table 2) but not in those of 'Fuyu' (Choi *et al*., 2003 b). In the same experiment, the severe summer pruning also reduced flower buds in both cultivars the following year, since low carbohydrates in the shoots (Choi *et al*., 2011) and excessive regrowth (Forshey *et al*., 1992) were negatively related to flower bud formation.

3. Fruit quality affected by summer pruning

Summer pruning has been recommended to improve

Table 1 - Effect of summer pruning severity on 29 July on light penetration and tree growth of 'Nishimurawase' persimmon (Choi *et al*., 2003 b)

Shoot-thinned (%)	Light penetration (%)	TCSA increment (%)	Regrowth (cm/tree)	SLW ($mg \cdot cm^{-2}$)	Leaf SPAD reading
0	11.3 b	6.8 a	0 a	10.14 b	51.6 a
25	24.7 a	7.8 a	63 a	10.92 ab	52.8 a
33	27.9 a	7.4 a	163 a	10.93 ab	51.8 a
50	30.9 a	6.1 a	215 a	11.18 a	54.8 a

After summer pruning of seven-year-old trees, the leaf-fruit ratio was changed from 20 of 0% thinning to 10 of 50% thinning in an orchard planted at 3.5 x 2 m.
TCSA= trunk cross-sectional area.
SLW= specific leaf weight.
Mean values in each column with the same letter are not significantly different by Duncan's multiple range test at p≤ 0.05.

Table 2 - Effect of summer pruning severity on 29 July on concentrations of carbohydrates and inorganic elements in dormant shoots of 'Nishimurawase' persimmon on 17 February (Choi *et al*., 2003 b)

Shoot-thinned (%)	Carbohydrates (% DW)		Inorganic elements (% DW)				
	Soluble sugars	Starch	N	P	K	Ca	Mg
0	12.2 a	5.4 a	0.60 a	0.21 b	0.60 a	0.36 b	0.17 a
25	12.0 a	4.4 ab	0.62 a	0.24 ab	0.73 a	0.39 ab	0.17 a
33	10.3 a	3.5 ab	0.60 a	0.24 ab	0.74 a	0.43 a	0.17 a
50	9.7 a	3.2 b	0.62 a	0.28 a	0.75 a	0.44 a	0.18 a

After summer pruning of seven-year-old trees, the leaf-fruit ratio was changed from 20 of 0% thinning to 10 of 50% thinning in an orchard planted at 3.5 x 2 m.
Mean values in each column with the same letter are not significantly different by Duncan's multiple range test at $p \leq 0.05$.

fruit quality in vigorous persimmon by increasing light interception (Mowat, 1987; Ullio, 2003; George *et al*., 2005; Yamada, 2008). However, there was no consistent effect of the pruning on fruit characteristics in many studies. Table 3 shows that thinning out some water sprouts in late July increased skin color with no reduction in fruit size. This kind of positive result might be possible in vigorous 'Fuyu' trees in densely-planted orchards, and the leaf-fruit ratio after the pruning was sufficiently high. Kim (2010) also found larger size and higher coloration of fruits in vigorous 'Fuyu' trees after thinning out some water sprouts in late July. Lower water consumption and thus improved water status during the growing season after summer pruning could benefit fruit growth and relieve the potential detriment due to carbohydrate shortage in apple (Li *et al*., 2003) and peach (Lopez et *al*., 2006). Fruit firmness was not significantly changed by the differences in pruning severity (Tables 4 and 5).

Table 3 - Effect of removing water sprouts on 28 July on light penetration and fruit characteristics in vigorous 'Fuyu' persimmon orchard (Choi *et al*., 2005)

Treatment	Light penetration (%)	Fruits		
		Average weight (g)	Skin color (Hunter a)	Soluble solids (°Brix)
Non-pruning	15	243	27.9	15.0
Summer pruning	33	257	29.8	15.2
Significance	**	NS	*	NS

By summer pruning of 1-year-old trees, water sprouts were removed to maintain leaf-fruit ratio 20 in an orchard planted at 6 x 3 m.
NS= not significant; * = significant at $P \leq 0.05$; ** = significant at $P \leq 0.01$.

Size, soluble solids, and skin color of persimmon fruits decreased when the leaf-fruit ratio was low (Choi *et al*., 2010). The appropriate leaf-fruit ratio for quality 'Fuyu' fruits has been set at about 20 in Korea (Choi *et al*., 2010) and Japan (Kishimoto, 1975; Yamamura *et al*., 1989). Loss of leaf area by summer pruning results in poor fruit quality

Table 4 - Effect of summer pruning severity on 28 July on fruit characteristics of 'Fuyu' persimmon harvested on 31 October (Choi *et al*., 2003 b)

Shoot-thinned (%)	Average weight (g)	Skin color (Hunter a)	Fruit firmness (N)	Soluble solids (°Brix)	Skin damage (%)
0	234 a	27.6 a	20.7 a	15.2 a	13.2 a
10	244 a	28.4 a	21.9 a	15.7 a	9.3 cb
20	249 a	28.3 a	20.1 a	15.1 a	7.8 c
30	233 a	29.5 a	20.3 a	15.3 a	9.8 b

After summer pruning of seven-year-old trees, the leaf-fruit ratio was changed from 39 of 0% thinning to 28 of 30% thinning in an orchard planted at 6 x 3 m.
Skin damage: blemish or stains on fruit skin.
Mean values in each column with the same letter are not significantly different by Duncan's multiple range test at $P \leq 0.05$.

Table 5 - Effect of summer pruning severity on 29 July on fruit characteristics of 'Nishimurawase' persimmon harvested on 26 September (Choi *et al*., 2003 b)

Shoot-thinned (%)	Average weight (g)	Skin color (Hunter a)	Fruit firmness (N)	Soluble solids (°Brix)	Skin damage (%)
0	144 a	32.2 a	34.3 a	14.5 a	8.8 a
25	139 a	32.2 a	33.4 a	14.0 ab	3.7 ab
33	137 a	31.2 ab	32.5 a	13.6 ab	4.6 ab
50	141 a	27.7 a	31.9 a	13.0 b	1.6 b

After summer pruning of seven-year-old trees on 29 July, the leaf-fruit ratio was changed from 20 of 0% thinning to 10 of 50% thinning in an orchard planted at 3.5 x 2 m.
Skin damage: blemish or stains on fruit skin.
Mean values in each column with the same letter are not significantly different by Duncan's multiple range test at $p \leq 0.05$.

if the pruning significantly reduces the ratio. When leaf-fruit ratio decreased to less than 13 with severe removal of the shoots, fruit size, skin color or soluble solids were significantly reduced (Table 5) (Choi *et al*., 2003 a). On the other hand, strong winds result in blemish of fruit skin due to rubbing of shoots and leaves against fruits (George *et al*., 1997 a). Skin staining of persimmon fruits is often caused by humid conditions in autumn (George *et al*., 1997 a), which become aggravated by the shoots growing vigorously. Thinning out some of the shoots in summer reduces these damages by improving the micro-environment within the tree canopy (Tables 4 and 5). Therefore, summer pruning has been recommended as a means to reduce the occurrence of skin staining (George *et al*., 1997 a, 2005), especially in newly-released Japanese cultivars like a crack-susceptible 'Taishu' (Yakushiji and Nakatsuka, 2007). The influence of summer pruning on fruit quality varies by the degree of canopy crowding and the timing and its severity, as has been documented in other fruit crops (Marini and Barden, 1987; Forshey *et al*., 1992; Zamani *et al*., 2006).

4. Water sprout management

Removing all water sprouts of vigorous trees too early in the season may induce severe regrowth (Fujimura, 1932), which disturbs light penetration and reserve accumulation in perennial organs (Kappel *et al*., 1983). Therefore, instead of removing all water sprouts, thinning some of them combined with bending or twisting the remaining ones down to horizontal in June may be recommended (Park and Choi, 2000; Huh *et al*., 2003; George *et al*., 2005). Securing leaf area even in water sprouts helps prevent the regrowth that may be related to the action of hormones produced in old leaves (Forshey *et al*., 1992). Some of the water sprouts may have some value as mother branches the next season. Water sprouts of 'Fuyu' could form flower buds as long as their terminal buds are set by early August in South Korea (Choi *et al*., 2011): they could serve as fruiting branches for the following year. In vigorous trees with poor fruiting, using the sprouts as mother branches to set fruits the next season is extremely important to make up for the yield reduction as well as to control tree vigor. When the sprouts were twisted and bent down under horizontal in mid- to late June after thinning out some, flower buds were formed in 84 to 97% of them the following year (Park and Choi, 2000). Changes in endogenous hormones might be closely involved in this treatment, particularly low gibberellin and high cytokinin, which play a role in flower bud formation (Banno *et al*., 1985). Heading-back pruning to four buds is also practiced in New Zealand to ensure future fruiting site from water sprouts (Mowat, 1987).

5. Secondary-shoot pruning, pinching and topping

Secondary growth from shoot terminal occurs from mid-June in vigorous persimmon trees (Nii, 1980; Park *et al*., 2003). Secondary growth often induced fruit drop (George *et al*., 1997 b). Park *et al*. (2003) studied the heading-back effect of secondary shoots leaving two to three basal leaves of the secondary growth on 'Fuyu' persimmon. When the heading-back was done on fruiting shoot, they found that the shoots had a lower dry weight which was accompanied by an increase in fruit weight. The result indicated the necessity of such cuts for fruit growth. Compared with the heading-backs before 10 July or after 10 August, those on 25 July produced the largest fruits in-season and exhibited the highest percentage of shoots that bore flowers and fruits the following year, indicating that pruning the secondary shoots on 25 July helps to direct the assimilates to fruit growth and flower bud development, not to vegetative growth.

'Nishimurawase' persimmons tend to bear staminate, not pistillate, flowers when the trees are old and not vigorous enough. Chijiwa and Hayashi (2007) reported a way to use water shoots to serve as fruiting mother branches for the next season by pinching at 15 cm from the base between May and June. Shoots left after the pinching or summer shoots regrown from the cut bore more pistillate and fewer staminate flowers the following year than the un-treated water shoots. Takano (1994) also reported a better mother branch formation by pinching adventitious buds of persimmon. The size of trees and yield efficiency are among the most important considerations in high density orchards. When the vigorous shoots of young 'Uenishiwase' persimmon were topped to a 30-cm length in early June, followed by the removal of the regrowth, trunk growth decreased and fruit set increased the following year (Song *et al*., 2001). The occurrence of secondary growth after heading was dependent on the treatment date. Topping the shoots at the fourth bud from the terminal on 20 May promoted secondary growth of 'Hiratanenashi' persimmon, but the same treatment after 22 June did not (Hasegawa and Nakajima, 1984). The summer topping of long shoots in summer was effective in forming fruiting shoots the following year in their lower parts. Pinching and topping the shoot would promote flower bud formation of that shoot if regrowth is not severe.

6. Conclusions

Severe summer pruning could suppress vegetative and fruit growth due to the lowered photosynthetic capacity, reducing the carbohydrate reserves in persimmon tree. However, summer pruning which is appropriate to tree vigor and environmental conditions would increase production of quality fruits by improving light distribution in the tree canopy or restricting vegetative growth. Since tree vigor is a result of the complex interactive effects with cultural practices, the pruning alone should not be used as a tool for controlling vegetative growth. It is necessary to incorporate the pruning into a comprehensive program

such as tree training, fruiting, irrigation, and fertilization to reduce vigorous growth. Growers should employ summer pruning methods while carefully monitoring for potentially negative effects on tree growth and fruit quality.

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