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Summer pruning to maintain slender spindle bush type of peach trees grafted on vigorous rootstocks

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Key words: peach, pruning, shading, shoot heading back, summer shoot thinning.

Abstract: The slender spindle bush type system is commonly used for compact-sized trees, especially grafted on dwarfing rootstocks. It is difficult to apply this system to trees grafted on vigorous rootstocks by winter pruning. Such practices only cause the trees to repeat imbalanced vegetative-oriented growth every year. Therefore, in the current work summer pruning was applied to slender spindle bush type of early maturing peach trees grafted on vigorous rootstocks. Three trials were conducted: summer shoot thinning, shoot heading back trials in the field and a shoot heading back and shading trial in the pot experiment. Summer shoot thinning reduced tree growth and recovered proper balance between vegetative and reproductive growth. The following season such shoot thinning enhanced bud burst and initial growth of new shoots but the final tree growth was less in the summer-pruned trees compared with winter-pruned trees. The fruit matured earlier and soluble solids content was greater and titratable acidity was lower in the summer-pruned trees. The summer shoot heading back trial revealed that it regenerates shoots, although they bear fewer flower buds compared with winter-pruned trees. Such heading back is effective to keep alive shoots and buds near the trunk in slender spindle bush type systems. Summer shoot heading back and shading experiments in the pot showed that shading reduced the number of regenerated shoots and flower bud formation and delayed flower blooming in the following year. Thus summer shoot thinning and heading back are applicable to early maturing peach cultivars grafted on vigorous rootstocks to maintain the slender spindle bush type because thinning favors reducing tree vigor and light penetration near the trunk, and heading back keeps alive shoots and buds near the trunk which otherwise weaken or die back due to apical dominance and/or shading.

1. Introduction

Slender spindle bush types are commonly used for compact-sized fruit trees such as apple cultivars grafted on dwarfing rootstocks. Peach trees can be dwarfed and trained as slender spindle types when they are grafted on *Prunus tomentosa* and *P. japonica* (Mizutani *et al*., 1985; Yaegaki *et al*., 2008). However, these rootstocks often show graft-incompatibility for some peach scion cultivars several years after grafting (Nakano and Shimamura, 1983; Yaegaki *et al*., 2008). It is difficult to maintain trees grafted on vigorous rootstocks as slender spindle types by winter pruning. Their shoot growth is so great that the inside parts of the tree are shaded, resulting in poor growth and even death of shoots near the trunk. In relation to shading, Neri *et al*. (2003) reported that shading caused leaf wilting, necrosis and abscission earlier under water-stressed conditions. It is important to maintain shoots and buds alive near the trunk to maintain the slender spindle types. Otherwise, shoots extend outward resulting in the crown type of tree. However, when the tree vigor is so great, severe annual winter pruning only repeats imbalanced vegetative-oriented growth cycles each year. Commercial fruit production is difficult under such conditions. Many reasons have been given to support the practice of summer pruning in peach trees. It has been reported that summer pruning reduces vegetative growth, improves light penetration, enhances fruit quality, concentrates fruit maturation and increases the number of flower buds.

In general, it is considered that the time of flower bud formation in deciduous fruit trees is around late July and August in the temperate zones of the Northern Hemisphere. Thus, the time of summer pruning is very important in relation to flower bud formation, especially when heading back pruning is conducted. After summer heading back pruning, new shoots are regenerated from remaining twig parts. Even thinning out pruning sometimes enhances branching and burst of buds which otherwise remain quiescent. In relation to shoot regrowth after summer pruning, Neri *et al*. (1992) reported that it was induced only when the whole root system was well irrigated. After summer pruning the regenerated shoots are considered physiologically young compared with the spring flushes. In apple trees, the earlier the pruning time, the greater the number of flower buds (Mizutani *et al*., 2000). Apple flower buds tend to bear in the apical buds of shoots. When summer pruning is carried out earlier, new plural shoots come out and bear flower

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buds in each shoot apex resulting in greater flower bud numbers (Mizutani *et al.*, 2000). However, later summer pruning diminishes such effects. It seems likely that a certain period is required for regenerated shoots to bear flower buds. Erez (1982) also reported that in the meadow orchard system of peach trees, four to five months are required for sufficient shoot regeneration and flower bud formation. Therefore he recommends that such systems are only applicable to early maturing cultivars, with a long enough growing season after fruit harvest.

Three trials (summer shoot thinning, heading back in the field, and heading back and shading in the pot) were conducted in the present work to develop new methods to maintain slender spindle bush type peach trees grafted on vigorous rootstocks.

2. Maintaining tree shapes as slender spindle bush type in peach trees grafted on vigorous rootstocks by summer shoot thinning

A. Objectives

At first we tried to maintain tree shapes as slender spindle bush type with 'AB-1' ('Akatsuki'x unknown peentao) peach trees grafted on vigorous rootstock (*Prunus persica* Batsch, wild form) by winter pruning. The trees grew well in the orchard (previously vineyard) in spite of the fact that chemical fertilizers were not applied. It was difficult to maintain tree shape as slender spindle type while producing quality fruit annually. To keep shoots and buds near the leader trunk, excessive severe winter pruning was practiced. Such practices resulted in an improper balance between vegetative and reproductive growth. The vegetative-oriented growth is represented by vigorous shoot growth, poor fruit set, much June drop and delayed fruit maturation. When the peach trees are vigorous, severe winter pruning only repeats such a tree cycle every year. Therefore, the objective of the first trial in the field was to determine whether summer shoot thinning can alter such imbalanced tree growth to the proper balance in the slender spindle type of peach trees grafted on vigorous rootstocks.

B. Materials and Methods

The orchard used in the experiment was formerly a vineyard to which chemical fertilizers had been applied according to a standard instruction in the Experimental Farm, Faculty of Agriculture, Ehime University. For the purpose of dwarfing peach trees grafted on vigorous rootstocks, we planned no application of chemical fertilizers during the course of experiments. By using nine-year-old 'AB-1' peach trees which had so far received winter pruning, we tried summer pruning to maintain the tree as slender spindle bush type. The harvest time of 'AB-1' peach is mid July. Summer pruning was conducted just after fruit harvest; most of it was conducted as thinning out methods not heading back. The weight of pruned shoots and leaves was measured. The following year new shoot growth, flowering, leaf mineral content, fruit growth and quality of harvested fruit were determined.

C. Results

Figure 1 shows summer- and winter-pruned trees just after summer pruning on 24 July. The weight of shoots removed by summer pruning was less than that removed by winter pruning (Fig. 2).

Fig. 1 - Peach trees just after summer pruning on 24 July (left: tree after summer pruning; right: tree without summer pruning)

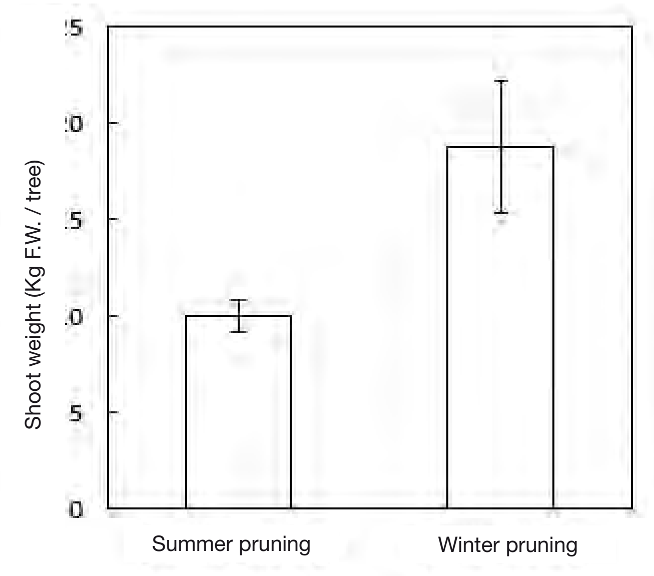

Fig. 2 - Weight of shoots removed by summer and winter pruning from peach trees. Data are presented as mean ± standard error (SE).

However, in the case of winter-pruned trees, there were no leaves at pruning time so that the actual biomass removed from the winter-pruned trees was much greater than the shoot weight pruned. Three or four days earlier bud break and flowering were observed in summer-pruned trees compared with winter-pruned trees in the following year (Fig. 3). The ovary size was greater in summer-pruned trees (Fig. 4).

The number of flowers however was less in summer-pruned trees (Fig. 3), while mineral and carbohydrate content in the new leaves and shoots was greater in the summer-pruned trees (Figs. 5 and 6). This indicates that the shoots remaining after summer pruning received enough

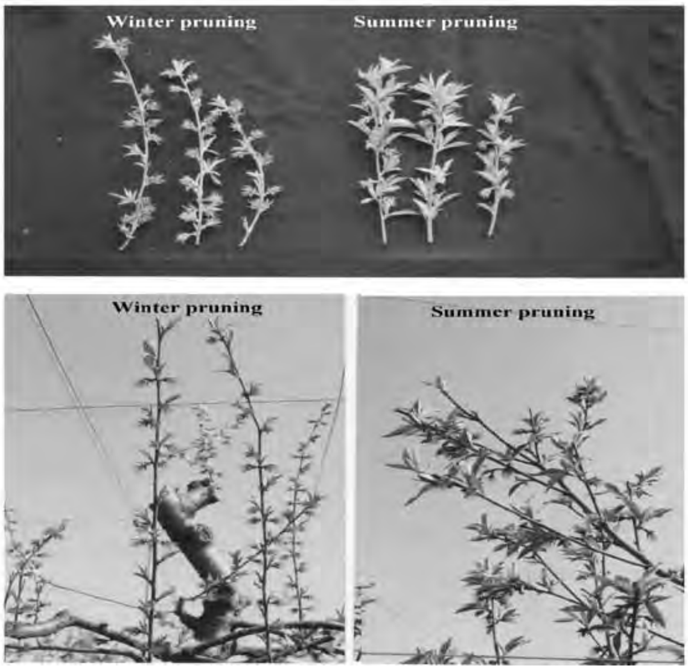

Fig. 3 - Effect of summer and winter pruning on the formation of new shoots, leaves and flowers of peach trees in the following season on April 4.

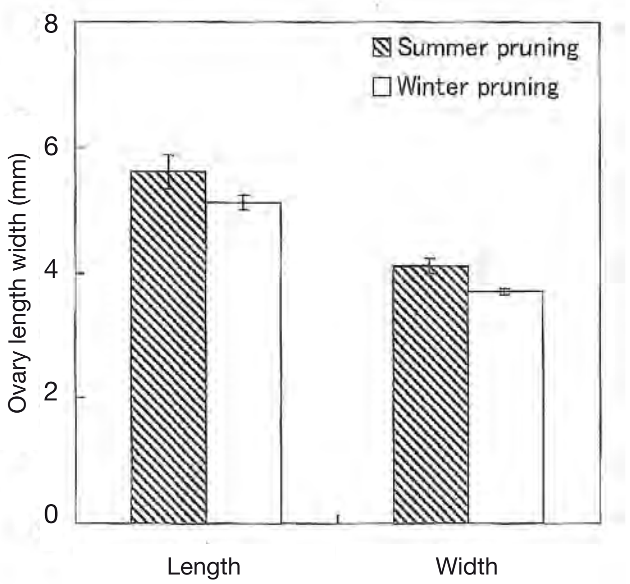

Fig. 4 - Effect of summer and winter pruning on ovary size of peach flowers on 4 April. Data are presented as mean ± standard error (SE).

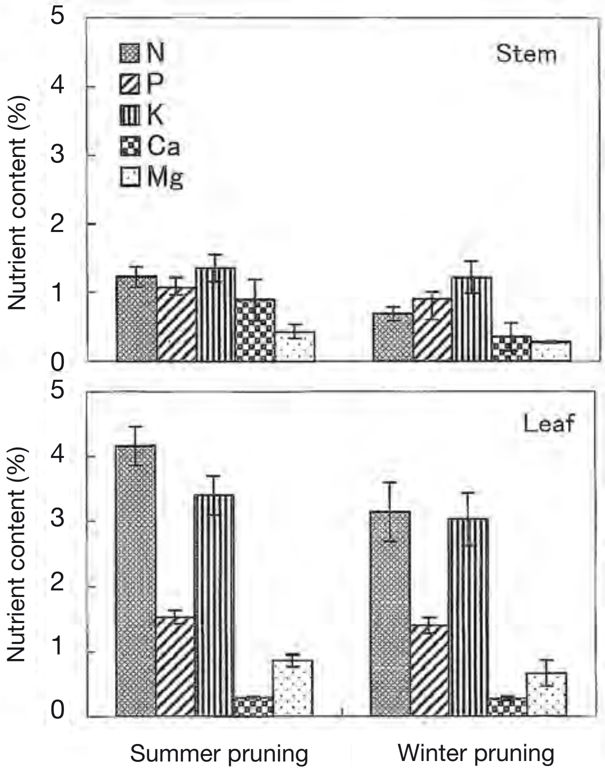

Fig. 5 - Effect of summer and winter pruning on mineral content of stems and leaves in peach trees on 4 April. Data are presented as mean ± standard error (SE).

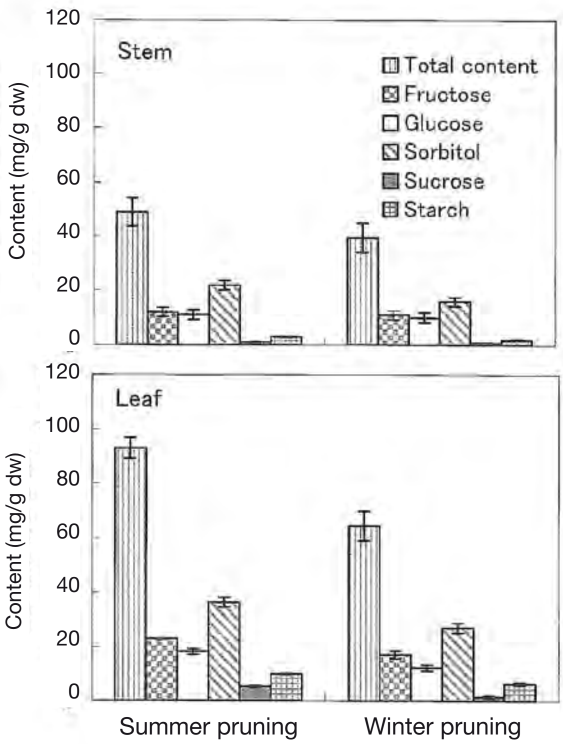

Fig. 6 - Effect of summer and winter pruning on sugar and starch content in stems and leaves in peach trees on 4 April. Data are presented as mean ± standard error (SE).

solar radiation to accumulate carbohydrate as reserves and mineral nutrient from the roots. On the other hand, in the winter-pruned trees, the shoots remaining near the trunk are supposed to have been shaded in the previous summer and fall. Although the initial tree growth was slightly enhanced in the summer-pruned trees, the shoot growth was accelerated in the winter-pruned trees in the middle growing season and final tree size became greater in the latter group (Fig. 7).

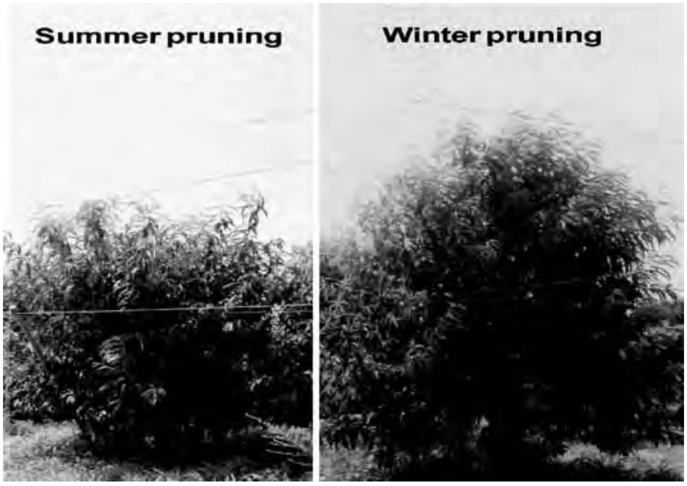

Fig. 7 - The photos show tree sizes on 24 July in the following year.

Fruit number and yield per tree were greater in the summer-pruned trees (Tables 1 and 2). Fruit weight was similar in both treatments but fruit seemed to mature earlier in summer-pruned trees. In this regard, the total soluble solids content in the juice was greater and titratable acidity was lower in summer-pruned trees. Thus, summer shoot thinning seems to be applicable to vigorous peach trees grafted on vigorous rootstocks in slender spindle bush type system to recover balanced vegetative and reproductive growth.

3. Shoot regeneration and flower bud formation after summer shoot heading back

A. Objectives

Because of apical dominant nature of shoots, the terminal shoot grows well, which retards the growth of lateral shoots. Whereas the apical part of buds on shoots burst and extend, the lower part of buds mostly remain quiescent. In the slender spindle bush type of tree it is very important to keep alive buds or shoots near the trunk. Without shoot heading back, terminal shoots extend outward, while the inside of the crown becomes shaded and shoots and buds near the trunk die back.

In the second trial in the field, we examined the effects of summer shoot heading back on shoot regeneration, leaf chlorophyll content (SPAD value), leaf drop and flower bud formation by using peach tree grafted on vigorous rootstocks.

B. Materials and Methods

Five-year-old ‘Hikawahakuho’ peach trees grafted on vigorous rootstock (*Prunus persica* Batsch, wild form) which were trained as slender spindle type were used. The harvest time of this cultivar is early July. Trees had been trained as slender spindle bush type by winter pruning before the experiment started. No chemical fertilizers were applied, as mentioned above, because the orchard was formerly a vineyard where the recommended amount of fertilizers had been applied according to the standard instruction. Tree vigor of ‘Hikawahakuho’ peach grafted on vigorous rootstocks used in this experiment was less compared with ‘AB-1’ peach described above in the previous section. Summer pruning consisted of heading back of current shoots to about 10 cm and removal of vigorous shoots, which was conducted after fruit harvest on 15 July. The number of regenerated shoots, shoot growth, flower bud formation, SPAD values and leaf drop were deter-

Table 1 - Effect of summer pruning on peach fruit yield and quality in the following season (2001)

Treatment	Fruit/tree (No.)	Yield (Kg/tree)	Fruit weight (g)	Fruit length (mm)	Fruit diameter (mm)	SSC (%)	Titratable acidity (%)
Summer pruning	136.0±36.7	13.0±3.1	102.2±5.3	59.4±0.7	62.2±0.7	9.27±0.26	0.27±0.01
Winter pruning	96.2±5.3	8.7±0.8	102.2±4.0	58.4±0.5	60.7±0.4	8.45±0.24	0.52±0.04

Data are presented as mean ± standard error (SE).

Table 2 - Effect of two-successive-year summer pruning on peach fruit yield and quality in the following season (2002)

Treatment	Fruit/tree (No.)	Yield (Kg/tree)	Fruit weight (g)	Maturity degree [Z]	SSC (%)	Titratable acidity (%)
Summer pruning	76.8±15.0	8.3±2.1	108.9±4.4	3.7±0.4	12.10±0.32	0.20±0.01
Winter pruning	66.4±8.0	6.6±1.0	103.5±3.5	2.4±0.3	9.31±0.29	0.45±0.08

[Z] For maturity degree, the score was given to green fruit=1 and ripen fruit=5.
Data are presented as mean ± standard error (SE).

mined. The following year, tree growth and fruit yield and quality were determined.

C. Results

Figures 8 and 9 show the shoot regeneration after summer pruning. There was no regrowth of shoots in winter-pruned trees. SPAD values of leaves were greater in summer-pruned trees than winter-pruned trees (Fig. 10). Leaf retention was prolonged by summer pruning (Fig. 11). Mierowska *et al*., (2002) also reported that in apple spur leaf total chlorophyll content was higher in summer-pruned than non-pruned trees. These facts indicate that regenerated shoots are physiologically young compared with spring flushes. The percent of flower buds were lower in summer-pruned trees than winter-pruned trees (Table 3); total shoot length in the following year was less in summer-pruned trees (Table 3).

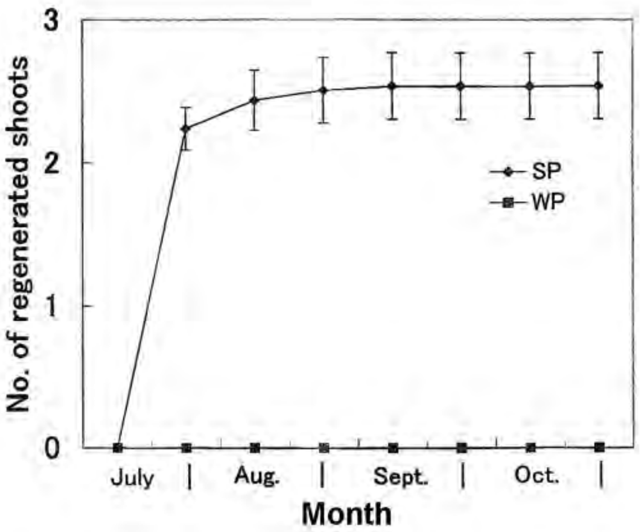

Fig. 8 - Effect of summer pruning on regenerated shoot numbers of peach trees. Data are presented as mean ± standard error (SE).

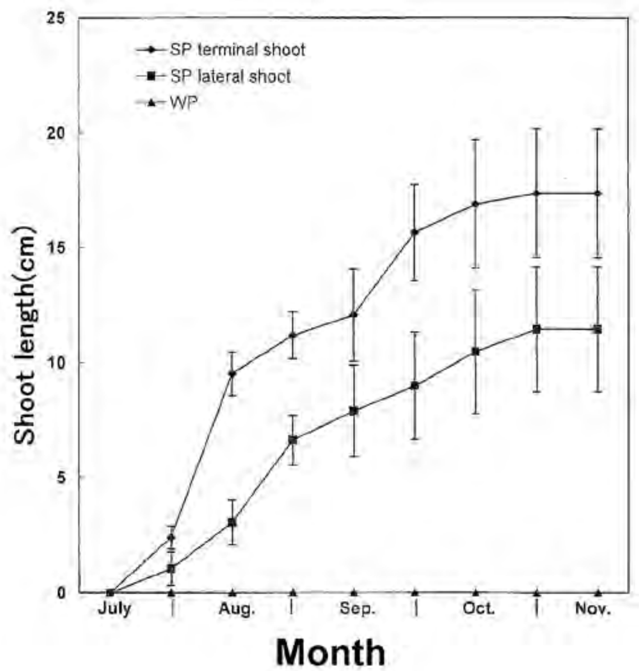

Fig. 9 - Effect of summer pruning on the regenerated shoot length of peach trees. Data are presented as mean ± standard error (SE).

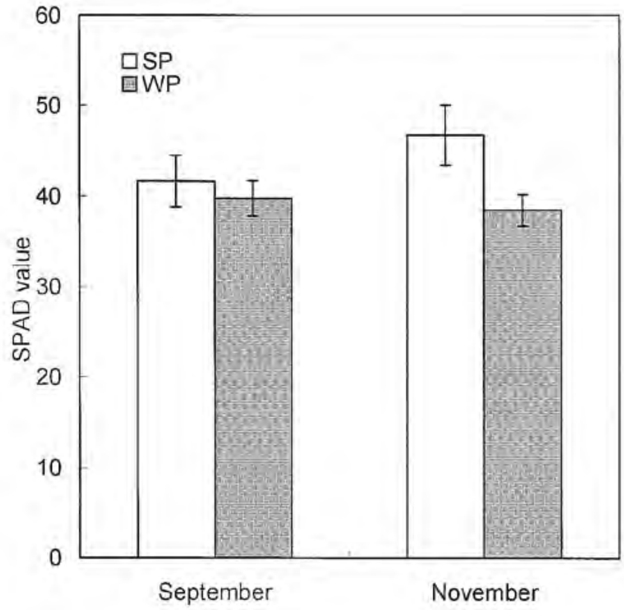

Fig. 10 - Effect of summer pruning on SPAD (chlorophyll content) in the leaves of peach trees in September and November. Data are presented as mean ± standard error (SE).

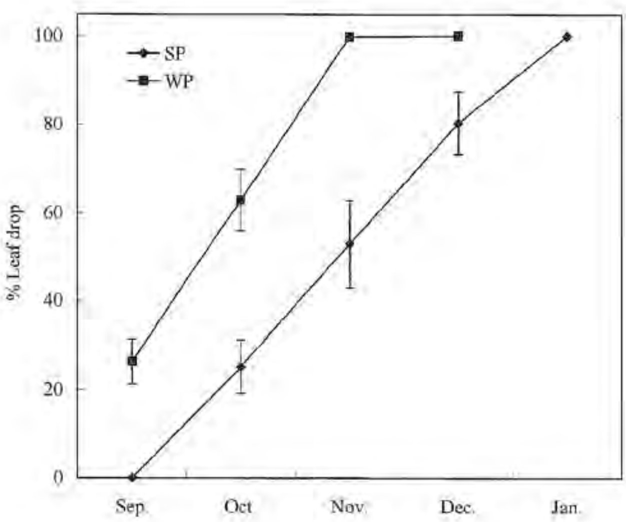

Fig. 11 - Effect of summer pruning on leaf drop in peach trees from September to late January. Data are presented as mean ± standard error (SE).

Table 3 - Effect of summer pruning on flower bud formation and total shoot length of peach trees in the following year

Treatment	Flower buds (%)	Total shoot length in the following year (m)
Summer pruning	17.2±4.5	21.8±4.9
Winter pruning	65.7±8.7	45.0±9.0

Data are presented as mean ± standard error (SE).

Therefore it can be said that the tree size of summer-pruned trees was reduced compared with winter-pruned trees. Figure 12 shows single year and two-successive-year summer pruning on the weight of shoots pruned. Two-successive-year summer pruning reduced the weight of pruned shoots. Fruit quality of harvested fruit as affected by single year and two-successive year summer pruning is presented in Table 4. Summer pruning enhanced maturation and increased soluble solids contents and reduced titratable acidity.

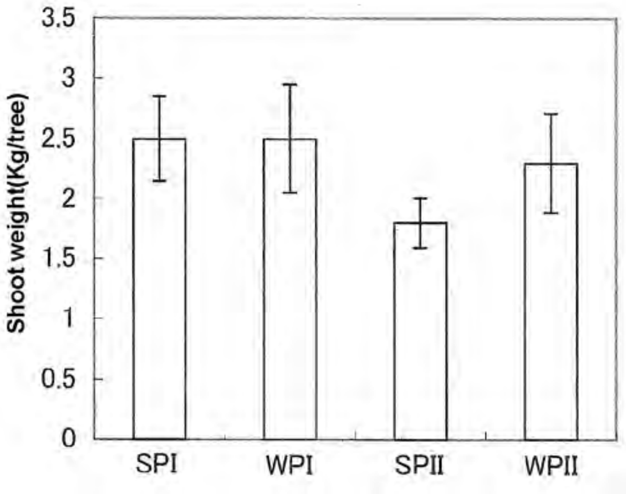

Fig. 12 - Effect of summer and winter pruning on pruned shoot weight of peach trees. Summer-pruned shoots include leaves. SPI, WPI and SPII, WPII indicate single-year and two-successive-year pruning, respectively. Data are presented as mean ± standard error (SE).

4. Shoot regeneration and flower bud formation after summer shoot heading back under shaded conditions

A. Objectives

It is important to keep alive shoots and buds near the trunk to maintain peach trees as a slender spindle type. Since shoots have apical dominance, terminal shoots extend outward so that inner parts of the crown become shaded without pruning. We further examined the effects of shading and summer shoot heading back on shoot regeneration and flower bud formation by using peach trees grafted on vigorous rootstocks in the pot trial.

B. Materials and Methods

Potted (30 cm diameter) one-year-old 'Hikawahakuho' peach grafted on vigorous rootstock (wild form) were used in the trial. Fertilizers (N, P_2O_5, K_2O=15%, 15%,15%) were applied at the rate of 30 g and 15 g per pot in mid March and early September, respectively. Treatments consisted of shading with white and black cheesecloth, shoot heading back (to 5 cm length from shoot base) and their combinations. Summer shoot heading back was conducted on 1 September. The number and length of regenerated shoots, leaf drop, SPAD values, flower bud formation and flowering time were determined.

C. Results

No shoot regeneration was found without summer shoot heading back under either non-shaded or shaded conditions (Fig. 13). Summer shoot heading back regenerated shoots but shading reduced their number (Fig. 13). Heavy shading (black cheesecloth) accelerated shoot growth as compared to light shading (white cheesecloth) and non-shading (Fig. 14). The number of flower buds was reduced by summer pruning and the tendency was accelerated by shading (Fig. 15). Shading tended to delay bloom in the following spring (Fig. 16). This indicates that the inner side shoots of the tree crown delayed bud burst and initial shoot growth as described in winter-pruned 'AB-1' peach in the previous section (Fig. 3).

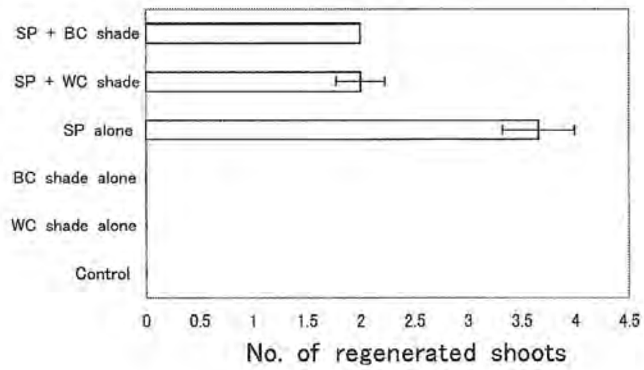

Fig. 13 - Effect of late summer pruning and shading on the number of regenerated shoots of peach trees. SP = summer pruning; WP = winter pruning, WC = white cheesecloth; BC = black cheesecloth. Data are presented as mean ± standard error (SE).

Table 4 - Effect of summer and winter pruning on fruit yield and quality in peach trees

Treatment	Fruit No./tree	Fruit weight (g)	Yield (Kg/tree)	Maturity degree (Z)	SSC (%)	Titratable acidity (%)
Summer pruning I (y)	28.1±4.1	131.0±0.5	3.7±0.7	3.5±0.4	12.8±0.2	0.27±0.03
Winter pruning I(y)	41.1±5.8	128.1±0.4	5.3±1.0	2.7±0.2	11.8±0.2	0.39±0.03
Summer pruning II	22.2±3.6	136.2±6.0	3.0±0.6	3.9±0.3	13.7±0.3	0.24±0.02
Winter pruning II	30.4±4.3	128.6±0.4	3.9±0.8	2.9±0.3	12.7±0.2	0.38±0.03

(Z) For maturity degree, the score was given to green fruit=1 and ripen fruit=5.
(Y) Indicate single-year and two-successive-year pruning, respectively.
Data are presented as mean ± standard error (SE).

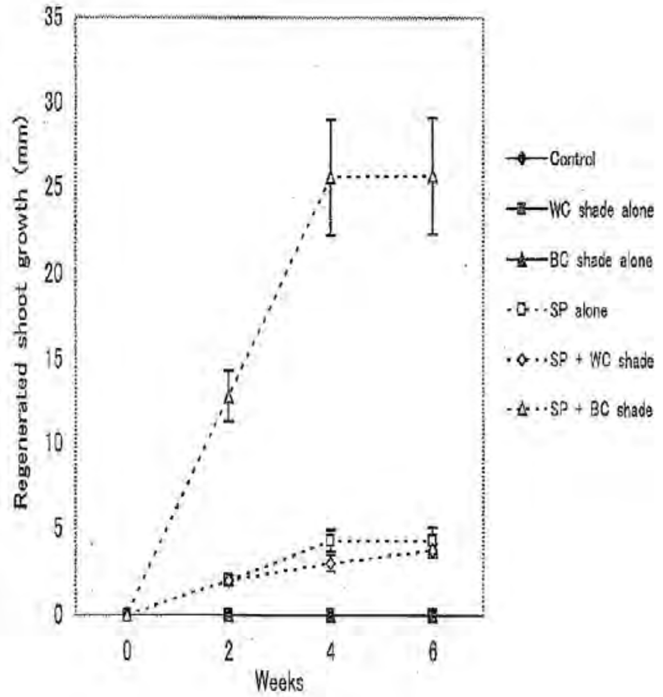

Fig. 14 - Effect of late summer pruning and shading on regenerated shoot growth of peach trees. Data are presented as mean ± standard error (SE).

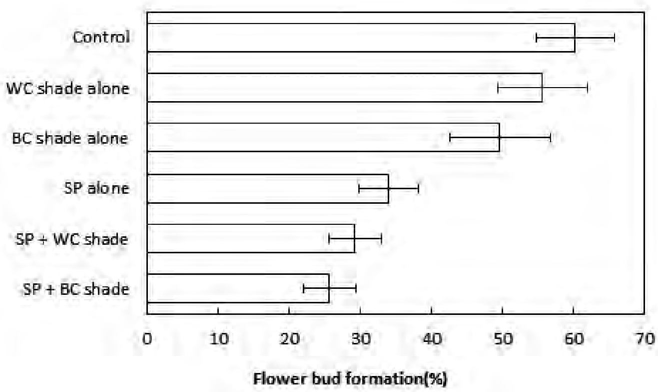

Fig. 15 - Effect of late summer pruning and shading on flower bud formation of peach trees. SP=summer pruning; WP= winter pruning; WC=white cheesecloth; BC=black cheesecloth. Data are presented as mean ± standard error (SE).

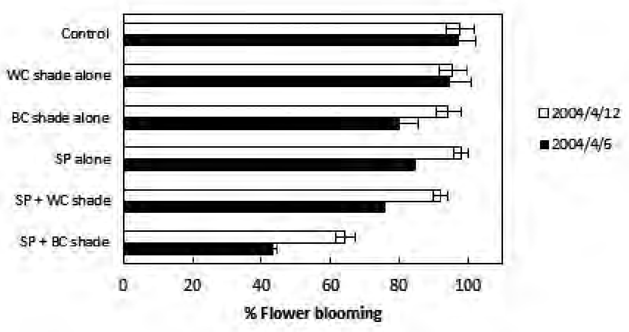

Fig. 16 - Effect of late summer pruning and shading on flower blooming of peach trees in the following year. Data are presented as mean ± standard error (SE).

5. Discussion and Conclusions

Slender spindle bush type training systems have been easily adopted in compact-sized trees grafted on dwarfing rootstocks (Mizutani *et al.*, 1985). However, when this system is applied to trees grafted on vigorous rootstocks, imbalanced vegetative-oriented cycle between vegetative and reproductive growth occurs. For commercial quality fruit production, a good balance between vegetative and reproductive growth is necessary. As suggested in the present work, application of summer shoot thinning can reduce vegetative growth in such vegetative-oriented trees of spender spindle type trees grafted on vigorous rootstocks. Neri *et al.* (2010) also reported that summer pruning reduced vigor in apricot trees. To maintain the slender spindle type, it is crucial to keep alive shoots and buds near the trunk. However, shoots exhibit apical dominance by nature so that they extend outward, thus the space near the trunk becomes shaded. Shading accelerates dieback of shoots and buds inside the crown. With regard to shading, Neri *et al.* (2003) reported that shading caused leaf wilting, necrosis and abscission earlier under water-stressed conditions. Thinning of shoots is effective for the penetration of solar radiation near the trunk in the crown. Furthermore, heading back of shoots near the trunk induces shoot regeneration from the buds at the base, which are otherwise quiescent or died back. Unless heading back is conducted, the base parts of shoots become bare without alive shoots or buds. Summer shoot heading back is efficient to keep such shoots and buds near the trunk, even under shaded conditions. Readers interested in further detailed information for current work are also referred to Hossain *et al.* (2004, 2005, 2006).

In conclusion, summer thinning is effective for reducing tree vigor and light penetration near the trunk, whereas summer heading back is essential for keeping alive shoots and buds near the trunk in slender spindle bush type peach trees grafted on vigorous rootstocks.

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