Scientia Horticulturae 126 (2010) 152–155

Contents lists available at ScienceDirect

Scientia Horticulturae

journal homepage: www.elsevier.com/locate/scihorti

Effect of different girdling dates on tree growth, fruit characteristics and reserve accumulation in a late-maturing persimmon

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ARTICLE INFO

Article history:
Received 20 May 2010
Received in revised form 21 June 2010
Accepted 29 June 2010

Keywords:
Diospyros kaki
Fruit maturity
Nonstructural carbohydrates
Storage reserves
Water sprout

ABSTRACT

Trunks of 8-year-old vigorous 'Fuyu' persimmon (*Diospyros kaki* Thunb.) were girdled to a 1 cm width on April 20 and June 10 2004. Tree growth and fruit characteristics were monitored for two years, with special emphasis on the carry-over effect in 2005. Girdling reduced trunk and shoot growth especially of April-girdled trees over two consecutive years. However, the most significant effect of girdling was in the occurrence of water sprouts: a control tree had 29.5 in 2004 and 27.3 in 2005, whereas the April-girdled trees had only 0.3 and 5.3, respectively. Girdling increased fruit set by nearly 50% and enhanced fruit colour in 2004 only. Girdling date did not significantly affect fruit size and soluble solids for two years. Fruit flesh of girdled trees in 2004, especially in the April-girdled trees, had lower N and P concentrations. The levels of starch, soluble sugars, and inorganic elements in flower-bearing distal buds measured just before new growth in 2005 were not significantly altered by the girdling in 2004.

1. Introduction

Lowering tree height has become an important practice for efficient management of persimmon trees. This practice is aimed not only to save labour but also to produce quality fruits. Tall trees reduce light penetration into the canopy, thereby reducing fruit quality (Yakushiji et al., 1997). Lowering tree height is accomplished most frequently by severely heading large scaffolds or tree trunks. This can lead to excessive shoot growth, increased fruit drop and delayed fruit maturity (Goren et al., 2004). Because of early frost in major persimmon growing area of South Korea, any delay in fruit maturity can result in harvesting immature fruits of late-maturing cultivars such as 'Fuyu.'

Trunk girdling is one of many options to control excessive shoot growth and to accelerate fruit maturation, especially of those trees that have been headed back. Trunk girdling temporarily diverts photosynthates to the aboveground parts of the tree, resulting in the decline in root growth (Noel, 1970; Goren et al., 2004). The absorption of inorganic elements (Day and DeJong, 1990; Fumuro, 1998) and the production of growth regulators such as cytokinins (Grierson et al., 1982; Cutting and Lyne, 1993; Goren et al., 2004) are thus reduced in the root. As a result, vegetative growth of the tree is decreased (Ido and Proctor, 1994; Arakawa et al., 1997; Fumuro, 1997, 1998), while fruit maturation is accelerated (Noel, 1970; Day and DeJong, 1990; Agustí et al., 1998; Mataa et al., 1998). An increase in fruit set due to girdling would also curtail shoot growth (Goren et al., 2004), but few studies are available in persimmon.

The effect of trunk girdling on tree growth and fruit quality and yield seems well documented in deciduous fruit crops (Noel, 1970; Grierson et al., 1982; Goren et al., 2004; Wargo et al., 2004). Steyn et al. (2008) evaluated the effects of girdling on the yield and quality performance of the astringent 'Triumph' in South Africa, but only limited studies have been conducted on the vigorous, non-astringent cultivar in South Korea. Furthermore, little information is available on the changes in carbohydrates and inorganic elements in 1-year-old twigs, on which fruits are borne the next season in persimmon. This experiment was conducted to evaluate the effects of two girdling dates on tree growth, fruit quality and nutrient composition of 1-year-old twigs and flowering-bearing buds of a late-maturing cultivar in South Korea. We also evaluated the effect of girdling on similar performance variables in the subsequent growing season.

2. Materials and methods

2.1. Plant materials

Eight-year-old trees of 'Fuyu' persimmon (*Diospyros kaki*) were used. The trees, grafted in early April 1997 on 'Fuyu' seedlings in a nursery, were transplanted at a spacing of 6 m × 3 m in sandy loam soil at Sweet Persimmon Research Institute, Gimhae, Korea. The trees were headed back in early March 2004 from about 3.5 m to

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doi:10.1016/j.scienta.2010.06.026

Table 1
Effect of different girdling dates in 2004 on trunk cross-sectional area (TCSA), shoot growth, and the number of water sprouts of 'Fuyu' persimmon in 2004 and 2005.

Girdling date	TCSA increment[a] (cm^2)		In 1-year-old twig[b]				Water sprout[c] (No./tree)	
	2004	2005	Terminal shoot length (cm)		No. of shoots		2004	2005
			2004	2005	2004	2005		
Control	16.7 a[d]	13.8 a	34 a	35 a	4.0 a	3.7 a	29.5a	27.3a
April 20	3.6 c	8.2 b	25 b	23 c	4.1 a	4.1 a	0.3 a	5.3 a
June 10	8.9 b	12.4 ab	33 a	31 b	4.4 a	3.8 a	8.3 b	13.3b

[a] TCSA increments for 2004 and 2005 are from April 20, 2004 to March 31, 2005 and from March 31 to October 29, 2005, respectively.
[b] One-year-old twigs were 25 ± 5 cm long.
[c] Upright shoots longer than 60 cm were counted.
[d] Mean separation within columns by LSD test at 5%.

about 2.2 m, leaving four scaffolds per tree. The trees had received standard care as prescribed by the institute. Fruit load was adjusted to a leaf-to-fruit ratio of 20 by bud thinning in mid-May combined with the final fruit thinning in late July.

2.2. Treatments

Tree trunks were girdled by removing a ring of bark, 1 cm wide, at 15 cm above the graft-union at two different dates: April 20 (AG hereafter), 27 days after budbreak, and June 10 (JG), 18 days after full bloom. On April 20, terminal shoots were about 8 cm long and actively growing, but they had stopped their extension growth by June 10. More than 80% of the girdling wounds were healed by early June in AG trees and by late July in JG trees. Four similar non-girdled trees served as the controls. Four single-tree replicates were assigned for each treatment in a completely randomized design.

2.3. Measurements

To determine the current and carry-over effect of the girdling on vegetative growth of the trees, the increment of trunk cross-sectional area (TCSA), shoot and leaf growth, the occurrence of long and upright water sprouts originating from latent buds, and pruning weights were recorded over a two consecutive year period. The TCSA value was calculated from trunk circumferences measured at 10 cm above the graft-union on March 31, 2005, and October 29, 2005. Shoot numbers were counted on twenty of 25 ± 5 cm long 1-year-old twigs per tree on November 30 in 2004 and 2005. On August 31, 2004 and June 3, 2005, 20 leaves per tree were sampled to measure greenness of the leaves with a chlorophyll meter (SPAD-502, Minolta Co., Japan) and leaf area with an area meter (AAM-8, Hayashi Denkoh Co., Japan). Specific leaf weight (SLW) was also calculated by dividing leaf area with its dry weight. Upright water sprouts that had grown longer than 60 cm were counted on November 30, 2004 and on July 21, 2005, just before summer pruning. After dormant pruning in March, 2005 and summer pruning in July, 2005, the fresh weight of each pruning was recorded.

The scaffold branches with 100–150 flowers were tagged to calculate percent fruit set on July 21, 2004 and 2005. Fresh weight, total soluble solids (N1, Atago Co., Japan), firmness (TA-XT2, Stable Micro Systems Co., England), and colour as Hunter *a* value to indicate redness (CM-508i, Minolta Co., Japan) were measured on 40 fruits harvested on each datum tree on November 1, 2004 and 2005. The peel was separated from the fruit flesh to determine inorganic elements in each part. Flower buds were counted on May 14, 2005, on twenty of 25 ± 5 cm long 1-year-old twigs per tree.

Since flowers are borne in several buds of the distal end of 1-year-old twigs in persimmon, concentrations of starch, soluble sugars, and inorganic elements were determined from ten of 25 ± 5 cm long such twigs and their five most distal buds collected on March 21, 2005. Samples were dried at 80 °C for 48 h and ground to pass through a 20-mesh screen. Concentrations of soluble sugars and starch were measured as described previously (McCready et al., 1950; Yoon, 1996), using glucose as a standard. Methods used for the determinations of inorganic elements were: Kjeldahl digestion for N, vanadate reaction for P, and atomic absorption for K and Ca. Five determinations per replication were made for all chemical analyses of fruits and twigs.

Statistical analyses were performed using the SAS program (SAS Institute, Inc., Cary, N C). Differences among the treatment means were detected by LSD test at 5%.

3. Results

Girdling reduced the growth of trunk and terminal shoots not only in 2004 but also in 2005 (Table 1). The reduction was more evident in AG than in JG trees. The TCSA increment in 2004 was 16.7 cm^2 in control trees while it was 3.6 in AG and 8.9 cm^2 in JG trees. Number of current season shoots on 1-year-old twigs was not significantly affected. Girdling greatly reduced the occurrence of water sprouts; the number in an AG tree was decreased to 0.3 and 5.3 from 29.5 and 27.3 in 2004 and 2005, respectively. A June-girdling was also effective, although less than AG, in reducing the occurrence of water sprouts. The leaves of AG trees were smaller only in 2004, but they showed lower SPAD values in 2004 and 2005 (Table 2). Girdling did not significantly affect the SLW. Pruning weights of AG trees decreased to a 51% level at dormant and a 29% level at summer pruning of the respective controls (Table 3).

Compared with the controls, girdling in April nearly doubled fruit set in 2004 (Table 4). There were no remnant effects of girdling on fruit set or flowering in the subsequent year.

Table 2
Effect of different girdling dates in 2004 on area and greenness of the leaves (SPAD) and specific leaf weight (SLW) of 'Fuyu' persimmon in 2004 and 2005[a].

Girdling date	Area (cm^2/leaf)		Greenness (SPAD value)		SLW ($mg\,cm^{-2}$)	
	2004	2005	2004	2005	2004	2005
Control	93 a[b]	86 a	52 a	42 a	11.8 a	8.3 a
April 20	75 b	83 a	38 c	33 b	12.3 a	9.0 a
June 10	90 a	88 a	46 b	38 a	11.9 a	8.7 a

[a] Leaf samples were collected on August 11 in 2004 and June 3 in 2005.
[b] Mean separation within columns by LSD test at 5%.