Agricultural Science
Volume 2, Issue 1 (2014), 01-08
ISSN 2291-4471 E-ISSN 2291-448X
Published by Science and Education Centre of North America

Differences in Fruit Quality and Plant Growth of 'Shiranuhi' Mandarin Trees, Planted and Top-Grafted Stock

Doo-Gyung Moon[1*], Young-Eel Moon[1], Jae-Ho Joa[1], Chun-Hwan Kim[1], Chang-Kyu Lim[1], Seong-Cheol Kim[1], Myeng-Whan Cho[1], In-Ho Yu[1], Hee-Ryong Ryu[1], and Ki-Cheol Seong[1]

[1]National Institute of Horticultural and Herbal Science, Rural Development Administration, Busan, Korea

***Correspondence:** Doo-Gyung Moon, Protected Horticulture Research Station, National Institute of Horticultural and Herbal Science, Rural Development Administration, 93 Nakdongbuk-ro, Gangseo-gu, Busan, 618-800, Republic of Korea. Tel:+82-51-602-2140. E-mail: dgmoon@korea.kr

DOI: 10.12735/as.v2i1p1

Abstract

Differences in fruit characteristics (soluble solids content, acidity and fruit weight) and growth properties of fruiting branches in both planted and top-grafted stock for 'Shiranuhi' mandarin [(*C. unshiu* x *C. sinensis)* x *C. reticulate*] trees were determined when fruit was harvested. It was found that fruiting branch length, leaves and soluble solids contents tended to be higher in the planted stock compared with the top-grafted trees. Fruit diameter, fruit weight, stem end protrusion, pulp weight and pulp thickness were larger in the planted than top-grafted stock. However, titratable acidity was higher in the top-grafted than in the planted stock. These results suggest that planted stock should be cultivated as part of crop management for improvement of fruit quality and plant growth in 'Shiranuhi' mandarin trees.

Keywords: acidity, fruit branch, fruit weight, soluble solids content

1. Introduction

The cultivation area of 'Shiranuhi' mandarin has been increased every year because fruit quality was the highest in the citrus fruits of domestic cultivation in Korea. Premium quality fruit in the domestic market has SSC (soluble solids content) above 13.0°Bx, acid content below 1.0% and weight above 250g. 'Shiranuhi' mandarin is also generally known to have higher SSC, acidity and fruit size compared with the general mandarin. It ranges from 12.5~15.8 °Bx for SSC (Matsumoto, 2001), 0.8~1.2% for acidity and 200~300g for fruit weight (Moon, Ko, Han, Choi, & Kim, 2008). It also has an oval shaped fruit in which SSC and acidity are highest in the stylar end (Moon & Mizutani, 2002; Moon *et al.*, 2008), and SSC, acidity and plant growth were highest in the upper part depending on canopy location (Moon *et al.*, 2011).

However, SSC, acidity and fruit weight play an important role in determining the premium quality of citrus fruit. It is one of the most important cultural practices for fruit thinning (Chikaizumi, Hino, & Yamashita, 2000; Kami, Inoue, & Fujiwara, 1998; Moon *et al.*, 2011), production of high quality fruit by regulating soil moisture (Moon *et al.*, 2008) and soil management (Kami *et al.*, 1998; Sugiyama, Emoto, Sugiyama, & Oshiro, 2003), fruit quality by grafted on rootstocks (Moon *et al.*, 2010; Takishita, Uchida, & Kusaba, 2004), fruit quality by virus or viroid (Ikeda, 1990) and that harvesting be staggered starting with fruit from the upper part of the canopy (Moon *et al.*, 2011). Therefore, the growth habit and fruit quality of the 'Shiranuhi' mandarin is easily influenced by environmental factors, cultural practices and rootstocks.

Trifoliate orange is an important rootstock for citrus in Korea, and of several citrus varieties it is the most tolerant to flooding, drought and cold. Therefore, satsuma and 'Shiranuhi' mandarins have been cultivated in Korea through grafting on the rootstock of trifoliate orange. Also, 'Shiranuhi' mandarin has partly been grafted on satsuma mandarin tree such as through top-grafting because fruit was rapidly produced after grafted 3-4 years in the farms. However, the 'Swingle citrumelo' rootstock, a variant of trifoliate orange, has recently been studied for 'Shiranuhi' mandarin scion (Moon *et al.*, 2010) in a push in the domestic citrus industry to increase plant growth and decrease fruit acidity. Tree and fruit growths on the citrus rootstocks have also been evaluated to have different hydraulic conductance (Iwasaki, Fukamachi, Satoh, Nesumi, & Yoshioka, 2011; Syvertsen, 1981) and sap flow rate (Yonemoto *et al.*, 2004).

To investigate the effect of difference in both planted stock and top-grafting trees on plant growth and fruit quality were evaluated in the 'Shiranuhi' mandarin farms. In this study, we report that differences in SSC, acidity, fruit characteristics and properties of fruiting branches are associated with canopy location in both planted stock and top-grafting of 'Shiranuhi' mandarin tree at harvested time.

2. Material and Methods

2.1 Plant Materials

Planted stocks were obtained from three orchards in Jeju, Korea, in which 9~10-year-old 'Shiranuhi' mandarin [(*C. unshiu* x *C. sinensis*) x *C. reticulata*] trees grafted on trifoliate orange rootstocks were being raised in non-heated plastic houses (Figure 1). Top-grafts were obtained from three orchards in Jeju (Korea) in which 9~10-year-old 'Shiranuhi' mandarin [(*C. unshiu* x *C. sinensis*) x *C. reticulata*] trees secondary grafted with satsuma mandarin trees grafted on trifoliate orange rootstocks were being raised in non-heated plastic houses (Figure 1). Along the canopy positions (upper, middle, and lower) and branches with attached fruit were sampled from three trees for planted stock and from five trees for top-grafting at each farm (15-40 branches per canopy position) by 270 days after anthesis (DAA), and pooled for each position to analyze branch growth and fruit characteristics. The canopy positions were divided three parts such as upper, middle and lower by Moon *et al.* (2011) indicated method. The leaf-fruit ratio was 100~120 for experimental orchards in both planted stock and top-grafting trees. However, mean of fruit yield was 24.4kg/tree for planted stock and 21.8kg/tree for top-grafted stock.

2.2 Determination of Branch and Fruit Growth Characteristics

Fruiting branch length and base diameter, fruit length and diameter, height and transverse width of stem end protrusion and pulp thickness were measured using a digital veneer caliper (Matsui, Japan).

2.3 Fruit Quality Analysis

Juice samples were manually extracted from the fruit by pressing through cheesecloth followed by filtration, and stored at -20°C pending analysis. After thawing to room temperature, juice soluble solids concentration (SSC) was measured using a digital refractometer (PR-1, Atago, Tokyo, Japan), while titratable acidity was determined by titrating 1 mL of juice with 0.1N NaOH to pH 8.1, using phenolphthalein as an indicator. Titratable acidity was converted to a citric acid equivalent.

Figure 1. Grafting position at planted stock (**left**) and top-grafting (**right**) in 'Shiranuhi' [(*C. unshiu* x *C. sinensis*) x *C. reticulata*] mandarin trees. (**Left**: arrow shows first graft on trifoliate orange rootstock, **Right**: arrow shows secondary graft on satsuma mandarin top-stock)

2.4 Statistical Analysis

Analyses of variance and Duncan's multiple range tests were performed to analyze the data using the SAS program. Differences of $p < 0.05$ were considered significant. Difference of branch growth by canopy location at tree was expressed as the mean ± standard deviation.

3. Results and Discussion

3.1 Difference of Branch Growth in both Planted Stock and Top-Grafting Trees

Table 1. Differences of branch growth in both planted stock and top-grafted stock at harvest in 'Shiranuhi' mandarin trees

Parts	Planted stock			Top-grafted stock		
	Fruiting branch length (cm)	Fruiting branch diameter (mm)	Fruiting branch leaves(number)	Fruiting branch length (cm)	Fruiting branch diameter (mm)	Fruiting branch leaves(number)
Upper	16.7±7.72[z]	3.80±0.62	8.95±3.61	14.4±9.11	3.82±0.66	7.52±4.20
Middle	12.2±7.31	3.50±0.56	6.88±2.87	11.6±6.03	3.64±0.63	6.34±3.06
Lower	10.2±4.51	3.23±0.56	5.87±2.29	9.4±5.23	3.40±0.71	5.06±2.45

[Z] Mean±standard deviation

Fruiting branch length tended to be longer in the planted stock compared with the top-grafted trees (Table 1). The number of leaves per fruiting branch was also higher in the planted stock than in the top-grafted stock. However, fruiting branch diameter tended to be thicker in the top-grafted than in the planted stock. The difference of fruiting branch length, leaves numbers and diameter in between planted stock and top-grafting trees were probably due to grafting number times and sink strength. Planted stock trees were first grafted on trifoliate orange rootstock. However, top-grafted trees were double grafted with satsuma mandarin that was grafted on trifoliate orange rootstocks. The length, number of leaves and diameter per fruiting branch were also higher in order toward the upper part, middle part and lower part in both planted stock and top-grafted (Table 1). Similarly, it has been reported that plant growth is highest in the upper part of the canopy (Moon *et al.*, 2011). However, differences in plant growth are more significantly affected by canopy location than by grafting (Table 1). Tree growth and vigor can be controlled by managing crop load (Chikaizumi *et al.*, 2000; Kami *et al.*, 1998), accumulation of photosynthates (Kadoya, 1973), exogenous application of gibberellins (Coggins Jr., Hield, & Garber, 1960; Powell & Krezdorn, 1977), ABA content (Kojima,

Table 2. Difference of fruit characteristics in both planted stock and top-grafted stock at harvest in 'Shiranuhi' mandarin trees

Parts	Fruit diameter (mm)	Fruit length (mm)	Stem end protrusion height (mm)	Stem end protrusion width (mm)	Fruit weight (g)	Pulp weight (g)	Pulp thickness (mm)	Soluble solids content (°Bx)	Titratable acidity (%)
Planted stock									
upper	87.5 a[z]	84.3 a	14.0 a	35.3 a	286.9 a	206.8 a	15.6 a	14.4 a	1.00 d
Middle	85.5 b	81.7 b	12.1 b	33.1 b	272.7 b	196.7 b	15.1 b	14.1 b	0.95 e
Lower	84.2 c	77.3 c	10.3 c	31.8 c	259.2 c	189.5 c	14.9 c	13.7 c	0.92 e
Top-grafted stock									
Upper	82.2 d	81.9 b	9.0 d	25.2 d	247.9 d	187.3 cd	14.1 d	14.2 b	1.94 a
Middle	80.8 e	82.1 b	8.6 d	26.0 d	240.7 e	183.2 d	13.8 e	13.2 d	1.73 b
Lower	79.7 e	81.7 b	7.9 e	26.1 d	232.8 f	176.9 e	13.5 f	12.5 e	1.66 c
Significance[y]	*	*	*	*	*	*	*	*	*

[z] Mean separation within columns by Duncan's multiple range test at $P = 0.05$.

[y] * Significant at $P = 0.05$.

Takahara, Ogata, & Muramatsu, 1994) and differences in rootstock (Iwasaki *et al.*, 2011; Moon *et al.*, 2010). Thus, growth differences of fruiting branches in 'Shiranuhi' mandarin tree may be closely linked to differences in grafting number times, sink strength, hormone balance and canopy position. Tree grow on the citrus rootstocks was higher in order to the 'Rough lemon', 'Swingle citrumelo', trifoliate orange and dwarf 'Hiryu' for different of hydraulic conductance (Iwasaki *et al.*, 2011; Syvertsen, 1981). Further studies are required to evaluate the connection between branch growth and hydraulic conductance by number of grafting and canopy location.

3.2 Difference of Fruit Characteristics in both Planted Stock and Top-Grafted Trees

Fruit diameter and height and width of stem end protrusions, fruit weight, pulp weight, pulp thickness and SSC were higher in the planted than in the top-grafted stock at harvest time (Table 2). Fruit length was similar in the planted and the top-grafted stock. Titratable acidity was lower in the planted stock tree than in the top-grafted tree at harvest time (Table 2). However, fruit diameter and length, height and width of stem end protrusions, fruit weight, pulp weight, pulp thickness, SSC and titratable acidity were highest in the upper part at the harvested time in both planted stock and top-grafted trees (Table 2). Similar to the findings of Moon *et al.* (2011), it was found that these were highest in the upper part of the tree during 'Shiranuhi' mandarin fruit maturation.

Difference among fruit diameter and length, stem end protrusion height and width, fruit weight and pulp weight by three parts were larger in the planted stock tree compared with the top-grafted tree. However, difference in SSC and titratable acidity by three parts were higher in the top-grafted than in the planted stock. The difference of gradient by canopy location of 'Shiranuhi' mandarin trees was probably due to plant growth (Table 1) and differences in sink strength because of the number of grafting. Fruit growth has been shown to be closely related to the differential accumulation of photosynthates (Kadoya, 1973), endogenously applied gibberellins (Coggins Jr. *et al.*, 1960; Kami *et al.*, 1998) and number of seeds per fruit (El-Zeftawi, 1977), fruit load (Chikaizumi *et al.*, 2000), soil moisture (Moon *et al.*, 2008), rootstock (Moon *et al.*, 2010) and canopy location (Moon *et al.*, 2011). Therefore, fruit growth and quality are affected by double grafting on grafted satsuma mandarin trees, such as top-grafting in 'Shiranuhi' mandarin.

3.3 Differences of SSC and Acidity

Means of fruit SSC and acidity in both the planted stock and the top-grafted trees were 14.0±0.63°Bx, 0.99±0.14% and 13.3±1.60°Bx, 1.78±0.24%, respectively (Figure 2). SSC was not significant difference in both the planted stock and the top-grafted trees. However, acidity was significantly higher in the top-grafted compared with the planted stock, by about 1.8 times (Fig. 2). Acidity is affected by water stress in citrus fruit because of secondary grafting on satsuma mandarin trees. Water stress retarded the reduction in acid content in both 'Shiranuhi' (Moon *et al.*, 2008) and satsuma mandarins (Moon & Mizutani, 2002; Mukai, Takagi, Teshima, & Suzuki, 1996; Sugai & Torikata, 1975; Yakushiji *et al.*, 1996). Likewise, acid content was highest in the upper part in 'Shiranuhi' mandarin (Moon *et al.*, 2011). Therefore, the top-grafted trees were probably more affected by water stress than the planted stock trees. However, the top-grafted stock retain more acidity and accumulated less sugar than the planted stock in 'Shiranuhi' mandarin trees. Moon *et al.*, (2008) reported that 'Shiranuhi' mandarin retains more acid and accumulate less sugar when exposed to water stress. Tree vigor and fruit acid content were affected by soil management to increase fine roots (Kami *et al.*, 1998; Sugiyama *et al.*, 2003). Difference of acidity was significantly increased compared to SSC in between planted stock and top-grafting of 'Shiranuhi' mandarin trees. This result suggests that distribution of SSC and acidity at tree became relatively uniform in the planted stock compared with the top-grafted trees. Thus, differences in fruit SSC and acidity were affected by number of grafting in 'Shiranuhi' mandarin, implying that variations in fruit quality attributes within the same tree are more pronounced in the top-grafted than in the planted stock. It would be interesting to study sap flow rate involved plant growth and fruit quality in both the planted stock and the top-grafted trees. The sap flow rate of satsuma mandarin trees was lower when grafted onto 'Hiryu' compared with trifoliate orange during fruit growth (Yonemoto *et al*., 2004).

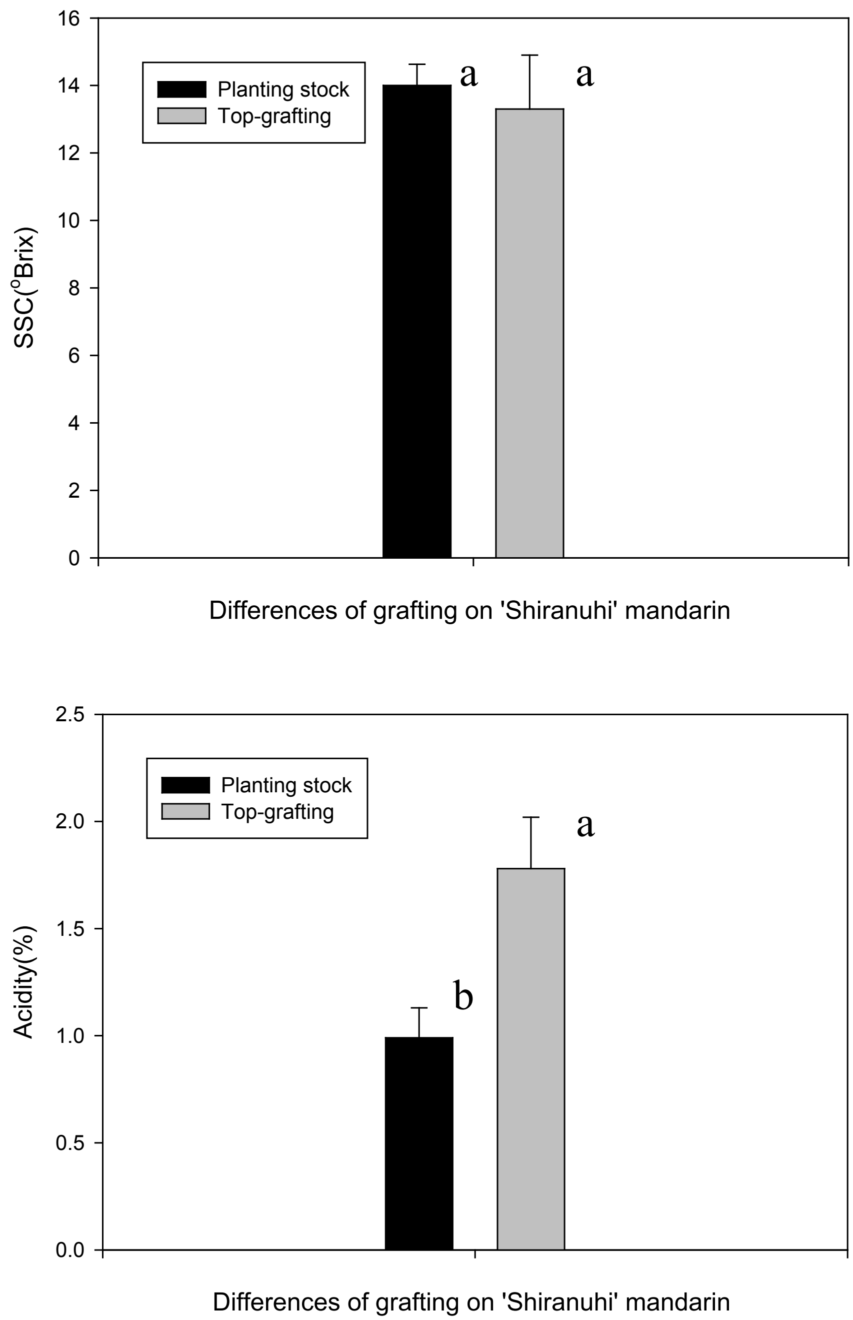

Figure 2. Means of fruit SSC and titratable acidity in both planted stock and top-grafted stock on 'Shiranuhi' mandarin fruits. Columns labeled with the same letter are not significantly different at $P = 0.05$ for differences of grafting. Vertical bars represent standard deviation (planted stock; n=9 trees, top-grafting; n=15 trees) from which all fruit per tree were selected for each determination

In this experiment, SSC and fruit weight were observed as generally high and acidity as low in the planted stock compared with the top-grafted stock (Figure 2 and Table 2). The premium quality in the Korean domestic market is considered as SSC above 13.0°Bx, acid content below 1.0% and weight above 250g in 'Shiranuhi' mandarin fruit. Our results show that premium fruit is found in the planted stock, regardless of canopy location (Figure 2 and Table 2).

In conclusion, we recommend that planted stock be cultivated on the farms to improve fruit quality and plant growth in 'Shiranuhi' mandarin trees.

References

[1] Chikaizumi, S., Hino, A., & Yamashita, N. (2000). Tree growth and distribution of photosynthates as affected by the fruit bearing in 'Shiranuhi' trees. *Journal of the Japanese Society for Horticultural Science, 69*(Suppl. 2), 275 (In Japanese).

[2] Coggins Jr., C. W., Hield, H. Z., & Garber, M. J. (1960). The influence of potassium gibberellate on Valencia orange trees and fruit. Proc. Amer. Soc. Hort. Sci., 76, 193-198.

[3] El-Zeftawi, B. M. (1977). Factors affecting pigment levels during regreening of Valencia orange. *The Journal of Horticultural Science & Biotechnology, 52*(1), 127-134.

[4] Ikeda, F. (1990). Studies on the accumulation of sugars in juice of satsuma mandarin. 14: Rootstock effects on the fruit characteristics of satsuma mandarin. *J. Japan. Soc. Hort. Sci., 59*(Suppl. 1), 24-25 (In Japanese).

[5] Iwasaki, M., Fukamachi, H., Satoh, K., Nesumi, H., & Yoshioka, T. (2011). Development of tree vigor prediction method at an early stage based on stem hydraulic conductance of seedlings in citrus rootstocks. *J. Japan. Soc. Hort. Sci., 80*(4), 390-395.

[6] Kadoya, K. (1973). Studies on the translocation of photosynthates in satsuma mandarin. IV. Diurnal fluctuations of fruit growth and some environmental conditions. *J. Japan. Soc. Hort. Sci., 42*(3), 215-220.

[7] Kami, Y., Inoue, H., & Fujiwara, F. (1998). Effects of fruit load and CO_2 enrichment on tree growth of citrus cultivar 'Shiranuhi' under greenhouse. *J. Japan. Soc. Hort. Sci., 67*(Suppl. 2), 193 (In Japanese).

[8] Kojima, K., Takahara, T., Ogata, T., & Muramatsu, N. (1994). Relationships between growth characteristics and endogenous ABA, IAA and GA levels in citrus rootstocks. *J. Japan. Soc. Hort. Sci., 63*(4), 753-760.

[9] Matsumoto, R. (2001). 'Shiranuhi' a late-maturing citrus cultivar. *Bulletin of National Institute of Fruit Tree Science, 35*, 115-120.

[10] Moon, D. G., & Mizutani, F. (2002). Relationship between fruit shape and acid content in different parts of citrus fruits. *J. Japan. Soc. Hort. Sci., 71*(1), 56-58.

[11] Moon, D. G., Ko, S. W., Han, S. G., Choi, Y. H., & Kim, Y. H. (2008). Sugar and acid contents in different portions of 'Shiranuhi' mandarin fruit as affected by water stress. *Horticulture, Environment, and Biotechnology, 49*(4), 216-220.

[12] Moon, D. G., Joa, J. H., Moon, Y. E., Seong, K. C., Kim, C. H., & Ahn, Y. K. (2011). Plant growth and fruit quality as affected by canopy locations in 'Shiranuhi' mandarin. *Horticulture, Environment, and Biotechnology, 52*(5), 443-447.

[13] Moon, Y. E., Kim, C. M., Kim, K. S., Yun, S. H., Park, J. H, An, H. J., . . . Moon, D. K. (2010). Effect of rootstock on the tree growth and fruit quality of 'Shiranuhi' mandarin hybrid in plastic film house. *Korean Journal of Horticultural Science and Technology, 28*(1), 65-69.

[14] Mukai, H., Takagi, T., Teshima, Y., & Suzuki, T. (1996). Sugar contents in parts of fruit of

satsuma mandarin tree under water stress in autumn. *J. Japan. Soc. Hort. Sci., 65*(3), 479-485.

[15] Powell, A. A., & Krezdorn, A. H. (1977). Influence of fruit-setting treatment on translocation of ^{14}C-metabolites in citrus during flowering and fruiting. *Journal of the American Society of Horticultural Science, 102*, 709-714.

[16] Sugai, H., & Torikata, H. (1975). Effects of soil moisture content in early autumn on growth and juice constituents of satsuma mandarin fruit. *J. Japan. Soc. Hort. Sci., 44*(4), 330-337.

[17] Sugiyama, Y., Emoto, Y., Sugiyama, K., & Oshiro, A. (2003). Effect of inorganic soil amendments and rate of nitrogen fertilizer application on fine root growth and fruit quality of 'Shiranuhi'. *J. Japan. Soc. Hort. Sci., 72*(Suppl. 1), 188(In Japanese).

[18] Syvertsen, J. P. (1981). Hydraulic conductivity of four commercial citrus rootstocks. *J. Amer. Soc. Hort. Sci., 106*, 378-381.

[19] Takishita, F., Uchida, M., & Kusaba, S. (2004). *Influence of rootstock on fruit sugar composition of citrus cultivars in Japan*. International Society of Citriculture. 10th ISC Congress, 126.

[20] Yakushiji, H., Nonami, H., Fukuyama, T., Ono, S., Takagi, N., & Hashimoto, Y. (1996). Sugar accumulation enhanced by osmoregulation in satsuma mandarin fruit. *J. Amer. Soc. Hort. Sci., 121*(3), 466-472.

[21] Yonemoto, Y., matsumoto, K., Furukawa, T., Asakawa, M., Okuda, H., & Takahara, T. (2004). Effects of rootstock and crop load on sap flow rate in branches of 'Shirakawa satsuma' mandarin (*Citrus unshiu* Marc.). *Scientia Horticulturae, 102*(3), 295-300.

Copyrights