MUSTAFA KEMAL ÜNİVERSİTESİ
ZİRAAT FAKÜLTESİ DERGİSİ

JOURNAL OF AGRICULTURAL FACULTY

ISSN 1300-9362

CİLT/VOLUME	SAYI/NUMBER	YIL/YEAR
19	2	2014

MKU Ziraat Fakültesi Dergisi 19 (2): 47-54, 2014 *ISSN 1300-9362*

Effects of Pollinizer Distance and Tree Direction on Fruit Set and Fruit Quality in Mandarin cv. 'Nova' under Open Pollination Conditions

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Abstract

In this study, the effects of pollinizer distance and direction on fruit set and fruit quality in mandarin cvs 'Nova' under open pollination conditions have been studied. According to average of two years, plants from row, adjacent to the pollinizer 7 meters (12.79%) were three times more fruit set than those 35 meters distance (4.90%) in the harvest period. The effect of pollinizer distance on the fruit quality characteristics except the number of seeds per fruit and rind colour were found insignificant. The number of seeds per 'Nova' fruit decreased while the distance from 'Fremont' tress increased. The best colored 'Nova' fruits were harvested both 7 m and 14 m pollinizer distance. The east direction had the higher percentage of fruit set than others. It was determined that eastern direction 2 or 3 times more productive (12.18%) than north (4.31%) and west (5.47%) directions in the harvest period. The effect of the tree direction on fruit quality was non significant, except for total soluble solids / total acidity ratio. According to study results, for best fruit set and fruit quality in 'Nova' cultivar rows are no more than four rows from the pollinizer. In addition, rows should be planted in north-south direction.

Keywords: Citrus, pollinizer row, tree direction, seed number, fruit color

Introduction

Turkey's citrus production has reached to 3.681.158 tons in 2013; with an increase of 36.0% in last 10 years. Also, mandarin production in Turkey was 670.000 tons in 2004 and 942.226 tons in 2013; making a 40.6% increase in this period. The statistics of 2013 indicates that among the Turkey's total citrus production, mandarin is the second species (Anonymous 2013).

'Nova' is a hybrid of the 'Fina' Clementine and 'Orlando' tangelo cross that was made in 1942. The rind color of 'Nova' is a more attractive reddish-orange and its internal quality is extremely high. The color is a deep orange and the segments are very juicy, tender and have a fine sweet flavor. Acid levels are moderate, resulting in a high sugar to acid ratio (Saunt 2000). Burdette (1993) reported that the use of a suitable pollinator is the most efficient method for producing self-incompatible cultivars such as 'Nova' mandarin, in terms of fruit yield and quality. In recent years, production of mandarins, such as 'Nova', has been increasing in Turkey (Demirkeser et al. 2009).

Adequate fruit set and yields are typically not problems for most citrus species, but some mandarin cultivars and hybrids have poor yield and inconsistent in yield from year to year. Eti et al. (1989) reported that applications of girdling and some growth regulators, and

Geliş Tarihi: 19.07.2014 *Kabul Tarihi: 02.12.2014*

use of suitable pollenizer to weakly parthenocarpic varieties increased fruit set and yields. Sufficient pollination is an important factor in the management of commercial mandarin orchards. Especially, the pollen source may have strong influence on the fruit characteristics and set (Demirkeser et al. 2001; Wallace et al. 2002). When orchard has been established with only cultivar in the 'Nova', 'Robinson' and 'Clementine' hybrids, which is self-incompatibility, low yield appears in these cultivars. Citrus producers have been complaining from low fruit set because of insufficient pollination. The most researches reported that growth regulators were used for the solution of this problem (Kojima 1997; Nirmaljit et al. 2000; Huang and Huang 2005). On the other hand, growth regulators and other chemical preparations for the natural production and the good agricultural practices should be used as little as possible in citrus cultivation. Therefore, use of pollinezer cultivar should be considered in the first in now and future for sufficient fruit set and yield in citrus. It is important to find the most suitable planting ratio of pollinizer trees to commercial cultivars. There is no data on pollinizer distance influence on the fruit characteristics and set of 'Nova' cultivar.

In addition, it is known that direction of area has an important in the management of horticultural cultivation, because each direction does not benefit the same grade from light intensity and temperature. The south-to-east facing slope has higher temperature than those on other directions. Thus, early bloom and fruit maturity have occurred at these directions. This situation has come out also on the tree (Ozbek 1977). Plants of the north direction appeared to have almost 60% lower photosynthetic activity than those on the east direction of tree canopy. On north direction, light intensity remains comparatively low, which results in low availability of photosynthates (Vasilakakis et al. 1996). Fruit quality indices influenced by light include fruit size, total soluble solids (TSS), acid concentration, and surface color (Kara 2000). If it is known in a certain area that one side of a tree produces the most fruit, the tree rows may be planted in a direction that favors the productive side. No detailed study has been found the effect of tree direction on the fruit set and fruit quality of citrus species and cultivars.

The purpose of this study was to investigate the effect of pollinizer distance and tree direction on the fruit set and fruit quality of 'Nova' mandarin, a monoembryonic cultivar of citrus known as self-incompatible.

Materials and Methods

The experiment was conducted in 'Nova' orchard which is the Dörtyol Research Station (Longitude, 36^{o} 09' E; Latitude, 36^{o} 51' N; Elevation: 9 m above sea level), Mustafa Kemal University, College of Agriculture (Fig. 1). The trees were planted in 1998, consisted of five 'Nova' rows adjacent to one 'Fremont' pollinizer row on the west side. The spacing of the trees was at 5 m between trees and 7 m between rows (285 trees/ha). The 'Nova' trees were grafted on sour orange rootstock and were uniform size. Row direction was north-south. The 'Nova' and 'Fremont' cultivars flowered with full coincide.

The fruit set percentage in 60 days after full bloom (AFB) and maturity and fruit quality characteristics were determined in 'Nova' cultivar during 2008 and 2009 years. 20 fruits were collected from five randomly selected the 'Nova' trees each row and four directions (east, west, north, south) per tree, and analyzed for quality. The fruit samples were weighted, and juiced using a standard juicer; then juice was weighted, and expressed as a percentage of the total fruit weight. Total soluble solids (TSS) content was determined with a refractometer (Atago ATC-1E model) using a few drops of juice. The total acidity

(TA) was determined by titration of 5 ml of fruit juice with 0.1 N sodium hydroxide (NaOH) to pH 8.1, and it was expressed as g citric acid 100 ml^{-1} juice.

Fruit rind color was determined with a Minolta Chroma Meter CR-300 (Osaka, Japan). Color measurements were recorded using the CIE L*a*b* color space. Fruit skin color is expressed as lightness (*L*) and hue angle (*h*°). From these values, hue angle was calculated as $h^{o} = \tan^{-1}$ (b*/a*). The hue angle is expressed in degrees and is a measure of color that, for example, from 0 to 90° spans from red to orange to yellow. Lightness separates color into bright and dark.

Data was subjected to ANOVA using SAS program (SAS Institute Inc., North Carolina, USA) and means were compared with Tukey test at 5% level of significance.

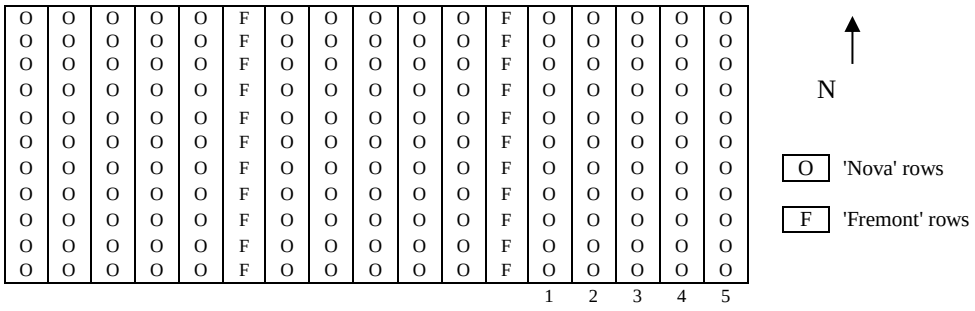


Figure 1. Schematic map of the experiment orchard. The rows, from which the data were collected, are numerated.

Results and discussion

The effect of distance pollinizer and tree direction on fruit set of 'Nova' mandarin under open pollination is shown in Table 1. The fruit set of both 60 days after full bloom (AFB) and maturity was affected by the pollinizer distance, and declined with increasing distance from pollinizer row. The fruit set was higher in adjacent row with 21.86% and 12.79%, in the 60 days AFB and maturity, respectively. The trees nearest from 'Fremont' pollinizer were 2.0 and 2.6 fold higher fruit set than those from the farthest in 60 days AFB and maturity, respectively. The findings that the fruit set began to decline as the distance from the pollinizer were similar in 'Orlando' tangelo (Krezdorn and Robinson 1958) and 'Orri' mandarin (Schneider et al. 2009). In addition, similar results were also reported on the other fruit species such as avocado (Guil et al. 1986), apple (Milutinovic et al. 1995), pecan (Wood 1997) and sweet cherry (Nunez-Elisa et al. 2008). The flowers of trees which are the nearest rows from pollinizer have high rate pollination by the bees, due to high yield in this rows is provided compared with other rows (Degani et al. 1989; Ish-Am l994). On the other hand, Kimura et al. (1997) mentioned that the fruit set of grapefruit was not affected by the pollinizer distance.

The tree direction had also significantly effect on fruit set of both 60 days AFB and maturity (Table 1). The fruit set was higher in east direction at 60 days AFB (19.39%) and maturity (12.08%) compared to the other direction. At maturity, the east direction of Nova trees were 2.8 and 2.2 fold higher fruit set than those from the especially north and west direction, respectively. Our fruit set findings are in harmony with those of Koch (1986) on 'Valencia' orange and those of Almela et al. (1996) on 'Clemantine' mandarin,

who found that the fruit set of south direction in maturity had higher than those of north direction. On the other hand, Yildirim (2003) mentioned that the fruit set of 'Washington Navel' on five rootstocks in harvest period was not affected by the tree direction. This may be based on that the light intensity and photosynthetic activity in south direction of tree are higher than those of north direction (Koch 1986). It has been reported that the fruit set percentage of Salustiana orange (Ibrahim et al. 2011) was observed in east and north side (20.67% and 20.18%, respectively). Researches had claimed that this may be a reason of more fruit set in north direction because of the northern side totally remains safe from the severe effect of high light intensity on fruit setting.

Table 1. The Effect of pollinizer distance and tree direction on fruit set in 'Nova' cultivar under open pollination conditions (%)
Çizelge 1. Serbest tozlanma koşullarında Nova çeşidinin meyve tutum oranları üzerine tozlayıcı mesafesi ve yöneylerin etkileri (%)

Source	60 days after full bloom	At maturity
Pollinizer distance (m)		
7	21.86	12.79
14	15.95	7.57
21	14.76	5.86
28	12.96	5.84
35	11.00	4.90
HSD (5%)	5.85	3.26
Direction		
East	19.39	12.08
West	12.03	5.47
North	13.22	4.31
South	16.59	7.61
HSD (5%)	3.72	3.50

Pollinizer distance influence on the fruit weight, juice content, TSS and TSS:TA ratio were statistically similar, while the number of seeds per fruit and fruit rind colour (L and hue values) for 'Nova' cultivar was affected by the pollinizer distance (Table 2). The number of seeds per fruit decreased in contrast to increasing distance from pollinizer. In rows 1 and 5 from 'Fremont', the average numbers of seeds per fruit were 7.99 and 4.08, respectively, and the number seeds were higher approximately 2.0 fold in the adjacent row than in the distant row. We did not find a relationship between seed number per fruit versus fruit weight for 'Nova' mandarin under open pollination. Other studies have found fruit size and seed number to be correlated (Vithanage 1991; Al-Hinai and Roper 2004). Krezdorn and Robinson (1958) on 'Orlando' tangelo, Brosh and Monselise (1977) on 'Topaz', Wallace et al. (2002) on 'Imperial' and Schneider et al. (2009) 'Orri' mandarin under open pollination found that the number of seeds per fruit declined with increasing space from pollinizer. The most likely explanation is that the number of viable 'Fremont' pollen grains deposited on each stigma decreased.

The juice content of 'Nova' fruits in the adjacent row from pollinizer had the higher than those from other rows, although juice content was not significantly different among pollinizer distance. According to two years mean, skin color L value of 'Nova' fruits had highest in the rows 3 and 4 from 'Fremont' pollinizer. The best colored 'Nova' fruits

were harvested from 7 m and 14 m pollinizer distance (hue values are 72.53 and 73.10, respectively). It is reported that the fruit weight of 'Imperial' mandarin (Wallace et al. 2002) and the fruit quality of apples (Brookfield et al. 1996; Buccheri and Vaio 2004) decreased with increasing distance from pollinizer. However, Schneider et al. (2009) identified that pollinizer distance influence on the fruit weight, TSS and TA contents of 'Orri' mandarin were not important. There are variable reports on almond (Jackson and Clarke 1991), sweet cherry (Granger 1997), avocado (Goldring et al. 1987; Degani et al. 1990) and mandarin (Wallace et al. 2002) on the distance of pollen scattering in fruit crop.

Table 2. Effect of pollinizer distance and tree direction on some fruit quality characters of 'Nova' cultivar under open pollination conditions
Çizelge 2. Serbest tozlanma koşullarında Nova çeşidinin bazı meyve kalite özellikleri üzerine tozlayıcı mesafesi ve yöneylerin etkileri

Source	Fruit weight (g)	Number of seeds per fruit	Juice content (%)	TSS (%)	TSS:TA ratio	Fruit skin colour	
						L	hue
Pollinizer distance (m)							
7	103.01	7.99	48.33	11.52	10.75	66.46	72.53
14	102.40	5.87	47.97	11.46	10.67	66.57	73.10
21	101.42	5.02	47.94	11.64	10.75	69.43	76.03
28	99.90	4.27	46.32	11.64	10.80	68.64	75.86
35	101.50	4.08	46.68	11.63	10.42	67.20	74.25
HSD (5%)	NS(1)	0.87	NS	NS	NS	1.40	1.68
Direction							
East	103.42	5.16	46.90	11.70	10.84 a	68.07	74.19
West	103.78	5.53	47.49	11.55	10.38 b	67.28	74.23
North	97.56	5.41	47.84	11.54	10.59 ab	67.50	74.41
South	101.82	5.68	47.56	11.52	10.89 a	67.79	74.59
HSD (5%)	NS	NS	NS	NS	0.41	NS	NS

(1): NS: Non-significant.

There was no consistent significant difference in fruit quality characteristics among tree directions, except for TSS:TA ratio (Table 2). Although the effect of tree direction on fruit weight was not found to be statistically significant, the lightest fruits of Nova cultivar were obtained from north direction of tree with 97.56 g. Among different directions of tree, the juice content were ranged between 46.90% (east) and 47.84 (north). The TSS:TA ratio of fruits in south and east directions of tree were higher than those of west and north directions. The skin color L and hue values in 'Nova' cultivar did not show any significant alteration based on different direction of tree. Our results are in agreement with those of Koch (1986) on 'Valencia' and Yildirim (2003) on 'Washington Navel', reporting that fruit quality was not generally affected by the tree direction. However, high values of TSS and TA content on Valencia (Koch 1986) and TTS content on Washington Navel (Yildirim 2003) were verified for fruits of Nova cultivar on east direction of tree. The orientation of planting is important for impact light penetration in orchard. Generally, in density planting, quicker shading becomes a problem.

The results of this study demonstrate a significant decrease in fruit set and quality such as the juice content and fruit rind color with increasing distance from the pollinizer row. There was not a significant reduction in fruit weight among rows. For best pollen flow and fruit quality, 'Nova' cultivar should be planted >28-30 m distance from pollinizer row. The east direction of 'Nova' trees in harvest period were 2.8 and 2.2 fold higher fruit set than those from the especially north and west direction, respectively. Although the effect of tree direction on fruit quality was insignificant, the lightest fruits were obtained from north direction of tree. An east-west row orientation results in more shading as compared to the north-south orientation of trees. Thus, rows should be planted in north-south direction.

Özet

Serbest tozlanma koşullarında Nova mandarin çeşidinin meyve tutum ve kalitesi üzerine tozlayıcı mesafesi ve yöneylerin etkileri

Bu çalışmada, Nova mandarin çeşidinde serbest tozlanma koşullarında tozlayıcı mesafesinin ve yöneylerin meyve tutum ve kalitesine etkileri incelenmiştir. İki yıllık verilerin ortalamasına göre derim döneminde tozlayıcı çeşide en yakın (7 metre) bitkilerin (%12.79) 35 metre (%4.90) mesafedeki bitkilere göre yaklaşık 3 kat daha fazla meyve tutumu sağladıkları tespit edilirken, tozlayıcı mesafesinin tohum sayısı ve meyve kabuk rengi dışında yer alan meyve kalite kriterleri üzerine etkisi istatistiksel olarak önemli bulunmamıştır. Tozlayıcı çeşit Fremont mandarininden olan uzaklığın artışıyla birlikte, Nova çeşidinin meyve başına tohum miktarı düşmüştür. En iyi renklenme tozlayıcıdan 7 ve 14 metre mesafede yer alan bitkilerden alınan meyvelerde elde edilmiştir. Doğu yöneyi tüm meyve tutum oranlarında diğer yöneylere göre daha yüksek değerler vermiştir. Derime ulaşan meyve oranı doğu yöneyinde (%12.18) özellikle batı (%5.47) ve kuzey (%4.32) yöneylere göre yaklaşık 2-3 kat daha fazla tespit edilmiştir. Yöneylerin SÇKM/Asit oranı dışında yer alan meyve kalite kriterleri üzerine etkisi istatistiksel olarak önemsiz bulunmuştur. Çalışma sonucuna göre, Nova mandarin çeşidinde iyi bir meyve tutumu ve kalitesi için tozlayıcı uzaklığının 4 sıradan daha fazla olmaması ve sıraların kuzey güney yönünde kurulması önerilebilir.

Anahtar kelimeler: Turunçgiller, tozlayıcı sırası, ağaç yöneyi, tohum sayısı, meyve rengi

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