

ROLE OF POLLINATION ON INCREASING FRUIT SET LEVEL IN SOME NON-ASTRINGENT PERSIMMON CULTIVARS

Şenay Karabiyik, Sinan Eti, Turgut Yeşiloğlu

Cukurova University, Faculty of Agriculture, Department of Horticulture, 01330, Adana, Turkey

Abstract

Non-astringent persimmon production is increasing due to its ease of consumption. However, fruit set of persimmon contends excessive fruit drops and often cannot show its real performance. This study aimed to determine the effects of pollination on fruit set and fruit quality such as; fruit weight, seed number and seedless-fruit ratio in some non-astringent persimmon cultivars.

In this study 'Fuyu', 'Giant Fuyu' and 'O'Gosho' were used as main cultivars. Non-pollination (bagging), open- and controlled-pollinations with 'Bruniquel', 'Ghora Gali', 'Mandarino' and 'Mercatelli' were investigated for determining the effects of pollination.

As a result, using pollinizer, especially 'Ghora Gali', increased fruit set up to 79.9% in 'Fuyu', 49.0% in 'Giant Fuyu' and 55.3% in 'O'Gosho'. Seedless fruit ratio showed that, 'Fuyu' and 'O'Gosho' has tendency to form parthenocarpic fruits while 'Giant Fuyu' needs pollination in order to set fruit. But, for a better fruit set there must be pollinizer in the orchard.

Key words: *Controlled-pollination, Diospyros kaki L., Fruit drop, Non-pollination, Parthenocarpy*

1. INTRODUCTION

Persimmon (*Diospyros kaki* L.) is a deciduous fruit tree belongs to Ebenaceae, which is native to China and can to grow in Turkey. Persimmon cultivars are classified into four types depending on the nature of astringency loss in the fruit and change in flesh color (Parfitt et al. 2015). Classification is as 'pollination constant non astringent' (PCNA), 'pollination variant non astringent' (PVNA), 'pollination constant astringent' (PCA) and 'pollination variant astringent' (PVA). Among these four types, PCNA type cultivars are highly desired because of astringency loss in the flesh on the tree without needing complete pollination or seed formation (Parfitt et al. 2015). However, PCNA type seedless fruits are likely to drop easily due to their low parthenocarpic character (Kajiura 1941, Badal et al. 2013) and hence poor fruit set becomes a major problem for producers. Nevertheless, world persimmon production expanded rapidly in recent years due to its healthy profits (FAO 2016).

Persimmon exhibits up to three waves of fruit drop (Candir et al. 2009), with the first two being normally seedless fruits (Choi et al. 2014). Fruit drop of persimmon is closely related with the competition between seeded and seedless fruits on the same tree (Kitajima et al. 1992). For that reason, pollinizers are required to increase fruit set, especially for persimmon cultivars that bear only pistillate flowers (Kim, Chae & Kang 1997). Many studies confirmed for improving fruit set with different pollination types (George et al. 1995; Sayilkan 1995; Woodburn & Andersen 1996; Kim, Chae & Kang 1997; Bellini 2002; Krisanapook et al. 2004; Messaoudi et al. 2009). Besides, pollination improves fruit diameter and forms nearly one-year vegetative growth flush (Messaoudi et al. 2009). This is so important for persimmon cultivars that sometimes come up with alternate bearing and set heavy crops of small fruit followed by light crops of large fruit (Collins & George 1996).

Persimmon cultivars vary in their seed setting and parthenocarpic ability (George et al. 1997). Today, parthenocarpy is generally considered as the formation of a fruit without fertilization of the ovules. Mesejo et al. (2013) have been reported that parthenocarpy can be distinguished as stimulative, i.e., caused by the stimulus of pollination; vegetative, i.e., occurs without any pollination and facultative, i.e. when ovary fertilized, it will develop into a seeded fruit and if not, it will develop into a seedless fruit. The parthenocarpic persimmon fruits are requested due to their seedless nature and ease of consumption.

In this study, the effects of pollination on fruit set, fruit weight, seed number and seedless-fruit ratio were determined in non-astringent 'Fuyu', 'Giant Fuyu' and 'O'Gosho' persimmon cultivars. At the same time, the intense fruit drop intervals were also determined.

2. MATERIALS AND METHODS

The experiment was performed in persimmon research field (Adana/Turkey) of Cukurova University grafted onto *D. kaki* L. rootstock and planted at 6 × 6 m spacing in 1995. 'Fuyu', 'Giant Fuyu' and 'O'Gosho' non-astringent persimmon cultivars were used as main cultivars while 'Bruniquel', 'Ghora Gali', 'Mandarino' and 'Mercatelli' were pollinizers.

2.1. Pollination Studies

In non-pollination treatment, branches of main cultivars were bagged before anthesis until the end of receptivity in order to prevent pollination. For open-pollination, flowers of appropriate branches were only counted without any pollination. For controlled-pollination, flowers of pollinizers were collected one day before anthesis and anthers were dried at room temperature for one night in order to release their pollens. The day after, flowers of main cultivars were pollinated before anthesis with these pollens and bagged to prevent any confusion.

In non-pollination and controlled-pollination, opened and little flowers on branches were picked in order to prevent any confusion. In all pollination studies, branches were thinned as the branch capacity and threatened flowers were counted and recorded. All pollination types were conducted with three replications with 50 flowers in each replication.

2.2. Fruit Set, Fruit Weight and Seed Numbers

For determining fruit-drop periods, fruit set was recorded monthly from flowering until harvest. Final fruit set was also determined by the percentage of fruit number at harvest to the first detected flower number. After harvest, fruit weight and seed number per fruit were also determined. Then ratios of seedless fruits to whole fruits were calculated to find seedless-fruit ratio of each pollination type.

2.3. Statistical Analysis

The data were analyzed with a completely randomized design with three replications by ANOVA and means of variables compared with LSD test at $p=0.05$ using SAS based programme, JMP statistical package (5.0.1. version). Percent values were analyzed after arcsine transformation.

3. RESULTS

3.1. Fruit-drop periods from flowering until harvest

In non-pollination, 'Fuyu' opposed a very intense fruit drop after one month from flowering (in May) and a poor fruit was left at harvest (Figure 1). However, in 'Giant Fuyu' and 'O'Gosho', whole fruits dropped until July (Figures 2 and 3). Fruit drops in open-pollination were higher than controlled-pollination for all cultivars.

The fruit drops of 'Fuyu' and 'O'Gosho' were intense for all pollination types until July and it was nearly stop since July. However, it continued every month, particularly in 'Giant Fuyu', and was more intense in May and June. Besides, pre-harvest drops were also seen in 'Giant Fuyu' and 'O'Gosho' cultivars.

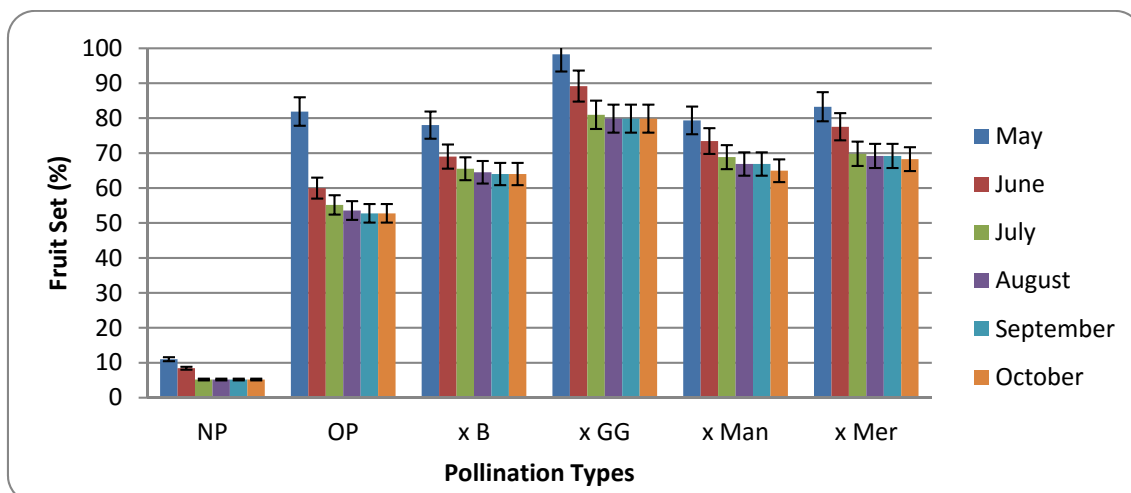


Figure 1. Fruit set level of different pollination types from flowering until harvest in 'Fuyu'.

NP: Non-pollination; OP: Open Pollination; xB: Controlled-pollination with Bruniquel; xGG: Controlled-pollination with Ghora Gali; xMan: Controlled-pollination with Mandarinino, xMer: Controlled-pollination with Mercatelli

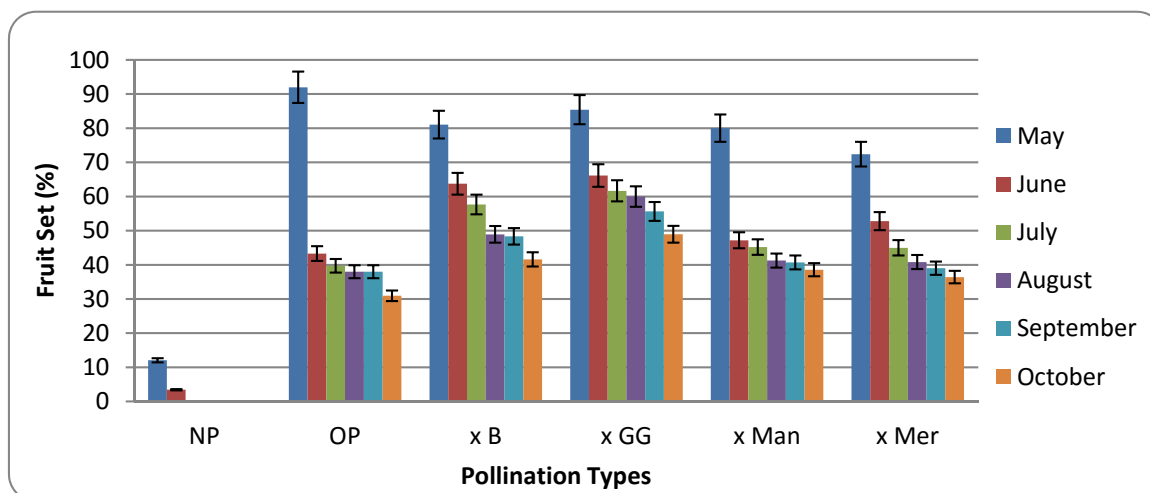


Figure 2. Fruit set level of different pollination types from flowering until harvest in 'Giant Fuyu'.

NP: Non-pollination; OP: Open Pollination; xB: Controlled-pollination with Bruniquel; xGG: Controlled-pollination with Ghora Gali; xMan: Controlled-pollination with Mandarinino, xMer: Controlled-pollination with Mercatelli

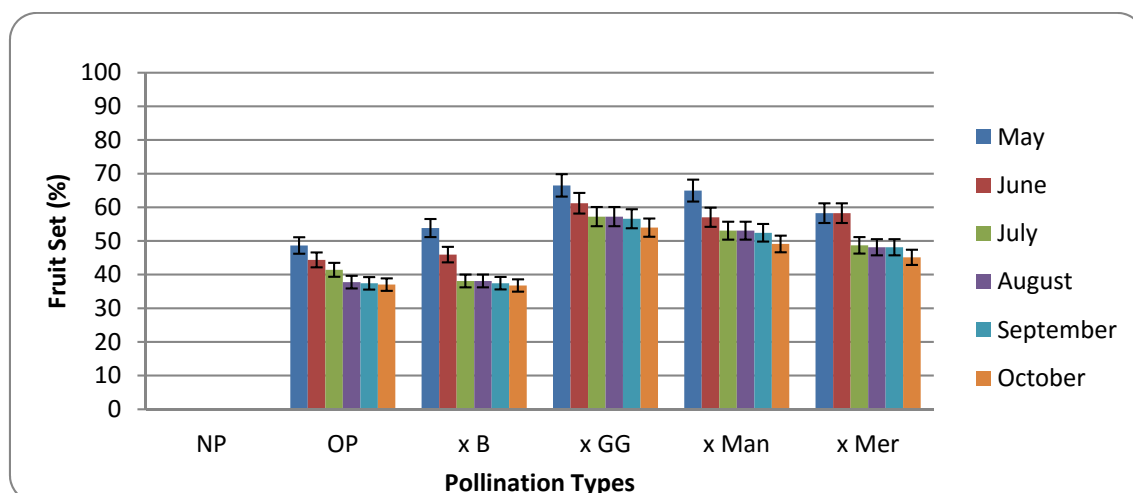


Figure 3. Fruit set level of different pollination types from flowering until harvest in ‘O’Gosho’.

NP: Non-pollination; OP: Open Pollination; xB: Controlled-pollination with Bruniquel; xGG: Controlled-pollination with Ghora Gali; xMan: Controlled-pollination with Mandarinino, xMer: Controlled-pollination with Mercatelli)

3.2. Final Fruit Set Ratio

Final fruit-set ratio was statistically influenced by pollination types in all cultivars (Table 1). Generally, fruit set was higher in controlled-pollination compared to open and non-pollination. Only ‘Fuyu’ set fruits in non-pollination (7.8%) while all flowers dropped in ‘Giant Fuyu’ and ‘O’Gosho’. The highest fruit-set ratio was obtained from controlled-pollination with ‘Ghora Gali’ for all cultivars; averagely 79.9% in ‘Fuyu’, 49.0% in ‘Giant Fuyu’ and 55.3% in ‘O’Gosho’. The lowest fruit-set ratios were obtained from open-pollination and differed between 31.0% (‘Giant Fuyu’) and 52.8% (‘Fuyu’), which was too low when compared to controlled-pollination. This shows the fruit production of Japanese persimmons cultivars is unstable when they are not pollinated.

Table 1. Effect of different pollination treatments on fruit set of persimmon cultivars (%)¹

Pollination Treatments	Fuyu		Giant Fuyu		O’Gosho	
Non-Pollination	7.8	b ²	0.0	c	0.0	b
Open-Pollination	52.8	a	31.0	b	37.0	a
× Bruniquel	64.0	a	41.6	ab	36.8	a
× Ghora Gali	79.9	a	49.0	a	55.3	a
× Mandarinino	65.0	a	38.6	ab	49.1	a
× Mercatelli	68.3	a	36.4	ab	45.1	a
Significance ²	*		***		***	

¹ Values were analyzed after arcsine transformation. ² Different letters in a column indicate significant difference at $p < 0.05$.

² *: Significant at $p < 0.05$, ***: Significant at $p < 0.001$.

3.3. Fruit Weight

Fruit weight was quiet low in ‘Fuyu’ compared to ‘Giant Fuyu’ and ‘O’Gosho’ (Table 2) but it is not statistically different among pollination studies. The highest fruit weights were obtained from cross-pollination in all cultivars which was 98.1 g in ‘Fuyu’ (Fuyu×Mandarino), 129.8 in ‘Giant Fuyu’ (Giant Fuyu×Bruniquel) and 114.4 g in ‘O’Gosho’ (O’Gosho×Mandarino).

Only ‘Fuyu’ set fruits in non-pollination but they become smaller (74.5 g). Open-pollination were also had good results in terms of fruit weight in all cultivars (between 92.3 g and 110.3 g).

Table 2. Effect of different pollination treatments on fruit weight of persimmon cultivars (g)

Pollination Treatments	Fuyu	Giant Fuyu	O’Gosho
Non Pollination	74.5	-	-
Open Pollination	92.3	102.8	110.3
× Bruniquel	84.4	129.8	98.4
× Ghora Gali	91.6	128.1	111.0
× Mandarino	98.1	95.2	114.4
× Mercatelli	90.7	109.1	105.8
Significance	NS	NS	NS

3.4. Seed number per fruit and seedless fruit ratio

Seed number was different between cultivars. While ‘Fuyu’ and ‘Giant Fuyu’ had higher seed numbers, ‘O’Gosho’ had lower even in controlled-pollination (Table 3).

The seedless-fruit ratio was calculated in order to determine parthenocarpic ability of the cultivars. In ‘Fuyu’, all fruits obtained from non-pollination were seedless, while in open-pollination fruits were all seeded (Table 4). The controlled-pollination of ‘Fuyu’ had low seedless fruit ratios varying between 2.78% (Fuyu x Bruniquel) and 7.41% (Fuyu x GhoraGali and Fuyu x Mercatelli). ‘O’Gosho’ had a very high seedless fruit ratio compared with ‘Fuyu’ and ‘Giant Fuyu’ (between 0.00% in open-pollination and 60.79% in O’Gosho x Bruniquel). Besides these, all fruits were seeded in different pollination types of ‘Giant Fuyu’.

The seedless fruit ratios conclude the parthenocarpic abilities of the persimmon cultivars as facultative parthenocarp in ‘Fuyu’ and stimulative parthenocarp in ‘O’Gosho’. ‘Giant Fuyu’ didn’t show any parthenocarpic ability.

Table 3. Effect of different pollination treatments on seed number of persimmon cultivars.

Pollination Types	Fuyu		Giant Fuyu	O'Gosho
Non Pollination	0.00	b ¹	-	-
Open Pollination	5.43	a	6.50	2.39
× Bruniquel	4.39	a	6.23	1.72
× Ghora Gali	4.50	a	6.02	2.02
× Mandarino	4.61	a	6.03	1.41
× Mercatelli	4.99	a	5.40	2.33
Significance ²	*		NS	NS

¹ Different letters in a column indicate significant difference at $p < 0.05$.

² *: significant at $p < 0.05$, NS: Non-significant

Table 4. Effect of different pollination treatments on seedless-fruit ratio of persimmon cultivars (%)².

Pollination Types	Fuyu		Giant Fuyu	O'Gosho	
Non Pollination	100.00	a ¹	-	-	
Open Pollination	0.00	b	0.00	0.00	b
× Bruniquel	2.78	b	0.00	60.79	a
× Ghora Gali	7.41	b	0.00	47.69	a
× Mandarino	3.70	b	0.00	58.47	a
× Mercatelli	7.41	b	0.00	31.74	a
Significance ²	***		NS	*	

¹ Different letters in a column indicate significant difference at $p < 0.05$. ² Values were analyzed after arcsine transformation.

² *: Significant at $p < 0.05$, ***: Significant at $p < 0.001$, NS: Non-significant.

4. DISCUSSION

Persimmon has a complicated flower structure. It has pistillate, staminate and hermaphrodite flowers together on the same or different trees. Besides, there is a great range in their seed setting potential. For that reason, persimmon cultivars are coincided with heavy fruit drops affecting fruit set quite a lot. In this study, using suitable pollinizer increased fruit set compared with open-pollination up to 51% in 'Fuyu', 58.1% in 'Giant Fuyu' and 49.5% in 'O'Gosho'. Krisanapook et al. (2004) reported that the fruit set in controlled-pollination of 'Fuyu' with different pollinizers were 76-90%, while open-pollination it was 61%. Moreover, Messaoudi et al. (2009) have concluded that in 'Fuyu', fruit drop was less intensive in controlled pollination compared with non- and open-pollinations.

Generally, fruit drop occurred in first three months intensively and the lowest drops were obtained from controlled-pollination in all cultivars. Sayilikan (1995) had similar results for nine different persimmon cultivars in the same ecological conditions (Adana /Turkey). In this study, the pre-harvest fruit drops were also distinct in 'Giant Fuyu' and 'O'Gosho'. In 'Giant Fuyu' this may originate from the bigness and fruitfulness of the trees while in 'O'Gosho' it may also originate from the seedlessness of the fruits besides bigness. Moreover, Messaoudi et al. (2009) have showed that fruit drop of 'Fuyu' decreased at the beginning of July for both pollinated and non-pollinated fruits. In general, persimmon

has a double-sigmoid growth pattern consisting of two rapid growth stages separated by a period of slow growth (Candir et al. 2009). Fruit drop periods were coincided with the rapid growth periods when the highest competition appears between seeded and seedless fruits (Kitajima et al. 1992; Choi et al. 2014).

Fruit weight of pollinated fruits in 'Fuyu' was increased when compared with non-pollinated fruits. Fruit weights of pollinated and open-pollinated flowers were not significantly different between pollination types. According to Messaoudi et al. (2009), the fruit weight was 114 g in non-pollinated flowers of 'Fuyu' while it was 168 g in pollinated ones, showing that pollination increases fruit weight. In this study, fruit weights were lower because of high fruit-set. It was thought that, this high fruit-set of whole tree could be the effect of top-pruning and the alternate bearing of the trees the year before the study. For some persimmon cultivars, which sometimes show alternate bearing, set lot of and small fruits followed by less and big fruits. This is because of high crop influences starch reserves of the tree in the following season (Collins & George 1996). Although pollination with 'Ghora Gali' did not show best results for fruit weight, like its potential in fruit set, it is still adequate for an optimum fruit weight for persimmon.

The seedless fruit ratios showed remarkable results. In 'Fuyu' and 'O'Gosho', there were seedless fruits except open-pollination, while in 'Giant Fuyu' all of the fruits were seeded. This means, 'Fuyu' and 'O'Gosho' have parthenocarpic abilities, while 'Giant Fuyu' does not. In all cultivars, open-pollination did not have any seedless fruits. In spite of this, Krisanapook et al. (2004) have reported that seedless-fruit ratio of open-pollinated flowers in 'Fuyu' persimmon were 28.9%, while in controlled-pollination it was 2.2-8.5%. This difference could be because of the intense bee activity and pollinizer performance.

In this study, non-pollination of 'Fuyu' could produce seedless fruits, while seeded fruits formed in other pollination types. In the case of facultative parthenocarpy, formation of seedless fruits will increase with unfavorable environmental conditions for pollination and fertilization. However, when fertilization occurs, seeded fruits are formed on the same tree that enables reproductive propagation of facultative parthenocarpic plants (Mesejo et al. 2013). In the light of this information, it can be thought that 'Fuyu' has a facultative parthenocarpic ability to set fruit. However, in the absent of pollinizer fruit set will be low. This means using pollinizer is important, even for 'Fuyu'. Although 'O'Gosho' did not have any fruits in non-pollination, it had some seedless fruits in controlled-pollination. This made us to think that there is stimulative parthenocarpy in 'O'Gosho', which occurs with the stimulus of pollination (Nitsch 1952; Mesejo et al. 2013). However, these properties need detailed studies for more definite results.

CONCLUSION

'Ghora Gali' is the most suitable pollinizer for non-astringent 'Fuyu', 'Giant Fuyu' and 'O'Gosho'. By using 'Ghora Gali' as pollinizer in new orchards, especially with these cultivars, fruit set will influence positively. On the other hand, 'Giant Fuyu' has all seeded fruits while 'Fuyu' and 'O'Gosho' has parthenocarpic fruits. However, using pollinizer is important even for 'Fuyu' and 'O'Gosho', for achieving a satisfactory fruit set.

ACKNOWLEDGEMENTS

The authors would like to thank Cukurova University Scientific Research Projects Coordination Office (Grant Number: ZF2010YL17) for the financial help.

REFERENCES

- Badal, E, Abd El-Mageed, TA, Buesa, I, Guerra, D, Bonet, L & Intrigliolo, DS 2013, 'Moderate plant water stress reduces fruit drop of "Rojo Brillante" persimmon (*Diospyros kaki*) in a Mediterranean climate', *Agricultural Water Management*, vol. 19, pp. 154-160.
- Bellini, E 2002, 'Cultural practices for persimmon production', *First Mediter Symp on Persimmon, CIHEAM*, Zaragoza, vol. 51, pp. 39-52.
- Candir, EE, Ozdemir, AE, Kaplankiran, M & Toplu, C 2009, 'Physico-chemical changes during growth of persimmon fruits in the East Mediterranean climate region', *Scientia Horticulturae*, vol. 121, no.1, pp. 42-48.
- Collins, RJ & George, AP 1996. 'Managing crop load on non-astringent persimmon (*D. kaki* L.) grown in the Sub-tropics', *Proceedings of the I. International Persimmon Symposium, Chang Mai – Thailand, Acta Horticulturae*, vol. 436, pp. 251-260.
- FAO 2016, 'Food and Agricultural Organisation Databases web site', viewed 20th February 2016. <<http://www.fao.org>>
- George AP, Nissen RJ, Collins RJ & Rasmussen TS 1995, 'Effects of fruit thinning, pollination and paclobutrazol on fruit set and size of persimmon (*Diospyros kaki* L.) in Subtropical Australia', *Journal of Horticultural Science*, vol. 70, pp. 477-484.
- George AP, Mowat AD, Collins RJ & Morley-Bunker M 1997, 'The pattern and control of reproductive development in non-astringent persimmon (*Diospyros kaki* L.): A review', *Scientia Horticulturae*, vol. 70, pp. 93-122.
- Kajiura, I 1980, 'Kaki culture in Japan (the persimmon)', *Orchardist New Zealand*, vol. 53 no. 3, pp 98-102.
- Kim J, Chae Y & Kang S 1997, 'Selection of economic pollinizers for Fuyu sweet persimmon', *Proceedings of the I. International Persimmon Symposium, Chang Mai City - Thailand, Acta Horticulturae*, vol. 436, pp. 395-401.
- Kitajima A, Akuta H, Yoshioka T, Entani T, Nakano M & Ishida M 1992, 'Influence of seeded fruit set in Japanese persimmon cv. Fuyu (*Diospyros kaki* L. f.)', *Journal of Jpn Society for Horticultural Science*, vol. 61, pp. 499-506.
- Krisanapook K, Sillapapetch K & Jutamane K 2004, 'Improvement of fruit set and fruit qualities in persimmon "Fuyu" using pollination', *Proceedings of the VII. International Symposium on Temperate Zone Fruits in the Tropics and Subtropics, Nauni, Solan –India, Acta Horticulturae*, vol. 662, pp. 429-433.
- Mesejo C, Yusta R, Martinez-Fuentes A, Reig C, Iglesias DJ, Primo-Millo E & Agusti M 2013, 'Self-pollination and parthenocarpic ability in developing ovaries of self-incompatible Clementine mandarins (*Citrus clementine*)', *Physiologia Plantarum*, vol.148, pp. 87-96.
- Messaoudi Z, Gmili RE, Khatib F & Helmy Y 2009, 'Effect of pollination, fruit thinning and gibberellic acid application on "Fuyu" kaki fruit development' *Proceedings of the IV. International Symposium on Persimmon, Firenze - Italy, Acta Horticulturae*, vol. 833, pp. 233-238.
- Nitsch, JP 1952, 'Plant hormones in the development of fruits', *The Quarterly Review of Biology*, vol. 27, pp. 33-57.
- Parfitt, DE, Yonemori, K, Honsho, C, Nozaka, M, Kanzaki, S, Sato, A & Yamada, M 2015, 'Relationships among Asian persimmon cultivars, astringent and non-astringent' *Tree Genetics & Genomes*, vol. 11, no. 2, pp. 1-9.
- Sayilkan, G 1995, 'Bazı yerli ve yabancı Trabzon hurması çeşitlerinin dölleme biyolojisi üzerine araştırmalar', MSc Thesis, Cukurova University, Turkey.

Woodburn, KR & Andersen, PC 1996, 'Pollination and pollen source influence fruit of oriental persimmon Fuyu and Tanenashi', *Hortscience*, vol. 31, no. 2, pp. 218-221.