

## Shoot Growth and Fruit Production of ‘Masui Dauphine’ Fig Trees Having High Limb Position with Downward Shoots

Akihiro Hosomi<sup>1\*</sup>, Yuka Miwa<sup>1</sup> and Takashi Mano<sup>2</sup>

<sup>1</sup>Research Institute of Environment, Agriculture and Fisheries, Osaka Prefecture, Habikino 583-0862, Japan

<sup>2</sup>Hyogo Prefectural Technology Center for Agriculture, Forestry and Fisheries, Kasai 679-0198, Japan

Shoot growth and fruit production of ‘Masui Dauphine’ fig trees (*Ficus carica* L.) were compared between a novel training method and a control method, with various tree spacing. In the novel training, the shoots were elongated downward from a horizontal limb at 180 cm height, whereas control training had upward growing shoots from a horizontal limb at 40 cm height. Sprouted shoots of the novel training trees leafed a few days earlier than controls. The difference in training did not significantly affect longitudinal growth (the internode length and leaf area) of the shoots but, on the apical portion of the shoots, the shoot diameter and leaf weight per area in novel training were less than in controls. Many lateral shoots sprouted on the shoots of the novel training in autumn. The novel training prevented failure of fruit set, which was observed on the basal portion of control shoots with excess vigour owing to narrow tree spacing. The novel training promoted coloring of fruit on the basal portion of the shoots and depressed it on the apical portion. The size and weight of fruit tended to be reduced on the shoots that underwent novel training. The observed characteristics of novel training may be due to the change of lighting conditions and reduced photosynthetic rate due to downward shoot positioning.

**Key Words:** *Ficus carica*, illuminance, planting density, shoot bending, straight line training.

### Introduction

In the Japanese fruit industry, fig trees are cultivated mainly around city areas, and second crops of common-type figs are shipped with fresh fruits. ‘Masui Dauphine’ (‘San Piero’ sensu Condit, 1955) is a major fig cultivar in Japan. Second cropping fruit is borne on every node of shoots and is harvested from the base to approximately the 20th node from August to November. For this cultivar, “straight line training” has been successfully adapted (Kabumoto et al., 1985). Straight line training involves bilateral horizontal limbs, and greatly improves the efficiency of cultivation (pruning, disbudding, and harvesting etc.), because the fig-bearing shoots are elongated in line in a regular fashion. Nevertheless, the training has some disadvantages, including discoloring

of fruit (Kabumoto et al., 1985), and freezing injury to trees (Horimoto et al., 1994). We present here a new form of training for fig trees. This training is distinct from normal straight line training and involves a long trunk and high limb position. We call this the “high limb style” and its advantages were confirmed as preventing freezing injury (Mano et al., 2012a) and animal (raccoon) invasion (unpublished), but the effect on fruit production was unknown. The high position of the limb will force shoots to be elongated on the horizontal trellis or be bent downward from the limb. In this study, downward positioning was adopted for the shoots, anticipating less harvesting labor than horizontal positioning. Inhibition of vegetative growth and the promotion of fruit set is expected to take place in the bent shoots. These effects are well known (Downing, 1869) and are termed “gravimorphism” as a reaction to gravity (Wareing and Nasr, 1958). The effect of shoot bending in fig trees is unknown, however. This study investigated how the novel training (high limb style with downward shoots) affects shoot growth and fruit productivity in various vigour types of fig tree. The usefulness of this training was then assessed.

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\*Corresponding author (E-mail: [hosomi@mbox.kannousuiken-osaka.or.jp](mailto:hosomi@mbox.kannousuiken-osaka.or.jp)).

## Materials and Methods

### Growing the test trees

An experimental field of ca. 10 a was used at the Research Institute of Environment, Agriculture and Fisheries, Osaka Prefecture, Japan. Nursery stock of 'Masui Dauphine' fig trees had been planted in the summer of 2004 with various tree spacing (0.2 m, 0.6 m, 1.0 m, and 6.6 m) in north-south rows with 2.5 m spacing between rows. Growth commenced with normal straight line training, with shoots upward from a horizontal limb of 40 cm height. These trees were cut short in March 2006 and redirected to the novel training, i.e. the whole of the limbs was cut off leaving one dormant shoot nearest to the trunk, and new shoots from the apical part of the dormant shoot were adjusted twice to 180 cm with a straight line for new primary scaffolds. The next year, primary scaffolds were prolonged with newly apical shoots, and the reconstruction of the training was completed at the end of the growing period in 2007, as shown in Figure 1. The primary scaffolds involved a trellis of 180 cm height. The mother shoots were arranged on the primary scaffolds with equal intervals of ca. 20 cm. The numbers of mother shoots were 1, 3, 5, and 33 per tree, according to the tree spacing. Eighteen, 15, 12, and 3 trees were trained with tree spacing of 0.2 m, 0.6 m, 1.0 m, and 6.6 m, respectively, and corresponding numbers of un-reconstructed trees acted as controls with normal straight line training. Other details of cultivation, such as irrigation, fertilization, and pest management, followed the normal schedule for fig orchard management.

### Shoot growth and fruit set

In April 2008, the date of first leafing of the earliest sound shoot from each mother shoot was recorded as the "day of leafing". One shoot per mother shoot was elongated as a bearing shoot; the other shoots were removed. The shoots of the trees to undergo the novel

training were tied down to cords descending from the trellis to the ground, and the shoots of control trees were tied up along the cords. All of each shoot, once the number of shoot nodes reached ca. 20, was pinched and the date was recorded. Lateral shoots, which had sprouted from the bearing shoots, and other shoots which had sprouted from the tree apart from the bearing shoots, were removed weekly from May to November, and their numbers were recorded as "removed lateral shoots" and "removed shoots" for each tree. "Removed shoots" included the shoots removed at bearing-shoot selection mentioned above. Failure of fruit set was counted on each node of the shoots in July and November. After harvesting, the shoots were measured: total length, internode length, basal diameter (diameters of the 2nd or 3rd internodes from the base), and apical diameter (diameters of apical internodes).

### Lighting condition and leaf growth

In October 2008, when leaf enlargement was estimated to be complete, the light conditions in the tree canopy and growth of the leaves were examined in the trees with spacing 6.6 m. Eight shoots (every two shoots located on the north, south, east, and west sides) of each tree, were examined. The relative illuminances, above and below the side of the canopy, were measured using an illuminance meter (LX-204; Custom Co., Tokyo, Japan), in the vicinity of the 3rd, 8th, 13th, and 18th shoot nodes from the basal portion, at noon on a cloudy day. The leaves on the 3rd, 8th, 13th, and 18th shoot nodes were sampled and each leaf area and leaf weight were measured.

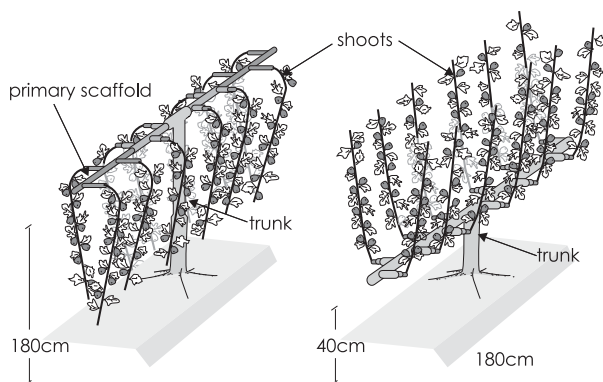
### Harvesting fruit and quality

One, 2, 3, and 16 shoots per tree with tree spacing 0.2 m, 0.6 m, 1.0 m, and 6.6 m, respectively, were selected for examination. Every fruit, judged "soft as mature fruit", was harvested. Mature fruits on the nodes of the 3rd, 8th, 13th, and 18th of selected shoots were examined, and the harvesting days, skin color, fruit length, fruit width, fresh weight, and Brix of fruit juice were all recorded. The fruit length was measured from the calyx top to the stylar end of the fruit; the fruit width was the diameter of an equatorial section of the fruit. The skin color of the fruit was categorized via a coloring index from faintly (1) to complete (5). The fruit juice was filtered from the flesh near an equatorial section through gauze, and Brix was measured using a digital refractometer (PR-101; Atago Co., Tokyo, Japan). The total weight of fruits on the shoot from the base to 20 nodes was estimated as the yield ( $Y$  kg/10 a) of each tree:

$$W = mF \cdot N,$$

$$Y = mW \cdot S \cdot T,$$

where  $W$  is product of the mean of fresh weights of fruits ( $mF$ ) and the number of fruit set ( $N$ ) at the base to 20 nodes of each shoot; estimated yield ( $Y$ ) is the



**Fig. 1.** Pattern diagrams of training for fig trees. At left is novel training. A long trunk and high limb (primary scaffold) position with downward shoots are structural features of this training. At right is normal straight line training, for control.

product of the mean of  $W$  ( $mW$ ), shoot number ( $S$ ) and the tree number per 10 a ( $T$ ) for each tree in each tree space.

## Results and Discussion

### Shoot and leaf growth and lighting conditions

Shoot growth is shown in Table 1. Shoots of the novel trained trees that had sprouted leafed 2–3 days earlier than the control trees. The internodes of shoots tended to be longer for novel trained trees and were significantly longer than controls in the trees with 0.6 m spacing. The shoot diameters tend to be larger with narrower tree spacing; this can be explained by enhanced shoot vigor with dense planting (Mano et al., 2011). The basal diameters of novel training shoots were significantly larger than in controls with 0.6 m and 6.6 m tree spacing. The apical diameters of novel training shoots were significantly smaller than in controls with 1.0 m and 6.6 m tree spacing. Trends observed in the shoots of novel training trees were that basal diameter is larger and apical diameter is smaller than in controls.

The growth of superfluous shoots is shown in Figure 2. The total number of removed shoots was greatest in May or June (upper group of Fig. 2). Narrower tree spacing increased the number of removed shoots, continuing to autumn. The novel training did not lead to more removed shoots than controls, although these showed a slight increase in autumn with 0.6 m tree spacing. Growth of lateral shoots is shown in the lower group in Figure 2. Narrower tree spacing also led to a greater number of lateral shoots, with two peaks in June/July and September. The novel training led to more lateral shoots than controls. It is well known that shoot bending releases

lateral shoots from apical dominance (Wareing and Nasr, 1958). Fig shoots show no exception to the law of apical dominance.

Illuminance in the canopy of the trees with 6.6 m spacing on a cloudy day in October was measured to characterize the lighting condition in the mature season of fig fruit (Fig. 3). The relative illuminance was strongly influenced by the height of the shoot nodes. Greater relative illuminance above was observed for basal nodes in novel training shoots, and for apical nodes in control shoots. The relative illuminance below was apparently less than above, but values for basal nodes were greater with novel training than in controls. Similar results for the lighting condition are expected for other tree spacings, because all shoots were arranged with equal intervals of ca. 20 cm, although these were not recorded directly. Figure 4 shows leaf sizes. The leaf area increased with the order of the shoot node. A slightly decrease of the leaf area was observed in novel training, but no significant difference was detected between both trainings, apart from the 8th node of shoots. The specific leaf weight (dry weight/surface area) was influenced by the height of the shoot nodes. Greater specific leaf weights were observed at basal nodes of novel training shoots, but at apical nodes on control shoots.

An effect of the shoot position, especially a downward position, can be detected for apple (Kato and Ito, 1962), grapevine (Lovisolo and Schubert, 2000; Oinoue, 1932; Schubert et al., 1995; Somkuwar and Ramteke, 2008), persimmon (Fujimura, 1932), and others, and depression of shoot growth is common. We did not find clear evidence of depressed vertical elongation in figs, because there was no delay in the pinching date and rather longer

**Table 1.** Effect of training methods on the shoot growth of ‘Masui Dauphine’ figs with various tree spacing.

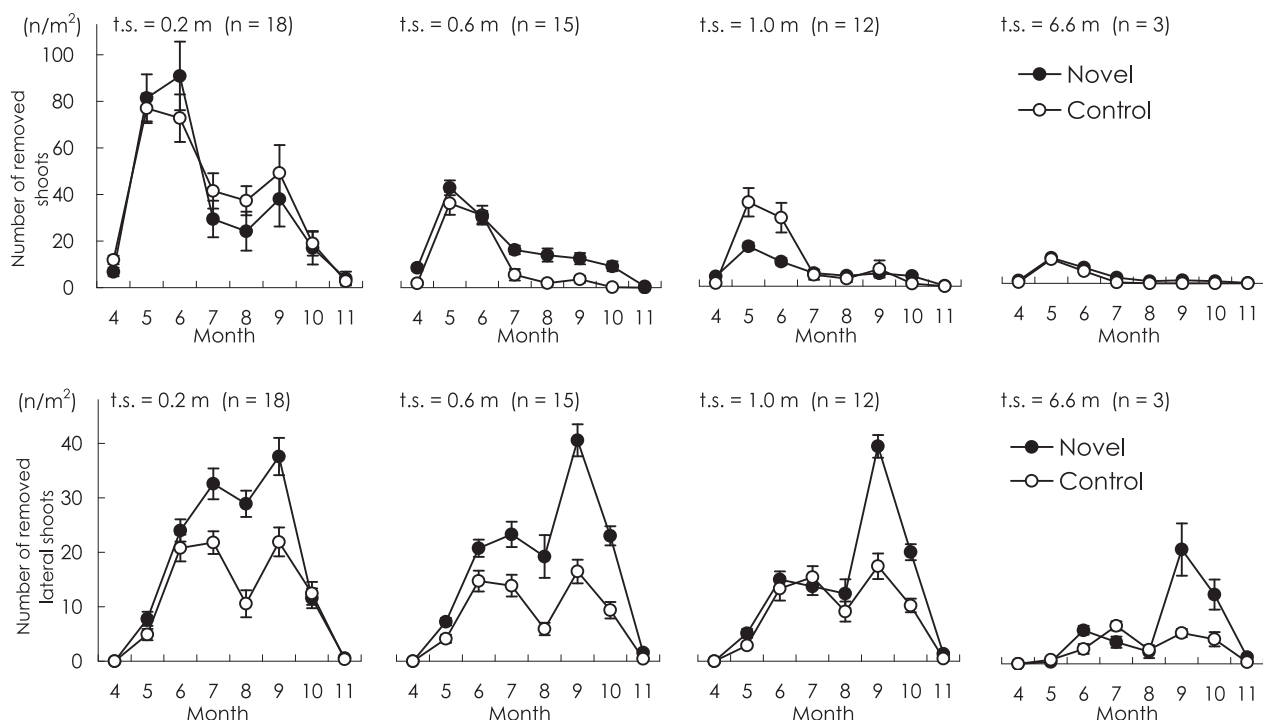
| Tree space<br>(m) | Training<br>methods | Tested<br>Shoots | Day of<br>leafing <sup>z</sup><br>(m/d) | Day of<br>pinching <sup>y</sup><br>(m/d) | Size of shoot           |                             |                           |                            | Failure of fruit set <sup>x</sup> |             |              |              |
|-------------------|---------------------|------------------|---|--|-------------------------|-----------------------------|---------------------------|----------------------------|-----------------------------------|-------------|--------------|--------------|
|                   |                     |                  |   |  | Total<br>length<br>(cm) | Internode<br>length<br>(cm) | Basal<br>diameter<br>(mm) | Apical<br>diameter<br>(mm) | 1–5<br>(%)                        | 6–10<br>(%) | 11–15<br>(%) | 16–20<br>(%) |
| 0.2               | Novel               | 18               | 4/24                                    | 7/16                                     | 139.4                   | 6.1                         | 28.6                      | 12.7                       | 8.2                               | 2.4         | 3.8          | 4.0          |
| 0.2               | Control             | 18               | 4/26                                    | 7/9                                      | 129.2                   | 6.0                         | 27.8                      | 13.4                       | 16.1                              | 2.8         | 7.2          | 3.3          |
|                   |                     |                  | NS <sup>w</sup>                         | **                                       | NS                      | NS                          | NS                        | NS                         | *                                 | NS          | NS           | NS           |
| 0.6               | Novel               | 30               | 4/23                                    | 7/9                                      | 138.5                   | 6.4                         | 27.9                      | 12.5                       | 2.0                               | 1.3         | 4.1          | 2.1          |
| 0.6               | Control             | 30               | 4/26                                    | 7/9                                      | 121.8                   | 5.6                         | 25.5                      | 12.9                       | 16.6                              | 9.7         | 6.2          | 4.4          |
|                   |                     |                  | **                                      | NS                                       | **                      | **                          | *                         | NS                         | **                                | NS          | NS           | NS           |
| 1.0               | Novel               | 36               | 4/21                                    | 7/6                                      | 135.0                   | 6.5                         | 26.0                      | 11.7                       | 5.6                               | 2.2         | 4.1          | 1.2          |
| 1.0               | Control             | 36               | 4/24                                    | 7/8                                      | 127.9                   | 6.2                         | 25.9                      | 13.1                       | 11.1                              | 1.1         | 1.7          | 2.9          |
|                   |                     |                  | **                                      | NS                                       | **                      | NS                          | NS                        | **                         | *                                 | NS          | NS           | NS           |
| 6.6               | Novel               | 48               | 4/23                                    | 7/7                                      | 128.2                   | 6.7                         | 23.3                      | 10.6                       | 3.8                               | 1.7         | 3.4          | 3.5          |
| 6.6               | Control             | 48               | 4/25                                    | 7/10                                     | 128.8                   | 6.4                         | 22.1                      | 11.4                       | 5.0                               | 1.3         | 2.1          | 0.4          |
|                   |                     |                  | **                                      | **                                       | NS                      | NS                          | *                         | *                          | NS                                | NS          | NS           | NS           |

<sup>z</sup> Day of first leafing of the earliest sound bud from each mother shoot.

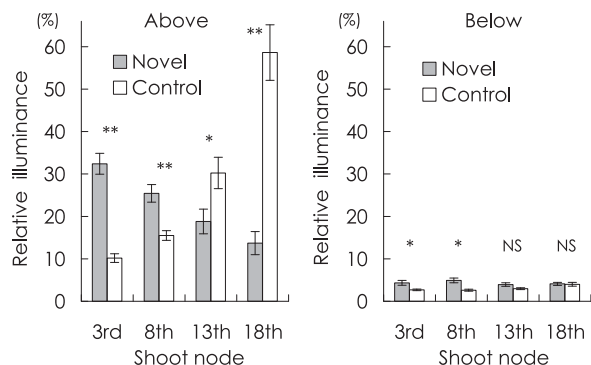
<sup>y</sup> Every shoot of each mother shoot was elongated. Each shoot was pinched when the number of its nodes reaches approximately 20. Values are mean days of pinching 80% shoots from first pinching.

<sup>x</sup> Percentage of nodes without fruit at 4 binnings of node order (1–5th, 6–10th, 11–15th, and 16–20th).

<sup>w</sup> Significances among training methods for each tree spacing (\*  $P < 0.05$ ; \*\*  $P < 0.01$ ; NS, non-significant by  $t$ -test). The failure percentage of fruit set was analyzed via angular transformation.

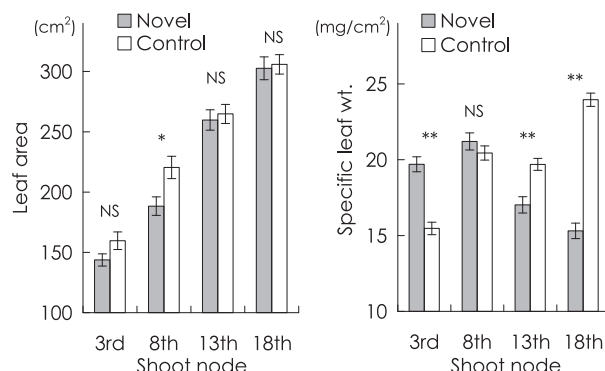


**Fig. 2.** Effect of training methods on seasonal sprouting of the superfluous shoots in 'Masui Dauphine' figs with various tree spacing (t.s.). The superfluous shoots were removed weekly, and these monthly numbers are summarized per ground area ( $\text{m}^2$ ). Consecutive charts show the lateral shoots from bearing shoots (lower group) and the shoots from the other parts of the tree (upper group). Vertical bars represent  $\pm$  SE.



**Fig. 3.** Effect of training methods on relative illuminance in the canopy of 'Masui Dauphine' figs with 6.6 m tree spacing. Vertical bars represent  $\pm$  SE ( $n=24$ ). Significances are shown among training methods at each shoot node (\*  $P<0.05$ ; \*\*  $P<0.01$ ; NS, non-significant by  $t$ -test).

internodes for the downward shoots, although pinching prevented the comparison of final shoot lengths. The leaf area reduction by training was also unclear; however, the width of the shoots and specific leaf weights were depressed in the apical part of novel training shoots. Kobayashi and Yoshimura (1953) reported that fig trees are readily able to adapt to poor lighting conditions. Matsuura and Araki (1995) also reported that shading below 40% increased the length of fig shoots and the leaf area and reduced the shoot diameter. In our novel training trees, the relative illuminance in apical and semi-apical regions (13–18th nodes) was 23–62% of controls. It is possible that the greater shoot elongation and leaf



**Fig. 4.** Effect of training methods on leaf growth of 'Masui Dauphine' figs with 6.6 m tree spacing. Surface area of the leaves (Left) and specific leaf weight (dry weight/surface area) of the leaves (Right) for various shoot nodes. Vertical bars represent  $\pm$  SE ( $n=24$ ). Significances are shown among training methods at each shoot node (\*  $P<0.05$ ; \*\*  $P<0.01$ ; NS, non-significant by  $t$ -test).

enlargement under poor illuminance offsets the inhibition due to downward positioning, and reduced the thickening growth mainly.

#### Fruit production

Table 1 shows the failure percentages of fruit set (FPFS). A high FPFS value was often observed in the basal portion of the shoots, and in trees with narrower tree spacing. Narrower tree spacing not only enhanced shoot vigour, but probably induced high FPFS due to excess growth of shoots (Kabumoto, 1986). The FPFS of the novel training trees tended to be low even with

narrow tree spacing, and was significantly less than for controls at the 1–5th node except with 6.6 m tree spacing. These findings suggest that bending prevented excess growth of shoots and prevented the failure of fruit set, but these effects are unclear in the case of normal shoot vigor promising good fruit set. It is well known that shoot bending promotes flower-bud differentiation and fruit set in various fruit tree species (Wareing and Nasr, 1958). Our results suggest that shoot bending leads to the same effect in fig trees.

For novel training and controls, we compared harvesting days and fruit qualities for each node order of shoots and each tree spacing (Table 2). Regarding the harvesting day, no difference was detected from controls except for the 13th node with 0.2 m and 6.6 m tree spacing. Narrower tree spacing tended to inhibit the coloring of fruit. On the basal portion of the shoots, the fruit coloring indexes of the novel training trees were significantly greater than for controls with every tree spacing, but less than controls in the apical portion of the shoots. The coloring index of matured fig fruits is closely related to direct light impinging on the fruit (Kabumoto, 1986). The opposite trend of fruit coloring for the portions of shoots in the two trainings must be due to the differing lighting conditions. The Brix of flesh tended to be lower in trees spaced more narrowly but was not influenced by training, apart from the 18th node with 0.6 m tree spacing and the 8th node with 1.0 m tree spacing.

Table 3 shows the fruit size, weight, and yield. The fresh weights of the fruit in novel training trees were significantly lower than for controls in the 8th nodes with 0.6 m tree spacing, the 18th nodes with 1.0 m tree spacing, and the 3rd and 8th nodes with 6.6 m tree spacing, except for larger fruit weight for the 3rd node with 0.2 m tree spacing. In general, the novel training tended to reduce the fruit weight slightly. A similar

tendency was observed for fruit size (length and width); fruit width was more closely synchronized with fruit weight. Severe shading (Matsuura and Araki, 1995) or artificial defoliation (Hosomi et al., 1989) reduces the fruit weight of figs. Hino et al. (1974) reported that, for fig trees, the photosynthetic activity of leaves declined with age after the maturation stage. In our study, low illuminance presumably inhibited the photosynthesis in younger mature leaves, which were located in the apical portion of the shoots, and insufficient carbohydrate production reduced fruit growth. Otherwise, a completely opposite relation was observed between illuminance and fruit size; the size of fig fruit increased under slightly reduced relative illuminance (Matsuura and Araki, 1995) or by direct shading of the fruit (Kabumoto, 1986). Studies should be made of whether the tendency to promote fruit growth was involved in the low illuminance condition of this novel training.

We should consider the possibility that downward shoot positioning affected not only the light condition but also sap flow in the shoots. Schubert et al. (1995) reported that downward positioning reduced the shoot growth of grapevines (*Vitis vinifera* cv. Cortese), and such shoots had a smaller xylem transectional area and lower hydraulic conductance than upward shoots. They also found that conductivity was more severely affected at the point of bending than at other internodes. The downward fig shoots in our test were bent close to the 5th node, and some inhibition of sap flow possibly takes place in the downward shoots of figs. Hosomi and Dan (1997) reported that strangulation of the base of fig tree shoots, which would disturb sap flow physically, did not affect fruit growth. It is not easy to relate reductions in fruit growth to lower hydraulic conductance in downward shoots.

**Table 2.** Effect of training methods on the fruit maturation and quality of ‘Masui Dauphine’ figs with various tree spacing.

| Tree space<br>(m) | Training<br>methods | Harvesting day (m/d) |      |      |       | Coloring index <sup>z</sup> |     |      |      | Brix of fruit juice (%) |      |      |      |
|-------------------|---------------------|----------------------|------|------|-------|-----------------------------|-----|------|------|-------------------------|------|------|------|
|                   |                     | 3rd                  | 8th  | 13th | 18th  | 3rd                         | 8th | 13th | 18th | 3rd                     | 8th  | 13th | 18th |
| 0.2               | Novel               | 8/28                 | 9/7  | 9/19 | 10/9  | 3.3                         | 3.0 | 2.9  | 2.6  | 12.0                    | 12.2 | 13.3 | 12.8 |
| 0.2               | Control             | 8/21                 | 9/1  | 9/12 | 9/28  | 2.7                         | 2.8 | 3.3  | 3.5  | 13.0                    | 11.9 | 13.0 | 13.6 |
|                   |                     | NS <sup>y</sup>      | NS   | **   | NS    | *                           | NS  | NS   | (**) | NS                      | NS   | NS   | NS   |
| 0.6               | Novel               | 8/21                 | 8/30 | 9/12 | 10/13 | 3.6                         | 3.2 | 3.0  | 2.7  | 13.8                    | 12.9 | 13.2 | 13.2 |
| 0.6               | Control             | 8/18                 | 8/27 | 9/15 | 10/6  | 3.0                         | 3.1 | 3.4  | 3.4  | 14.2                    | 13.7 | 13.5 | 14.3 |
|                   |                     | NS                   | NS   | NS   | NS    | *                           | NS  | NS   | (**) | NS                      | NS   | NS   | (*)  |
| 1.0               | Novel               | 8/19                 | 8/28 | 9/13 | 10/6  | 3.7                         | 3.1 | 2.9  | 2.5  | 14.5                    | 13.7 | 13.7 | 13.8 |
| 1.0               | Control             | 8/18                 | 8/29 | 9/14 | 10/3  | 2.9                         | 3.0 | 3.6  | 3.5  | 14.2                    | 12.8 | 13.5 | 14.1 |
|                   |                     | NS                   | NS   | NS   | NS    | **                          | NS  | (**) | (**) | NS                      | *    | NS   | NS   |
| 6.6               | Novel               | 8/17                 | 8/26 | 9/19 | 10/18 | 3.8                         | 3.4 | 3.3  | 2.9  | 15.4                    | 14.3 | 14.5 | 14.5 |
| 6.6               | Control             | 8/15                 | 8/28 | 9/13 | 10/11 | 3.3                         | 3.1 | 3.5  | 4.2  | 14.9                    | 13.8 | 15.0 | 16.1 |
|                   |                     | NS                   | NS   | **   | NS    | **                          | **  | NS   | (**) | NS                      | NS   | NS   | NS   |

<sup>z</sup> Coloring index of fruit skin, from faintly (1) to complete (5).

<sup>y</sup> Significances among training methods in each tree spacing (\*  $P < 0.05$ ; \*\*  $P < 0.01$ ; NS, non-significant). The markers in ( ) denote significantly lower values for novel training. The statistical methods used are the *U*-test for color index and *t*-test for the others.

**Table 3.** Effect of training methods on the fruit size and yield of 'Masui Dauphine' figs with various tree spacing.

| Tree space<br>(m) | Training<br>methods | Length <sup>z</sup> (mm) |      |      |      | Width <sup>y</sup> (mm) |      |      |      | Fresh weight (g) |       |      |       | Estimated <sup>x</sup><br>yield<br>(t/10a) |
|-------------------|---------------------|--------------------------|------|------|------|-------------------------|------|------|------|------------------|-------|------|-------|--|
|                   |                     | 3rd                      | 8th  | 13th | 18th | 3rd                     | 8th  | 13th | 18th | 3rd              | 8th   | 13th | 18th  |  |
| 0.2               | Novel               | 103.2                    | 77.4 | 73.8 | 67.4 | 64.1                    | 55.4 | 53.2 | 54.5 | 118.5            | 87.0  | 78.9 | 76.3  | 3.46                                       |
| 0.2               | Control             | 84.7                     | 84.5 | 84.3 | 74.4 | 53.1                    | 56.0 | 54.9 | 55.5 | 84.7             | 94.4  | 90.7 | 90.1  | 3.41                                       |
|                   |                     | ***                      | NS   | (**) | (*)  | **                      | NS   | NS   | NS   | **               | NS    | NS   | NS    | NS   |
| 0.6               | Novel               | 97.9                     | 80.7 | 78.4 | 67.9 | 57.9                    | 52.1 | 55.7 | 52.6 | 104.4            | 81.5  | 90.5 | 77.6  | 3.46                                       |
| 0.6               | Control             | 88.1                     | 85.6 | 82.3 | 69.3 | 56.3                    | 54.8 | 56.1 | 54.2 | 98.1             | 93.4  | 95.1 | 82.8  | 3.36                                       |
|                   |                     | *                        | NS   | NS   | NS   | NS                      | NS   | NS   | NS   | NS               | (**)  | NS   | NS    | NS   |
| 1.0               | Novel               | 98.3                     | 79.5 | 75.9 | 71.1 | 58.3                    | 56.5 | 55.0 | 55.9 | 107.6            | 94.4  | 89.8 | 86.6  | 3.67                                       |
| 1.0               | Control             | 93.0                     | 87.3 | 83.3 | 75.0 | 59.0                    | 56.4 | 56.3 | 59.0 | 112.6            | 97.3  | 96.4 | 103.4 | 3.92                                       |
|                   |                     | NS                       | (**) | (**) | NS   | NS                      | NS   | NS   | (*)  | NS               | NS    | NS   | (**)  | NS   |
| 6.6               | Novel               | 95.1                     | 78.8 | 68.0 | 63.4 | 57.7                    | 54.1 | 54.8 | 56.6 | 109.4            | 88.2  | 84.7 | 84.1  | 3.50                                       |
| 6.6               | Control             | 95.3                     | 83.3 | 78.1 | 62.4 | 60.1                    | 58.0 | 55.0 | 53.4 | 121.3            | 102.4 | 89.1 | 77.9  | 3.80                                       |
|                   |                     | NS                       | (**) | (**) | NS   | (*)                     | (**) | NS   | *    | (*)              | (**)  | NS   | NS    | NS   |

<sup>z</sup> Length from the calyx top to the stylar end of fruit.

<sup>y</sup> Diameter of equatorial section of the fruit.

<sup>x</sup> The yield ( $Y$ ) of each tree was estimated from the equations:  $W = mF \cdot N$ ,  $Y = mW \cdot S \cdot T$ , where  $W$  is product of the mean of fresh weights of fruits ( $mF$ ) and the number of fruit set ( $N$ ) at the base to 20 nodes of each shoot; estimated yield ( $Y$ ) is product of the mean of  $W$  ( $mW$ ), the shoot number ( $S$ ) and the tree number per 10 a ( $T$ ) for each tree of each tree space.

<sup>w</sup> Significances among training methods in each tree spacing (\*  $P < 0.05$ ; \*\*  $P < 0.01$ ; NS, non-significant by  $t$ -test). The markers in ( ) denote significantly lower values for novel training.

#### Application for practical use

We have confirmed elsewhere the beneficial effect of the novel training in preventing injury due to freezing, probably because of the smaller temperature differences on the primary scaffold (Mano et al., 2012a). Another benefit is the reduction of animal invasion in the early harvest season when a high market price is expected. In this study, two additional beneficial effects of the novel training with downward shoots were identified, promoting fruit set and coloring on the shoot in the basal portion. Fruit set was promoted only with narrower tree spacing. Such dense planting is not yet common, but is promising for early tree maturation (Mano et al., 2011). Fruit set promotion by the novel training will become more useful with the diffusion of dense planting. The promotion of fruit coloring is particularly useful because the coloring disorder in the basal portion of the shoot is a structural problem encountered in straight line training in fig culture (Kabumoto et al., 1985). Novel training can resolve this problem. Fruit coloring in the apical portion of the shoots of novel training trees was worse. The commercial harm due to reduced coloring will be slight, because the season of maturity for such fruits is late and the market price will be fairly low.

Two technical problems arose in this novel training. One problem is increasing the number of lateral shoots. From 2 to 3 times the number of shoots sprout in autumn, and the farmer must pay labor costs for disbudding. Estimating other labor for novel training is important in practical use. The lobar in harvesting was lower in the novel training than controls, because of the larger proportion of fruit on the shoot in the upper half (120–180 cm GL) of the tree where working in a standing

position is possible (unpublished). The total labor, including disbudding, shoot training, and harvesting, for cultivation in novel training must be assessed in a future demonstration study.

A further problem is the decrease in fruit weight, because the weight of each fruit will restrict the total yield and reduce profit. In our study, the yield per area was estimated as 3.36 to 3.92 t/10 a (Table 3). A lower fruit weight correlated with lower yield in the novel training with 1.0 m or 6.6 m tree spacing, and no significant difference was detected. In the next study, suitable shoot positioning will be investigated to overcome these problems, because the lighting condition may be an important factor in relation to shoot bending.

A year-by-year constant effect of training is important in practical use. Similar studies have confirmed that the advantages (promoting coloring) and disadvantages (more removed lateral shoots and reduction of yield) of novel training were reproducible annually (unpublished). No reserve nutrient reduction was observed in those studies. For instance, the starch and water soluble sugar content in dormant shoots of novel training was equal to or greater than values in normal training (Mano et al., 2012b). Premature defoliation, disorders in germination, and failure of fruit set in the novel training were not observed in subsequent years. These observations were based on trials of only a few years. Longer continuous research and physiological investigation are required to characterize better the advantages of the novel training.

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### Literature Cited

- Condit, I. J. 1955. Fig varieties: A monograph. *Hilgardia* 23: 323–538.
- Downing, A. J. 1869. *Fruits and fruit trees of America*. p. 38–45. John Wiley, New York.
- Fujimura, J. 1932. Comparison of shoot growth from upright and horizontal twigs of young Japanese persimmon trees. Scientific papers dedicated to the tenth anniversary of the Miye College of Agriculture and Forestry: 43–56 (In Japanese).
- Hino, A., S. Amano, Y. Sawamura, S. Sasaki and T. Kuraoka. 1974. Studies on the photosynthetic activity in several kinds of fruit trees II. Seasonal changes in the rate of photosynthesis. *J. Japan. Soc. Hort. Sci.* 43: 209–214 (In Japanese with English summary).
- Horimoto, M., K. Matsuura and H. Araki. 1994. Freezing tolerance of fig trees and protective covering with aluminum coated film. *Bull. Hyogo Pre. Agri. Inst. (Agriculture)* 42: 37–42 (In Japanese).
- Hosomi, A. and M. Dan. 1997. Effect of pinching and strangulation of shoot on fruit growth of ‘Houraishi’ fig. *Kinki Chūgoku Agr. Res.* 94: 45–48 (In Japanese with English summary).
- Hosomi, A., Y. Okuda and M. Dan. 1989. Ripening control and fruit quality of fig (*Ficus carica* L.) practical application of plural oleification by ethephon. *Bull. Osaka. Agr. For. Res. Ctr.* 25: 31–37 (In Japanese with English summary).
- Kabumoto, T. 1986. Physiological and ecological studies on the training method of fig tree. *Special Bull. Hyogo Pref. Agr. Cent.*: 1–88 (In Japanese).
- Kabumoto, T., T. Nakaoka, T. Taniguchi, T. Fujiwara and T. Fujiwara. 1985. Studies on the training method of fig tree, 2 Developing new training method and on the tree growth, yield, quality and laboring hours for cultivation in straight line training. *Bulletin of the Hyogo Prefectural Agricultural Center for Experiment, Extension and Education* 33: 74–78 (In Japanese).
- Kato, T. and H. Ito. 1962. Physiological factors associated with the shoot growth of apple trees. *Tohoku Journal of Agricultural Research* 13: 1–21.
- Kobayashi, A. and F. Yoshimura. 1953. Growth of young fruit trees as related to shading. *Studies from the Institute of Horticulture, Kyoto University* 6: 64–68 (In Japanese with English summary).
- Lovisolo, C. and A. Schubert. 2000. Downward shoot positioning affects water transport in field-grown grapevines. *Vitis* 39: 49–53.
- Mano, T., Y. Mizuta and T. Moriguchi. 2011. Super-high density planting of fig (*Ficus carica* L.) for early recovery from sick soil and low temperature injury. *Hort. Res. (Japan)* 10: 367–373 (In Japanese with English abstract).
- Mano, T., Y. Mizuta, A. Ito, T. Isobe, A. Hosomi and T. Moriguchi. 2012a. Effect of height of primary scaffold branch on freezing injury of fig (*Ficus carica* L.). *Hort. Res. (Japan)* 11: 351–356 (In Japanese with English abstract).
- Mano, T., A. Ito, T. Isobe, Y. Miwa, A. Hosomi, Y. Mizuta and T. Moriguchi. 2012b. Effect of height of primary scaffold branch on freezing injury and reserve nutrient of fig (*Ficus carica* L.). *Hort. Res. (Japan)* 11 (Suppl. 2): 375 (In Japanese).
- Matsuura, K. and H. Araki. 1995. Effect of shading on the growth, fruit set, yield and fruit quality in fig trees of ‘Masui Dauphine’. *Bull. Hyogo. Pre. Agri. Inst. (Agriculture)* 43: 21–26 (In Japanese with English summary).
- Oinoue, Y. 1932. Some observations on the reversibility of Ricôme’s effect in grape vine. *J. Japan. Soc. Hort. Sci.* 3: 41–48 (In Japanese with English summary).
- Schubert, A., M. Restagno, V. Novello and E. Peterlunger. 1995. Effects of shoot orientation on growth, net photosynthesis, and hydraulic conductivity of *Vitis vinifera* L. cv. Cortese. *Am. J. Enol. Vitic.* 46: 324–328.
- Somkuwar, R. G. and S. D. Ramteke. 2008. Effect of shoot orientation on growth, biochemical changes and fruitfulness in Thompson Seedless (*Vitis vinifera* L.) grapes. *J. Plant Sci.* 3: 182–187.
- Wareing, P. F. and T. Nasr. 1958. Effects of gravity on growth, apical dominance and flowering in fruit trees. *Nature* 182: 379–380.