

## EFFECT OF DIFFERENT STRAWBERRY POLLINATORS ON FRUIT PROPERTIES OF LOCAL OSMANLI STRAWBERRY CULTIVAR IN TURKEY

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**Abstract.** In this study, impact on the fruit characteristics of different pollinators used on the Osmanli strawberry cultivar, which is male sterile and therefore necessarily needs foreign pollination, was studied. In the trial three foreign cultivars, as well as three local varieties obtained from farmers in Northeast of Turkey, where these local varieties were grown with the Osmanli strawberry, were used as pollinators on Osmanli strawberry cultivar. Before pollination, pollen viability and pollen germination capability of pollinator cultivars were determined; and then, the physical properties, photochemical and aroma components of the hybrid fruit of strawberry, as well as the fruits of six parent cultivars used as pollinators, were analyzed. The study showed that the pomological and phytochemical characters as well as aroma components of fruits in Osmanli strawberry can be influenced by the pollinators of its flower. Since the highest aroma components were obtained from Sweet Charlie as pollinator, this cultivar with its well aroma can be used as pollinator on the Osmanli strawberry cultivar.

**Keywords:** *male sterility, phytochemicals, pollinator, pomology, metaxenia*

### Introduction

Strawberries grown in many countries of the world in the soft fruit group are preferred due to their unique aroma, taste and rich nutritional content. There are diploid species *Fragaria vesca* and *Fragaria viridis* in the flora of Turkey. These wild species, together with local and old octoploid F. X ananassa varieties which have been used for many years, constitute the strawberry genetic resources of the country. Local varieties such as the Osmanli (Ottoman) and Arnavutkoy have narrowed and limited production areas by the growing use of more efficient commercial strawberry varieties. Cultured strawberry species have bigger fruits and give higher yields than the wild species, but the local or wild species have better aroma than the commercial varieties in use. Concentration of taste and aroma compounds generally decreases in commercial varieties with increasing fruit size (Zebatakis and Holden, 1997). Quantities of sugars and organic acids are qualitative and quantitative in essence of qualities in fruit. Sugar / acid balance is also a very important issue for breeders. In strawberry fruit, sugar and organic acids are important factors in determining the harvest time and the taste of fruit (Mina et al., 2017). There are many genetic and environmental factors in the formation of strawberry aroma, such as genes controlling some aroma compounds (Jetti et al. (2007), or cultural applications to plants (Loughrin and Kasperbauer, 2002). Osmanli strawberry cultivar which comes to foreground in terms of very good flavor of the local strawberry varieties decreases day by day and faces the danger of disappearance. This local cultivar is morphologically male sterile and a pollinator strawberry is necessary for fruiting.

On the other hand, pollens have effects on endosperm and embryo development (xenia), on the developing maternal tissues of seed or fruit outside the embryo and

endosperm (metaxenia), or on the carpel tissue (carpoxenia) in foreign-pollinating species. Since pollen sources totally come from outside in self-incompatible and infertile species, fruit quality attributes may vary based on pollen source. The variations in aroma and other fruit quality attributes of Osmanli strawberries may also result from either variation in climate parameters or pollinating species. Therefore, there is a need for a research to elucidate such variations. Various researchers reported effects of pollinator on fruit quality attributes (Gerçekcioglu, 1997).

The aroma of strawberry fruit is composed of various esters, alcohols, aldehydes and sulphur compounds and it is originated from degradation of carbohydrates, proteins and fats throughout ripening period (Samykanno et al., 2013).

In this study, in order to determine the effects different pollinators on the fruit characteristics of Osmanli strawberry cultivar, which is male sterile and therefore necessarily needs foreign pollination, three local ('Karacilek', 'Tuylu', 'Deli') and three commercial ('Cabarla', 'Sweet Ann' and 'Sweet Charlie') strawberry varieties were used as pollinators for Osmanli local cultivar. Morphological, phytochemical composition and aroma compounds of the fruits by different pollinators were investigated. Another objective was to determine the role of pollinator and to select proper pollinator or pollinators for Osmanli strawberry cultivar.

## Material and method

In the trial, as well as three commercial cultivars ('Cabarla', 'Sweet Ann' and 'Sweet Charlie'), three local varieties ('Karacilek', 'Tuylu', 'Deli') obtained from farmers in North west of Turkey, where these local varieties were grown with the Osmanli strawberry, were used as pollinators on Osmanli strawberry cultivar. Before pollination, pollen viability and pollen germination power of pollinator cultivars were determined; and then, the physical properties, photochemical and aroma components of the hybrid fruit of Osmanli strawberry, as well as the fruits of six parent cultivars used as pollinators, were analyzed. The plants Osmanli seedlings used as mother parent were moved to a temperature-controlled greenhouse into tulle-covered cages and ten Osmanli seedlings were left for open pollination. The flowers over mother parent were emasculated and the flowers were covered with parchment paper. Then throughout following three days, pollinations were performed. Ten pots were used for each pollinator and ten flowers were pollinated for each plant. The non-pollinated fruits were plucked and removed. Pomological measurements such as appearance of calyx flowers, position of calyx with respect to fruits, position of achenes over the fruit, width of the sections without achenes over the fruit, acheneity and achene depths were analyzed in accordance with UPOV (The International Union for the Protection of New Varieties of Plants 2012) criteria, which is used for the definition of morphological and pomological characteristics within the species. Fruit mass, fruit width and length was measured and fruits were grouped based on length/width ratio in accordance with Cekic et al. (2003). Fruit external color (cheek and tip), fruit firmness, water soluble dry matter (WSDM) content, pH, titratable acidity, ascorbic acid (vitamin C) content (%), fruit aroma compounds were determined.

Fruit mass was determined through weighing with a precise balance ( $\pm 0.01$  g). Fruit width and length was measured with a digital caliper ( $\pm 0.05$  mm); fruits were grouped based on length/width ratio in accordance with Çekiç et al. (2003). Fruit external color (cheek and tip) was measured with Minolta CR400 color-meter and L, a, b, *Chroma* (C) and Hue (h) values were determined. Fruit firmness was measured in  $\text{kg}/\text{mm}^2$  with a

penetrometer vertically penetrating 10 mm into the fruit. Water soluble dry matter (WSDM) content was measured with a portable hand-refractometer. The pH values were measured with a digital pH meter. Titratable acidity was measured with potentiometric titration method. Ascorbic acid (vitamin C) content (%) was measured by using Kromasil (250 × 4.6 mm 100-5C18 5 µm) HPLC column and Perkin Elmer (Series-200) UV detector at 215 nm wave length.

All the observations and analyses were performed in three replications, and carried out in this study were considered as the average of 10 fruits. All the resultant data were subjected to variance analyses and means were compared with LSD multiple comparison test. SAS software was used in statistical analyses.

## **Results and discussion**

### ***Pollen vigor tests***

Before hybridization works, pollen vigor levels of local and standard cultivars to be used as a pollinator for Osmanli cultivar were determined with tri-phenyl tetrazolium chloride (TTC) test. The greatest vigor was observed in Cabarla cultivar (74.4%) and the lowest vigor was observed in Tuylu cultivar (6.7%).

Eti et al. (1995) in a study used 8 different strawberry cultivars and reported pollen vigor levels through TTC test as between 5.07-73.71%. Present values varied between 6.7-74.4% and the present range of vigor was higher than the one reported by Eti et al. (1995).

### ***Success of hybridization and fruit set***

From a total of 321 hybridizations, 253 plants were obtained. The most successful hybridization was achieved in Sweet Charlie cultivar (91.4%) and the worst yield was observed in Tuylu cultivar (14.4%). About 78.8% of hybridizations yielded a fruit.

### ***Appearance of calyx leaves and position of calyx with respect to fruit***

Appearance of calyx leaves and their position with respect to the fruit are provided in *Table 1* based on UPOV criteria. Since calyx leaves were taken out during emasculation process from the fruit samples obtained from hybridizations with Osmanli cultivar, data about the appearance of calyx leaves were not available for these fruits. Considering the position of calyx with respect to the fruit, it was observed that Cabarla, Sweet Charlie and Karacilek cultivars at the end of hybridization did not present their own criteria and reflected the characteristics of Osmanli cultivar (buried within the fruit).

### ***Position of achenes over the fruit***

Position of achenes over the fruit is provided in *Table 1*. In Sweet Ann and Sweet Charlie cultivars used as pollinator, achenes lost their characteristics of being within the fruit surface and reflected the characteristics of the parent Osmanli cultivar.

### ***Width of the sections without achenes over the fruit***

The width of the sections without achenes over the fruit is provided in *Table 1*. In Cabarla and Sweet Ann cultivars, the width of sections without achenes lost their characteristics of being 'narrow' and turned into 'absent or very narrow' characteristic of

parent Osmanli cultivar. Besides in Sweet Charlie, Tuylu and Karacilek cultivars, width of the sections without achenes had 'absent or very narrow' characteristics of themselves and parent Osmanli cultivar.

**Table 1.** Fruit characteristics of parents and hybrids according to UPOV criteria

| Parents and hybrids     | Attitude of sepals | Position of calyx attachment | Position of achenes | Width of band without achenes |
|-------------------------|--------------------|------------------------------|---------------------|-------------------------------|
| Cabarla                 | Upwards            | Level with fruit             | Below surface       | Medium                        |
| Sweet Charlie           | Upwards            | Level with fruit             | Below surface       | Absent or very narrow         |
| Sweet Ann               | Upwards            | Inserted                     | Below surface       | Narrow                        |
| Tuylu                   | Downwards          | Inserted                     | Below surface       | Absent or very narrow         |
| Deli                    | Downwards          | Inserted                     | Below surface       | Absent or very narrow         |
| Karacilek               | Upwards            | Level with fruit             | Below surface       | Absent or very narrow         |
| Osmanli                 | Downwards          | Inserted                     | Below surface       | Absent or very narrow         |
| Osmanli x Karacilek     | X                  | Inserted                     | Below surface       | Absent or very narrow         |
| Osmanli x Tuylu         | X                  | Inserted                     | Below surface       | Absent or very narrow         |
| Osmanli x Sweet Ann     | X                  | Inserted                     | Below surface       | Absent or very narrow         |
| Osmanli x Cabarla       | X                  | Inserted                     | Below surface       | Absent or very narrow         |
| Osmanli x Sweet Charlie | X                  | Inserted                     | Below surface       | Absent or very narrow         |

X: calyx and corolla were totally removed from mother plants while emasculation of stubborn anthers

### **Fruit mass (g/fruit)**

Mean fruit mass values are provided in *Table 2*. Significant differences were observed in fruit mass of strawberry genotypes used in this study at 5% level. The fruits of Osmanli x Tuylu hybrids had the lowest fruit mass values and other hybrids were not significantly different from each other with regard to fruit mass.

### **Fruit length and width (mm)**

Fruit length and widths of strawberry genotypes were measured in accordance with Cekic et al. (2003) (*Table 2*). The greatest fruit length and width were observed in Sweet Ann cultivar. The lowest fruit width was seen in Osmanli x Tuylu hybrid and the lowest fruit length was observed in Tuylu cultivar. The fruits obtained from the pollination of Osmanli cultivar with Karacilek cultivar had the greatest length and width scale.

### **Length/width ratio**

Length/width ratio is one of the pomological characters of strawberry fruits, where the fruit shapes can be like sphere, flattened or cylindrical depending of the ratio. Although the ratio was over 1 in the fruits of cabarla, sweet charlie and sweet ann cultivars, the fruits of Osmanli pollinated with them were flattened with the ratio lower than 1. So, it can be said that pollinators had no effect on the fruit shape of Osmanli cultivar (*Table 2*).

### **Number of achenes per fruit**

Number of achenes per fruit is provided in *Table 2*. The greatest number was observed in Sweet Charlie (301.8) and the lowest number was observed in Osmanli cultivar (59.6). After hybridization with Osmanli cultivar, the greatest number was observed in Osmanli x

Cabarla hybrids (147.5). With regard to achenity according to 1 (less achenes) – 9 (highly achenes) scale, ‘Sweet Charlie’ was expressed with 9 and ‘Osmanli’ was expressed with 1.

**Table 2.** Pomological characteristics of fruits

| Parents and hybrids     | Weight* (g/fruit) | Width* (mm) | Length* (mm) | Length/width* | Fruit firmness* (kg) | Achene number* | Achene number/fruit size* |
|-------------------------|-------------------|-------------|--------------|---------------|----------------------|----------------|---------------------------|
| Cabarla                 | 12.5 b            | 28.7 a      | 37.1 a       | 1.28 ab       | 1.47 a               | 242.9 ab       | 189.59 ab                 |
| Sweet Charlie           | 14.4 b            | 30.3 a      | 40.5 a       | 1.32 a        | 1.47 a               | 301.8 a        | 229.35 a                  |
| Sweet Ann               | 21.9 a            | 32.2 a      | 44.0 a       | 1.36 a        | 1.18 ab              | 273.6 a        | 200.66 ab                 |
| Tuylu                   | 2.6 d             | 18.0 bc     | 14.9 c       | 0.83 e        | 0.59 d               | 77.7 de        | 91.50 de                  |
| Deli                    | 4.1 cd            | 19.1 bc     | 19.5 c       | 1.02 cd       | 0.84 bcd             | 124.5 cde      | 121.55 cde                |
| Karacilek               | 9.0 bc            | 23.6 b      | 27.6 b       | 1.13 bc       | 1.11 abc             | 189.2 bc       | 160.68 bc                 |
| Osmanli                 | 3.5 cd            | 20.4 bc     | 17.9 c       | 0.87 de       | 0.62 d               | 59.6 e         | 68.86 e                   |
| Osmanli x Karacilek     | 4.1 cd            | 21.2 bc     | 17.6 c       | 0.82 e        | 0.72 cd              | 114.4 cde      | 140.34 bcd                |
| Osmanli x Tuylu         | 2.6 d             | 17.4 c      | 15.6 c       | 0.89 de       | 0.81 bcd             | 60.8 e         | 68.08 e                   |
| Osmanli x Sweet Ann     | 3.4 cd            | 19.6 bc     | 15.4 c       | 0.78 e        | 0.65 d               | 94.3 de        | 120.97 dce                |
| Osmanli x Cabarla       | 3.0 cd            | 18.7 bc     | 15.6 c       | 0.82 e        | 0.69 cd              | 147.5 cd       | 177.66 abc                |
| Osmanli x Sweet Charlie | 3.8 cd            | 20.4 bc     | 17.0 c       | 0.82 e        | 0.59 d               | 143.0 cd       | 173.45 abc                |

\*The difference between the values indicated by different letters in the same column is significant at the 0.05 probability level

### ***Achene number and Achene number/fruit size***

In the strawberry, one component of yield is fruit size, which we have shown to be determined by the number of fertilized ovules (achenes) on the surface and the degree of receptacle expansion associated with each achene. Berry weight is highly correlated with achene spacing and achene number, so that for each value of achene spacing there is a linear relation between berry weight and achene number (Abbot and Webb, 1970). This data was taken to determine the success of fertilization by the different pollinators and the effect of pollinators on the achene numbers. While number/fruit size ratio in the open pollinated Ottoman cultivar was 68.86, this ratio varied between 91.50 (Tuylu) and 229.35(Sweet Charlie) in the pollinators. On the other hand, this ratio ranged from 68.08 to 177.66 on the fruits of Osmanli pollinated with Tuylu and Cabarla, respectively.

### ***Fruit firmness***

Fruit surface and flesh firmness are significant factors for transport and storage of strawberries. Fruit firmness values are provided in *Table 2*. Values were significant at 5% level. The greatest firmness was observed in Cabarla cultivar (1.47 kg) and the lowest value was seen in Tuylu cultivar (0.59 kg).

Özdemir et al. (2007) carried out a study with 7 different strawberry cultivars and reported the greatest firmness for Cabarla cultivar (0.63 kg). Gündüz and Özdemir (2012) also reported Cabarla cultivar as prominent with its fruit firmness. In another study, Osmanli cultivar was reported as the softest cultivar (Özuygur, 2005).

### **Water soluble dry matter (WSDM) content**

WSDM is among the most significant quality criteria for strawberries and it is mostly related to sugar content of the fruits. WSDM directly influences fruit taste. Therefore, high WSDM values are preferred in strawberry fruits. Among the main plants, the greatest WSDM content was observed in Osmanli cultivar. Among the hybrids, Osmanli x Tuylu (12.1%) had the greatest WSDM content. The Sweet Ann cultivar and Osmanli x Sweet Charlie (9.1%) hybrids had the lowest WSDM contents (*Table 3*).

Besides plant genetics, environmental factors also influence WSDM content of the fruits (Shaw, 1988; Galletta and Bringhurst, 1990; Abeytilakathna et al., 2013). Özdemir et al. (2007) and Macit et al. (2011) reported that ‘Cabarla’ cultivar had lower WSDM content than the other cultivars.

### **pH**

The pH values of strawberry cultivars are provided in *Table 3*. Gelling of jellies, marmalades and jams, color, taste and aroma of foodstuff and taste, aroma and odor development are closely related to fruit pH levels. Present values were not able to be subjected to statistical analyses because of insufficient number of fruits. Among the hydrides, Osmanli x Tuylu (3.79) had the greatest pH and among the main cultivars, Osmanli (3.67) had the greatest pH value. The lowest pH (3.33) was obtained from Karacilek cultivar.

Sürücü (2010) reported the pH value of Osmanli cultivar as 3.65 and such a value was parallel to the present value.

**Table 3.** Phytochemical characteristics of fruits

| Parents and hybrids     | Water soluble dry matter (%) <sup>*</sup> | ph <sup>**</sup> | Titrateable acidity (%) <sup>*</sup> | Water soluble dry matter/titrateable acidity <sup>*</sup> | Vitamin C content (mg/100g) <sup>*</sup> |
|-------------------------|---|------------------|--------------------------------------|---|--|
| Cabarla                 | 8.8 bc                                    | 3.62             | 0.69 d                               | 12.75 ab  | 16.77 d                                  |
| Sweet Charlie           | 7.4 c                                     | 3.42             | 0.82 cd                              | 9.02 b  | 23.81 b                                  |
| Sweet Ann               | 6.0 d                                     | 3.49             | 0.86 cd                              | 6.97 c  | 19.23 c                                  |
| Tuylu                   | 10.3 ab                                   | 3.59             | 1.26 ab                              | 8.17 bc   | 27.32 a                                  |
| Deli                    | 8.1 bc                                    | 3.60             | 0.94 c                               | 8.61 bc   | 19.13 c                                  |
| Karacilek               | 11.3 ab                                   | 3.33             | 0.85 cd                              | 13.29 a   | 19.24 c                                  |
| Osmanli                 | 12.2 a                                    | 3.67             | 1.08 bc                              | 11.29 ab  | 27.97 a                                  |
| Osmanli x Karacilek     | 9.7 ab                                    | 3.40             | 1.24 ab                              | 7.82 bc   | 24.44 b                                  |
| Osmanli x Tuylu         | 12.1 a                                    | 3.79             | 1.07 b                               | 11.30 ab  | ***                                      |
| Osmanli x Sweet Ann     | 10.8 ab                                   | 3.76             | 1.10 b                               | 9.81 b  | ***                                      |
| Osmanli x Cabarla       | 9.3 ab                                    | 3.60             | 1.15 b                               | 8.08 bc   | 23.34 b                                  |
| Osmanli x Sweet Charlie | 9.1 b                                     | 3.59             | 1.34 a                               | 6.79 c  | 24.34 b                                  |

\*The difference between the values indicated by different letters in the same column is significant at the 0.05 probability level

\*\*The difference between the values is not significant in terms of statistics

\*\*\*Not enough fruit was available for analysis

### ***Titration acidity***

Titrateable acidity values of strawberry cultivars are provided in *Table 3*. A single value was obtained from each cultivar because of insufficient number of fruits from the cultivars. Therefore, results were not subjected to statistical analyses. The greatest acidity was observed in Osmanli x Sweet Charlie (1.34%) hybrid. Among the main cultivars, the greatest acidity was observed in Tuylu cultivar (1.26%). The lowest acidity was observed in Osmanli x Tuylu (1.07%) hybrid. Among the entire cultivars used in this study, Cabarla (0.69%) had the lowest titrateable acidity.

Özuygur (2005) in a study reported the lowest titrateable acidity for Sweet Charlie (0.75%) cultivar. In that study, titrateable acidity of Osmanli cultivar was reported as 0.92% and the value was measured as 1.08% in present study.

### ***WSDM/Acid ratio***

The WSDM/acid ratios for experimental cultivars are provided in *Table 3*. The greatest ratio was observed in Karacilek (13.29) and the lowest ratio was observed in Osmanli x Sweet Charlie (6.79) hybrid.

Schöpplein et al. (2002) reported WSDM/acid ratio of 11 strawberry genotypes as between 8.7-12.4. The WSDM/acid ratios varied within a larger range (6.79-13.29) in present study.

Özuygur (2005) in a study reported the WSDM/acid ratio of Osmanli cultivar as 11.12 and such a value was quite close to the present value. Özuygur (2005) reported WSDM/acid ratio of Sweet Charlie as 10.21 and the cultivar had the second greatest ratio after Osmanli cultivar.

### ***Ascorbic acid (vitamin C) content***

Ascorbic acid values of parents and hybrids are provided in *Table 3*. The values were found to be significant at 5% level. The greatest value was obtained from Osmanli (27.97 mg/100 g), it was followed by Tuylu cultivar and the lowest value was obtained from Cabarla (16.77 mg/100 g) cultivar. Ascorbic acid values were not able to be obtained from Osmanli x Tuylu and Osmanli x Sweet Ann hybrids because of insufficient number of fruits from these hybrids. The differences in ascorbic acid values of the other three hybrids were not found to be significant.

Hakala et al. (2003) reported vitamin C content of strawberry cultivars as between 32.4-84.7 mg/100 g, but indicated that vitamin C contents of the years were significant. Özuygur (2005) reported the lowest average ascorbic acid content for Osmanli cultivar (26.22 mg/100 g) and reported ascorbic acid content of Sweet Charlie cultivar as 50.88 mg/100 g. Although present values of Osmanli cultivar were close to the ones reported by Özuygur (2005), present values for Sweet Charlie were significantly different. Eti (2006) reported the greatest ascorbic acid content for Sweet Charlie (57.29%) cultivar. Sürücü (2010) reported vitamin C content of Osmanli cultivar as 59 mg/100 g.

### ***Aroma compounds***

Mass spectroscopy (MS) library of NIST and WILEY was used for the identification of aroma substances. With regard to number of aroma substances, 15 different substances were identified in Cabarla, 10 in Sweet Charlie, 9 in Tuylu, 7 in Deli, 11 in

Karacilek, 11 in Osmanli, 8 in Osmanli x Cabarla hybrid and 9 substances in Osmanli x Sweet Charlie hybrid. Data were not able to be obtained for Sweet Ann cultivar.

The greatest lactone content was observed in Deli cultivar, it was respectively followed by Cabarla, Sweet Charlie, Osmanli x Sweet Charlie and the lowest value was seen in Osmanli cultivar. Furaneol (2,5-dimethyl-4-OH-3(2H)-furanone) was identified only in Cabarla (6.65%) cultivar. Furaneol has quite low threshold detection value (10 µg/L; Schieberle and Hoffmann, 1997) and with caramel aroma provided to strawberries, it is a significant aroma substance. The 2,5-dimethyl-4-methoxy-3(2H)-furanon (mesifurane) is a lactone compound with great contributions to strawberry aroma. The greatest amount of this compound was respectively observed in Cabarla, Osmanli and Sweet Charlie cultivars. Schieberle and Hoffmann (1997) reported detection threshold for mesifurane as 25 µg/L and indicated that this compound contributed a fragrance to strawberries.

Acids with high detection thresholds have quite low contributions to general aroma of the fruits. The greatest 'trans cinnamic acid' was observed in Osmanli (29.24%) cultivar, the greatest 'hexanoic acid' was observed in Sweet Charlie (28.39%) cultivar and the greatest 'succinic acid' was observed in Osmanli x Cabarla (20.96%) hybrid. Cinnamic acid was identified only in Osmanli cultivar (1.10). Palmitic acid was identified in Sweet Charlie (2.81) and Osmanli (2.18) cultivars.

### ***Fruit color parameters***

Multiple color spaces are often used to define color parameters of fruits. Among them, CIE L\*a\*b\* (CIELAB) specified by International Commission on Illumination is the most common one (Fairchild, 2013) were used to evaluate the skin color parameters (L\*, a\*, and b\*). L\* represents lightness (100: white, 0: black), a\* indicates the difference between red (+a\*) and green (-a\*), and b\* represents the difference between yellow (+b\*) and blue (-b\*). Hue angle (h°) and Chroma (C\*) values were derived from a\* and b\* values. Mean color parameters (L, a, b, *Chroma* and h°) were measured from the cheeks and tips of the fruits using a Minolta Chroma Meter CR-400 (MinoltaKonica, Japan) on the basis of CIE L\*a\*b\* color space. Equations in the scientific literatures (Viscarra Rossel et al., 2006; Kus et al., 2017) were used for calculations. The differences in color parameters of strawberry genotypes were found to be significant at 5% level. A decrease was observed in 'L' values of all hybrid fruits. The greatest cheek L value was observed in Osmanli x Sweet Ann (49.0) hybrid and the greatest tip L value was observed in Osmanli x Tuylu (50.7) hybrid. As compared to Osmanli cultivar, an increase was observed in 'a' values of all hybrids. Hybrids had greater 'b' values than Osmanli cultivar. Osmanli x Cabarla (30.9) hybrid had the greatest cheek measurement and Osmanli x Karacilek (30.7) hybrid had the greatest tip measurements. '*Chroma*' values of hybrid fruits were higher than Osmanli fruits. While cheek 'h' values of all hybrids were greater than Osmanli cultivar, a decrease was observed in tip 'h' values of Osmanli x Sweet Ann and Osmanli x Sweet Charlie hybrids as compared to Osmanli cultivar. The differences in cheek and tip values of hybrid fruits and Osmanli fruits were not found to be significant (*Table 4*). Özüyüğü (2005) reported the greatest 'L' and 'h' (60.7 and 81.2) and lowest 'a', 'b' and 'C' (7.2; 47.8 and 48.5) values for Osmanli cultivar and the second greatest 'C' value (78.0) for Sweet Charlie cultivar. Parallel to present findings, Skupien and Osmianski (2004) in a study reported L values as between 35.32 and 41.11. Nunes et al. (1995) indicated high correlations of 'a' values with anthocyanin content of strawberries. Skupien and



Osmianski (2004) reported negative correlations of 'a' value with pelargonidin-3-glucozid and total pelargonidin contents. Gündüz and Özdemir (2012) observed the brightest fruit external color on 'Osmanli' cultivar and indicated that Sweet Charlie had also sufficient brightness. Kafkas (2004), Serçe et al. (2004), Kıyga (2009), Yılmaz (2009) and Gündüz and Özdemir (2012) reported the greatest 'h' values for 'Osmanli' cultivar.

**Table 4.** Color (*L*, *a*, *b*, Chroma ve *h*<sup>0</sup>) values of fruits

|                   | <i>L</i> * |           | <i>a</i> * |        | <i>b</i> * |           | Chroma* |         | <i>h</i> <sup>0</sup> * |          |
|-------------------|------------|-----------|------------|--------|------------|-----------|---------|---------|-------------------------|----------|
|                   | Cheek      | Tip       | Cheek      | Tip    | Cheek      | Tip       | Cheek   | Tip     | Cheek                   | Tip      |
| Cabarla           | 41.4 ef    | 45.5 cde  | 38.5 a     | 39.7 a | 33.4 ab    | 40.5 a    | 51.1 a  | 56.8 a  | 40.8 c                  | 45.4 bc  |
| Sweet Charlie     | 39.4 f     | 41.5 e    | 37.5 a     | 38.8 a | 32.3 abc   | 34.5 b    | 49.6 a  | 52.1 ab | 40.3 c                  | 41.4 c   |
| Sweet Ann         | 44.8 def   | 47.3 bcde | 35.4 a     | 38.2 a | 38.2 a     | 41.1 a    | 52.3 a  | 56.4 a  | 47.0 bc                 | 47.0 abc |
| Tuylu             | 59.9 a     | 58.4 a    | 17.5 c     | 16.7 b | 22.8 d     | 22.6 e    | 29.0 c  | 28.3 d  | 53.0 ab                 | 53.4 ab  |
| Deli              | 50.5 bcd   | 53.0 ab   | 27.1 b     | 26.2 b | 34.3 ab    | 34.2 bc   | 44.3 ab | 43.5 bc | 53.1 ab                 | 53.8 ab  |
| Karacilek         | 51.1 bc    | 51.1 bcd  | 22.7 bc    | 23.8 b | 29.6 bc    | 31.4 bcd  | 38.2 b  | 40.8 c  | 56.9 a                  | 57.5 a   |
| Osmanli           | 53.4 b     | 52.0 bc   | 23.3 bc    | 24.2 b | 26.3 cd    | 27.7 cde  | 35.3 bc | 37.0 cd | 49.0 ab                 | 48.9 abc |
| Osm. x Karacilek  | 47.7 bcd   | 48.1 bcde | 25.9 bc    | 24.9 b | 30.8 bc    | 30.7 bcd  | 40.4 b  | 39.6 c  | 49.7 ab                 | 51.0 abc |
| Osm. x Tuylu      | 48.6 bcd   | 50.7 bcd  | 25.2 bc    | 25.2 b | 29.8 bc    | 30.6 bcd  | 39.2 b  | 40.0 c  | 49.8 ab                 | 52.0 abc |
| Osm. x S. Ann     | 49.0 bcd   | 50.2 bcd  | 25.7 bc    | 24.3 b | 30.3 bc    | 28.2 bcde | 39.8 b  | 37.5 cd | 49.6 ab                 | 48.8 abc |
| Osm. x Cabarla    | 46.9 cde   | 44.3 de   | 25.8 bc    | 24.4 b | 30.9 bc    | 26.8 de   | 40.4 b  | 36.4 cd | 50.0 ab                 | 47.6 abc |
| Osm. x S. Charlie | 46.7 cde   | 46.1 cde  | 24.5 bc    | 26.7 b | 28.8 bcd   | 30.4 bcd  | 37.9 b  | 40.6 c  | 49.3 ab                 | 48.2 abc |

\*The difference between the values indicated by different letters in the same column is significant at the 0.05 probability level

## Conclusion

Osmanli strawberries morphologically infertile, but they have stubborn anthers. Therefore to improve the reliability of hybrids, calyx and corolla were totally removed from mother plants while emasculation of anthers. Then, calyx was not observed in hybridized plants. Variation was not observed in achenes over the fruits obtained through all pollinators and thus all fruits reflected achene characteristics of open-pollinating Osmanli cultivar. A similar case was also observed in widths of sections without achenes. In all fruits with controlled pollinators, width of sections without achenes reflected the fruit characteristics of Osmanli cultivar. Fruit size of pollinators did not reflect over the fruits obtained through controlled pollination. Among the pollinators, Tuylu cultivar reduced fruit size as compared to open-pollinating ones and large-fruit pollinators did not increase their fruit size.

Among the Osmanli cultivar and pollinators, Tuylu had the lowest fruit firmness, but the fruits of pollinated Osmanli cultivar had the greatest firmness values. The fruits pollinated by firm-fruits also had soft fruit flesh. Therefore, it was concluded that pollinator had adverse effects on fruit firmness. With regard to pH values of the fruits, there were not significant differences between the fruits of pollinator cultivars and controlled-pollinated Osmanli cultivar. While Osmanli cultivar was the richest in ascorbic acid content, pollinators decreased ascorbic acid contents of Osmanli strawberries. Since Osmanli cultivar is male-infertile and needs a pollinator, Karacilek with the greatest ascorbic acid content may be recommended as a pollinator. The greatest number of aroma compounds was observed in fruits pollinated with Sweet Charlie cultivar, therefore Sweet Charlie may be recommended as a pollinator for Osmanli cultivar prominent with its own aroma.

As to conclude, pollinator selection is a significant issue for male-infertile Osmanli strawberries. The present study proved that some characteristics of pollinators relatively passed into Osmanli strawberries at different levels in the same year and the effects of pollens on fruits in foreign-pollinating cultivars (metaxenia) were also observed in Osmanli strawberries. Pollinator resulted in changes in fruit pomological and phytochemical characteristics and aroma characteristics which are significant attributes for Osmanli strawberry varied based on pollinators. Although a common known knowledge these terms (xenia, metaxenia, carboxenia), there is not enough scientific literature on this area. Our study serves some preliminary data about the first effects of pollinators on the fruit. Based on this study, in depth studies should be done on strawberries and other species.

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