園学雑. (J. Japan. Soc. Hort. Sci.) 70 (1) : 1-6. 2001.

The Effects of Different Night Temperatures and the Amount of Hydroponic Solution on the Growth and Fruiting of Own-rooted Fig Cuttings

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Summary

The basal ends of cuttings of fig cv. Masui-Dauphine were imbedded into rockwool cubes on 2 December 1996 and raised in an enclosed nursery kept at 17 ℃ or 23 ℃ night temperatures(NT). The cuttings, raised at 17 ℃ NT, had shorter shoot but the leaves had higher photosynthetic rates than had those raised at 23 ℃ NT. The nursery plants were then transplanted onto a non-circulating closed hydroponic system in a greenhouse held at 11 ℃ or 17 ℃ NT on 16 January 1997.

Shoot growth was restricted after being transplanted in the greenhouse kept at 11 ℃ NT, regardless of the NT in the nursery; the first fruit was formed at the 5th node approximately 50 days after transplanting, whereas on nursery plants raised at 17 ℃ NT grown in the greenhouse kept at 17 ℃ NT, the first fruit was formed at a lower node 5 days later than those previously raised at 23 ℃ NT. When these plants were weighed, dried, and reweighed on 24 March, their shoot weights did not differ significantly, but the root weights of nursery plants raised at 17 ℃ NT were heavier than were those raised at 23 ℃ NT.

Shoots of nursery plants, supplied 100 ml of nutrient solution per plant daily 30 days after transplanting, were shorter than were those supplied 150 ml of nutrient solution. However, root growth and the nodal position of first fruiting did not differ between the two plots.

Key Words: cutting, fig, hydroponic, night temperature, photosynthetic rate.

Introduction

Previously (Teragishi et al., 1998b) we found that one-year-old fig cuttings, raised hydroponically in a phytotron under a 14-hr photoperiod with 8.5 klx of light and at 23 ℃, developed good roots and leaf color. After transplanting onto a non-circulating closed hydroponic system, those plants formed many fruits while absorbing a large amount of nutrient solution. Fruit growth was promoted by a high photosynthetic rate during harvest from May to July. These results led to the possibility of obtaining early summer crops, but whether it was cost-effective was not known because of the cost of artificial lighting. Hence, to double-crop figs within one year, a winter crop was cultivated from mid-July to December, followed by a summer crop until July to investigate whether our cultural method and investment were economically feasible.

Inayama and Murakami (1973) reported that in cucumber plants raised in a nursery under low night temperature, shoots grew slower than roots because photosynthates were translocated to the roots faster than in plants raised under high night temperature. Also, Sung et al. (1997) found that the size of cucumber plants in the nursery affected subsequent shoot growth, root weight, and photosynthetic capacity.

In this study, the effects of two night temperatures on fig cuttings in the nursery on their growth, photosynthetic capacity, and fruiting and after transplanting on subsequent plant and fruit growths were examined. Simultaneously, the influence of the amount of nutrient solution administered for 30 days after transplanting on subsequent shoot and root growths, and fruiting were studied.

Materials and Methods

This study was conducted in the greenhouse at Kyoto Prefectural Yamashiro Horticultural Research Institute (Present; Kyoto Prefectural Agricultural Research Institute, Ornamental Plants Division, at Kyotanabe in Kyoto Prefecture).

Cuttings of fig (*Ficus carica* L.) cv. Masui-Dauphine were made on 25 November 1996 from current shoots between the 5th-10th nodes. They were kept at 0.5 ℃ for 7 days to increase the percentage of transplantable cuttings (Teragishietal.,1998a). On 1 December, they were re-cut to 22 cm in length (about 17 mm in diameter) and the basal ends dipped in 50 ppm IBA.

Received; October 25, 1999. Accepted; April 17, 2000.

After 24 hr the cuttings were then imbedded into rock-wool cubes of 422 cm^3 in a greenhouse kept at a maximum of 30 ℃.

1. Effects of 17 ℃ or 23 ℃ at night in the nursery on subsequent shoot growth and fruiting

Cuttings anchored in rockwool were kept at 17 ℃ or 23 ℃ at night (hereafter, 17 ℃- or 23 ℃-raised, respectively) in the nursery from 2 December to 16 January 1997. Until 10 December, water was supplied with rockwool, and Hoagland II solution of EC 2.4 ds・m^{-1} was supplied. All nursery plants were disbudded to a single leader on 20 December.

On 16 January 1997, shoot length and the fresh weights of shoots and roots of 20 nursery plants were recorded. The leaf color score was measured with SPAD-501 Colorimeter (Minolta Co.,Tokyo). Subsequently, the shoots and roots dried and reweighed while the leaves were analyzed for chlorophyll content.

2. Effects of exposure to 11 ℃ or 17 ℃ at night after transplanting and different amounts of nutrient solution supply on shoot and root growths and fruiting

A total of 27 nursery in 17℃- and 23℃-raised plants were transplanted on 16 January to a non-circulating closed hydroponic system (Teragishi et al., 1998a) in a greenhouse kept at 11℃ or 17℃ at night (hereafter, 11℃- or 17 ℃-greenhouse). Plants in the 17 ℃-greenhouse were supplied with 100 ml or 150 ml of Hoagland II solution (EC 2.4 dS・m^{-1}) per plant daily until 15 February. The effects of the 100 ml and 150 ml treatments on shoot and root growths and fruiting were recorded.

From 16 February to 24 March, cuttings in the 11 ℃- and 17 ℃-greenhouse were supplied with 400 ml of solution which was absorbed completely.

When the 1st fruit formed on the cuttings, its nodal position and date were recorded and the days after transplanting calculated.

On 14 March, 6 plants from all plots were sampled and the fresh and dry weights of shoots and roots and the number of fruits per plant were recorded. The remaining plants in 17 ℃-greenhouse were pinched just above the 17th node on 14 March.

The photosynthetic capacity was measured with a portable photosynthesis system (SPB-2, Shimadzu., Kyoto) at 11 AM on 16 January on the 3rd leaf from the base, 16 days after full expansion, and on 6 and 24 February and 18 March on the 2nd leaf from the apex which was exposed to maximum PPFD.

On 28 March, 6 plants from all plots in the 17 ℃-greenhouse were analyzed as above.

Results

1. Characteristics of 17℃- and 23℃-raised nursery plants

The 17 ℃-raised nursery plants at transplanting had shorter shoots than had those of 23 ℃-raised plot but their color scores of the 3rd leaf and the total chlorophyll content per g FW were not significantly different (Table 1). The shoot dry weight of the 17 ℃-raised nursery plant was half that of the 23 ℃-raised nursery plant but root dry weights between the two plots were not significantly different. Thus, the shoot/root (S/R) ratio differed.

2. Comparison of shoot and root growths and fruiting of cuttings exposed to (a) 11 ℃ and 17 ℃ after transplanting and (b) water supply

a. The sizes of shoots and roots of fig plants kept at 11 ℃ of night temperature for 57 days after transplanting (14 March) were significantly different whether they were initially cultured at 17℃ or 23℃ at night (Table 2). Plants from the 23 ℃-raised plot produced more leaves than did those from the 17 ℃-raised plot. The first fruit was formed about 50 days after transplanting at the 4th to the 5th nodes, 3 additional fruits were formed per plant at higher nodes in both plots.

b. Shoot length, number of leaves, and maximum leaf area of fig plants in the 100 ml and 150 ml treatments differed significantly, but not those in the 17 ℃- and 23 ℃-raised plants (Table 3). No difference was observed in fresh and dry weights of roots among all plots.

The nodal position of first fruiting was lower on the 17 ℃-raised plants than that on the 23 ℃-raised plants, but it was the same in the 100 ml and 150 ml treatments.

Table 1. Effect of different night temperatures on growth of fig cuttings in the nursery.[z]

Night temperature (℃)	Shoot length (cm)	Number of leaves per plant	Leaf color[y] (Spad)	Total chlorophyll content (mg・g^{-1} FW)	Shoot weight (g)		Root weight (g)		S/R
					Fresh	Dry	Fresh	Dry	
17	13.3	5.3	26.8NS	1.4NS	9.4	1.2	7.6NS	0.6NS	2.0
23	18.0*[x]	6.8*	28.7	1.5	20.7*	2.5*	6.8	0.6	4.3*

[z] Measured at 16 January.

[y] The 3rd leaf from the base of plant was measured.

[x] * or NS indicate significant or not significant difference at 5% level.

Table 2. Effect of different night temperatures in the nursery on shoot and root growth, and fruiting in 11 ℃-greenhouse[z].

Night temperature in the nursery (℃)	Shoot length (cm)	No. of Leaves	Maximum leaf area (cm^2)	Root weight (g)		The nodal position of 1st fruiting	No. of fruiting	Days to 1st fruiting after transplanting
				Fresh	Dry			
17	60.7NS[y]	14.7	310NS	45.0NS	4.3NS	4.6NS	4.2NS	50.1NS
23	66.2	16.7*	327	43.3	4.1	4.7	3.7	48.1

[z] Measured on 14 March.
[y] * or NS indicate significant or not significant difference at 5% level.

Table 3. Effects of different night temperatures and the amount of irrigation supplied for 30 days after transplanting on shoot and root growth, and fruiting in 17 ℃-greenhouse[z].

Amount of irrigation[y] (liter・$plant^{-1}$・day^{-1})	Shoot length (cm)	No. of leaves	Maximum leaf area (cm^2)	Root weight (g)		The nodal position of 1st fruiting	No. of fruiting	Days to 1st fruiting after transplanting
				Fresh	Dry			
17 ℃-raised plant								
100	70.3b[x]	17.3b	396b	65.4NS	5.2NS	3.5a	8.2a	40.1a
150	94.0a	18.9a	535a	55.7	4.5	3.2a	8.4a	42.1a
23 ℃-raised plant								
100	77.2b	17.8b	436b	63.3	4.9	5.0b	6.7b	35.5b
150	97.5a	18.9a	541a	53.3	4.4	5.0b	6.7b	36.5b

[z] Measured at 57 days after transplanting (14 March).
[y] The nutrient solution was supplied from 16 January to 15 February.
[x] Mean separation within columns by Duncun's multiple range test at 5% level.

Table 4. Effect of different night temperatures on growth of fig cuttings and cumulative amount of absorbed solution in 17 ℃-greenhouse 67 days after transplanting.

Night temperature in the nursery (℃)	Shoot length (cm)	Shoot weight (g)		Root weight (g)		S/R	Cumulative amount of absorbed solution[z] (liter・$plant^{-1}$)
		Fresh	Dry	Fresh	Dry		
17	99.2NS[y]	348NS	31.6NS	72.5*	5.6*	5.6*	20.0
23	93.0	337	33.4	53.6	4.1	8.1	18.2

[z] Measured between 16 January and 24 March.
[y] * or NS indicate significant or not significant difference at 5% level.

The days to first fruitng after transplanting were about 5 days longer in 17 ℃-raised plants than that in 23 ℃-raised plants, but plants administered 100 ml and 150 ml of nutrient solution daily formed their first fruits on the same day.

Shoot length and their fresh and dry weights of plants from the 17 ℃-greenhouse did not differ 67 days after transplanting whether they were previously grown at 17 ℃ or 23 ℃ in the nursery (Table 4). However, the fresh and dry weights of their roots on the 17 ℃-raised plants were heavier than those on the 23 ℃-raised ones. Therefore, the 23 ℃-raised plants had a significantly larger S/R ratio than had the 17 ℃-raised ones.

The amount of nutrient solution absorbed between 16 January and 24 March was 1.8 liter more in the 17 ℃-raised plants than that in the 23 ℃-raised ones.

Data on photosynthetic rates (Pn), transpiration rates (Tr) and stomatal conductances (Gs) on 16 January, the transplanting date, revealed that the 17 ℃-raised plants had higher Pn and Gs than the 23 ℃-raised ones but Tr was the same. On 2 February, the 17 ℃-raised plants still had a higher Pn than the 23 ℃-raised ones, but their Tr and Gs did not differ (Table 5). On 24 February, the 17 ℃- and 23 ℃-raised plants had the same Pn, but Tr and Gs were higher in the former than in the latter. On 18 March all measurements on the 17 ℃-raised plants were higher than those on the 23 ℃-raised ones.

Discussion

When eggplant (Rou and Kato, 1987) and cucumber (Murakami and Inayama, 1974) were grown under a high night temperature in nursery, shoot growth was promoted in both species and the first fruit was formed at a higher node than plant exposed to low night

Table 5. Effect of different night temperatures in the nursery on photosynthetic and transpiration rates, and stomatal conductances on fig plants grown hydroponically.

	Night temperature in the nursery (℃)	16 Jan.	2 Feb.	24 Feb.	18 Mar.
		0	17	39	61 days[z]
Photosynthetic rate[y]	17	6.6*[x]	5.6*	7.6NS	9.6*
($mg\,CO_2 \cdot dm^{-2} \cdot hr^{-1}$)	23	5.1	4.7	7.4	6.0
Transpiration rate[y]	17	4.2NS	4.6NS	4.0*	5.0*
($g\,H_2O \cdot dm^{-2} \cdot hr^{-1}$)	23	4.2	4.0	2.8	3.4
Stomatal conductance[y]	17	4.4*	1.2NS	1.0*	1.0*
($cm \cdot sec^{-1}$)	23	2.7	1.1	0.5	0.5

[z] The days were calculated after transplanting.

[y] The 3rd leaf from the base of plant was measured at 16 January, and the 2nd leaf from the top of plant on other dates.

[x] * or NS indicate significant or not significant difference at 5% level.

temperature. However, high night temperatures resulted in lower starch and chlorophyll contents which were attributed to a lower photosynthetic rate and poor rooting after transplanting. Hence, high night temperature increased S/R ratio based on dry weight.

Our data revealed that fig cuttings exposed to 23 ℃ at night before transplanting, promoted greater shoot than root growth, resulting in a larger S/R ratio than at 17 ℃. Pn on 16 January was lower at the 23 ℃-raised plants than at the 17 ℃-raised one (Table 5), the first fruiting occurred at a lower nodal position in the 17 ℃-raised plants than the 23 ℃-raised ones (Table 3). Thus, we believe that to induce fruiting at a lower node, nursery plants should have a small S/R ratio at transplanting and a high Pn. Ito (1972) reported that the high net assimilation rate of tomato in nursery plants correlated with a small S/R ratio. On the contrary, fig cutting in the nursery exposed to 17 ℃ at night had higher Pn than those grown at 23 ℃ at night, even though their chlorophyll contents were equal. Hence, the influence of temperature on Pn, assimilation of carbohydrates and their loss through respiration by nursery plants, and their fruit formation after transplanting need to be assessed.

With 'Kadota' fig, Hosomi (1997) found that the nursery plants grown at 11 ℃ for 20 days had restricted shoot growth and formed the first fruit at a low node. But with 'Masui-Dauphine', exposed to 11 ℃ at night after transplanting, shoot growth was restricted and fruiting node was higher compared to the nursery plants exposed to 17 ℃ at night. Hence, we conclude that the first fruit is not necessarily formed at a lower node when shoot growth is restricted.

The fig nursery plants, kept at 17 ℃ at night and supplied with more nutrient solution, developed longer shoots and larger leaves compared with those getting less nutrient solution, while roots grew equally well in all plots. These results are contrary to nursery-grown tomamto plants treated with uniconazol (Asao et al., 1996).

Our data show that root growth and the nodal position of the first fruit are unaffected by the growth rate of shoots and leaves after transplanting. Therefore, to increase yield, cuttings should be exposed to 17 ℃ at night, subsequently they should be transplanted to a greenhouse kept at 17 ℃ at night.

Hereafter, it is necessary to investigate the minute temperature in nursery in order to advance harvest, because days to first fruiting after transplanting were 5 days longer in 17 ℃-raised plants than in 23 ℃-raised ones.

The rooting of hardwood grapevine cuttings was hardly affected by photosynthesis in young leaves at an early stage of propagation (Ooishi et al.,1980). But, in this study, shoot and root growths in 17 ℃-raised plant were promoted after transplanting, shoot length and weight in 17 ℃-raised plant were equal with those in 23 ℃-raised one, and root weight was significantly greater in 17 ℃-raised plant 67 days after transplanting. Our data reveal that reserved carbohydrates during raising may subsequently affect Pn. Okubo and Utsunomiya (1996) reported that the dry weight of fig roots increased when Pn and Tr were high. In satsuma mandarin, Shrestha et al. (1995) reported that inoculation by VAM fungi affected leaf temperature, increased Pn and Tr;the increases were accompanied by increased root growth. In one-year-old satsuma mandarin trees (Morinaga and Ikeda, 1990), promotion of root growth was attributed to an increase in Pn and shoot growth. Likewise, shoot growth and subsequent yield were accompanied with greater root growth in bell pepper (Leskovar and Cantliffe, 1993). In this study, the larger roots in the 17 ℃ than in the 23 ℃ treatment after 18 March are attributed to a differential partitioning of photo-assimilates to roots as a consequence of faster Tr and Pn.

In conclusion, we recommend that fig cuttings should be exposed to 17 ℃ at night rather than 23 ℃ to reduce the respiration rate and, thereby, conserve reserved carbohydrates. This would promote the growth of roots which would, in turn, improve nutrient uptake after transplanting and induce the first fruits to be initiated at lower nodes.

Acknowledgements

We wish to thank Dr. M.Nakano and Dr. M.Ishida of Kyoto Prefectural Univ. for their useful suggestions. We also would like to express our gratitude to emeritus prof. Y. Sobajima of Kyoto Prefectural Univ. for his guidance.

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夜温と給液量が養液栽培したイチジク挿し木苗の生長と着果に及ぼす影響

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摘　要

イチジク‘桝井ドーフィン’の穂木を1996年12月2日にロックウールに挿し木し，夜温17℃または23℃で育苗した．夜温17℃で育苗した苗は夜温23℃で育苗した苗よりも新梢長が短く，光合成速度は高かった．1997年1月16日に夜温11℃又は17℃としたハウス内の非循環閉鎖型養液栽培システムに定植した．定植後，夜温11℃では新梢の生長が抑制された．また，育苗中の夜温の違いに関係なく，第1果は定植から50日後に約5節目に着果した．一方，夜温17℃のハウスでは，第1果は夜温17℃で育苗した区の方が低節位に着果したが，夜温23℃で育苗した区よりも着果が5日遅かった．3月24日に，新梢の乾物重に育苗中の夜温の違いによる差はなかったが，根の乾物重は夜温17℃で育苗した区の方が23℃で育苗した区よりも大きかった．また，同じく17℃のハウスでは，定植後30日間の給液量を株当たり100ml/日または150ml/日の2区を設定した．定植後30日間の給液量を100ml/日とした区では新梢の生長が抑制されたが，根の生長および第1果着果節位に差はなかった．