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Gozlekci S., Kaynak L.

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Physical and chemical changes during fruit development and flowering in pomegranate (*Punica granatum* L.) cultivar Hicaznar grown in Antalya region

S. Gozlekci and L. Kaynak
Department of Horticulture, Faculty of Agriculture, Akdeniz University,
P.O. Box 510, 07070 Antalya, Turkey

SUMMARY – In this study, flowering, fruit setting and fruit growing characteristics of Hicaznar grown in Antalya conditions, which is one of our important standard cultivars, were examined. At the same time some interactions between some physical and chemical changes which occur during fruit growing and developing periods were researched. According to the results, the total number of flowers that blossomed on the examined trees, which were 10 years old, varied between 2184-2508. 77.68-86.20% of the flowers were determined as unfertile (A type) and 13.58-22.32% were determined as fertile (B type) flowers. While fruit setting rates of total flowers on the examined trees varied between the values of 7.59% and 16.07%, fruit setting of total fertile (B type) flowers varied between the values of 44.0-71.99%. While fruit growth was fast at the beginning of growing period, it slowed down afterwards. A sigmoid, thus, fruit growth curve was obtained. While fruit diameter, length, volume, 100-aril weight, juice and aril yield, pH, total soluble solid content showed a regular increment, titratable acidity and skin amount had a decrement from first fruit setting to maturity.

Key words: Pomegranate, *Punica granatum* L., flowering, fruit setting, fruit development.

RESUME – *"Changements physiques et chimiques pendant le développement et la floraison du fruit chez le cultivar de grenade (*Punica granatum *L.) Hicaznar cultivé dans la région d'Antalya". Dans cette étude, on a examiné la floraison, la mise à fruit et les caractéristiques de croissance du fruit de Hicaznar cultivé dans les conditions d'Antalya, qui est l'un de nos cultivars standards importants. En même temps, on a fait des recherches sur certaines interactions entre quelques changements physiques et chimiques qui surviennent pendant la croissance du fruit et les périodes de développement. Selon les résultats, le nombre total de fleurs qui fleurissaient sur les arbres examinés, qui avaient 10 ans d'âge, variait entre 2184-2508. 77,68-86,20% des fleurs furent déterminées comme étant des fleurs non fertiles (type A) et 13,58-22,32% comme étant des fleurs fertiles (type B). Tandis que les taux de mise à fruit des fleurs totales sur les arbres examinés variaient entre les valeurs de 7,59% et 16,07%, la mise à fruit des fleurs fertiles totales (type B) variait entre les valeurs de 44,0-71,99%. Tandis que la croissance du fruit était rapide au début de la période de croissance, elle s'était ralentie par la suite. On obtenait ainsi une courbe sigmoïde de croissance du fruit. Tandis que le diamètre, la longueur, le volume, le poids de 100 arilles, le jus et le rendement en arilles, le pH, le contenu en solides solubles totaux montraient une augmentation régulière, l'acidité titrable et la quantité de peau diminuaient depuis la première mise à fruit jusqu'à la maturité.*

Mots-clés : *Grenadier,* Punica granatum *L., floraison, mise à fruit, développement du fruit.*

Introduction

Turkey is one of the main pomegranate producer countries in the world. It is possible to grow pomegranates in all parts of Turkey except some regions (Onur, 1982). Although Turkey's total pomegranate production changes from one year to another, recent production has reached to 56,000 tonnes (Anonymous, 1996). The most important pomegranate growing area is the Mediterranean region of Turkey. Aegean and Southeast Anatolia regions are two other important regions. The production and consumption in both domestic markets and outside markets have been increasing. Especially, Hicaznar pomegranate cultivar, which was selected in Mediterranean region, is the most important cultivar for exporting to European countries and also preferred in domestic markets.

In order to grown a fruit cultivar economically in one region, all the morphological and physiological events which occur during flowering and fruit development period should be known. These events are flower bud formation, flowering, pollination, fertilisation, fruit setting and fruit maturation. Since there is

not enough work conducted on the above stated subjects, there are still some unknown issues on pomegranate growing.

The cultural precautions, which ensures the high yield and quality, are not known exactly. The fact that obtaining high quality and marketable fruits every year depends on the knowledge about all the morphological and physiological events from flower bud formation to fruit maturation. For this purpose, the physical and chemical changes occur during flowering and fruit development of Hicaznar cultivar, which is the most produced and one the of important standard cultivars in Antalya region, were investigated.

Materials and methods

Experiments were conducted in Antalya Citrus and Greenhouse Crop Research Institute, Serik-Kayaburnu Station, and Physiology Laboratory of Department of Horticulture, Faculty of Agriculture, University of Akdeniz, in two consecutive years between 1994 and 1995.

Experimental Hicaznar cultivar fruits were taken from the 10-year-old trees. Hicaznar cultivar is known as a late cultivar, because it gets mature after 15 October. The fruit weight varies between 350 and 500 g. Skin colour and aril colour are dark red. Seed is moderately hard. Since the soluble solid content amount is 17-17.5% and acid content is 1.8-1.9%, its taste is known as sour-sweet.

In order to find out the number of flower types, A is unfertile and B is fertile, on a single tree, a total of five trees were examined.

Fruit diameter and length were measured on the samples taken at two-week intervals during a period from first fruit setting to maturation.

The fruit characteristics, fruit weight, diameter, length, skin thickness, juice and aril yield, weight of 100 arils, soluble solid content, pH and titratable acidity were examined on fruit samples taken in each month from fruit setting to maturation.

Results and discussion

Flowering

There are two types of flowers in pomegranate, A and B type. A type flowers take a part in fertilisation of B type flowers so that B type flowers set fruits. Since yield obtained from a single tree depends on the number of B type flowers present on the tree, total number A and B type flowers were determined during the vegetation period. Total number of flowers on examined trees varied between 2184, and 2508. It was found that while the percentages of A type flowers in total flowers of examined trees varied 77.68%, and 86.20%, percentages of B type flowers varied between 13.58%, and 22.32%. Other researchers stated different percentages of A and B type flowers, as they worked different cultivars under different ecological conditions, i.e. Nalavadi *et al*. (1973) reported that 12-61% fertile flowers in total flowers.

While the fruit setting ratio in total flowers of examined trees changed between 7.59% and 16.07%, it varied between 44.0% and 71.99% for B type flowers. These findings showed similarities with Nalavadi's *et al*. (1973) and El-Sese's (1988) results.

Fruit growth

The fruit growth from first fruit setting to maturation are shown in Figs 1 and 2. As can be seen from the Figures, fruit diameter and fruit length were equal during a period of two weeks of the first fruit setting. After first two weeks, a rapid increment in fruit growth was observed and continued until end of June. Afterwards, fruit growth slowed down and became stable until harvest time due to high temperature in July, August, September and October. While fruit growth was fast at the beginning of the growing period, it slowed down afterwards in 1994 and 1995. Thus, a sigmoid fruit growth curve

was obtained. It was found that slowing down observed in fruit growth was due to the stoppage of seed tissue growing and the increment in testa hardness. These results are similar with findings of Chace *et al*. (1981), Ben-Arie *et al*. (1984), Shulman *et al*. (1984), Khodade *et al*. (1991) and Saad (1991).

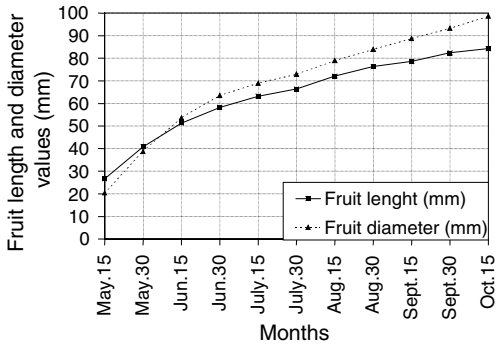

Fig. 1. The fruit growth curves in 1994.

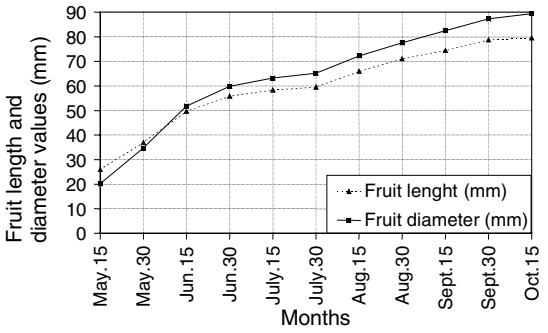

Fig. 2. The fruit growth curves in 1995.

Fruit weight

The fruit weight was measured from fruit setting to maturation in each growing period of the years of 1994 and 1995. While the average fruit weights in 1994 from June to October were 25.60 g, 72.02 g, 149.61 g, 229.24 g and 337.33 g, respectively, these values were 26.25 g, 72.98 g, 152.50 g, 219.45 g and 329.87 g, respectively in 1995 (Fig. 3). As can be seen from Fig. 3, as fruits got more mature, fruit weight also increased. Increment in fruit weight in September and October was much more than the rest of the months of the growing period.

A similar research was conducted in different ecological conditions and cultivars in Israel. In Israel's conditions it was reported that increase on fruit weight varied depending on ecology and cultivar (Shulman *et al*., 1984).

Fruit volume

While the average fruit volumes in 1994 from June to October were 28.76 ml, 76.87 ml, 157.85 ml, 240.06 ml and 355.68 ml, respectively, these values were 29.42 ml, 75.70 ml, 162.00 ml, 233.63 ml and 342.88 ml, respectively in 1995 (Fig. 4). As can be seen from Fig. 4, as fruits got more mature, fruit volume also increased. Increment in fruit volume in September and October was much more than the rest of the months of the growing period. As fruit developed, there was also an increase on fruit weight. Thus, one can say that there is a close connection between fruit weight and fruit volume. Similar results were also obtained on different crops. For example a relationship between fruit volume, fruit weight, fruit diameter and fruit length was reported in avocado (Undurraga *et al*., 1987).

Fruit length

While the average fruit lengths in 1994 from June to October were 22.67 mm, 46.45 mm, 58.54 mm, 67.87 mm and 74.43 mm, respectively, these values were 35.31 mm, 44.22 mm, 58.64 mm, 66.02 mm and 73.96 mm, respectively in 1995 (Fig. 5). As can be seen in Fig. 5, changes in fruit length were similar in 1994 and 1995. Increment in fruit length occurred in June and July as happened for fruit weight and volume. Fruit length increased as fruits became more and more mature.

Fruit diameter

While the average fruit diameters in 1994 from June to October were 36.12 mm, 50.79 mm, 65.51

mm, 75.89 mm and 85.87 mm, respectively, these values were 35.49 mm, 51.06 mm, 65.89 mm, 75.40 mm and 86.20 mm, respectively in 1995 (Fig. 6). As can be seen in Fig. 6, changes in fruit diameter were similar in 1994 and 1995. Increment in fruit diameter occurred in June and July like fruit weight, volume and length. Fruit diameter increased as fruits became more and more mature. Similar results were also reported for Israel's conditions (Ben-Arie *et al*., 1984).

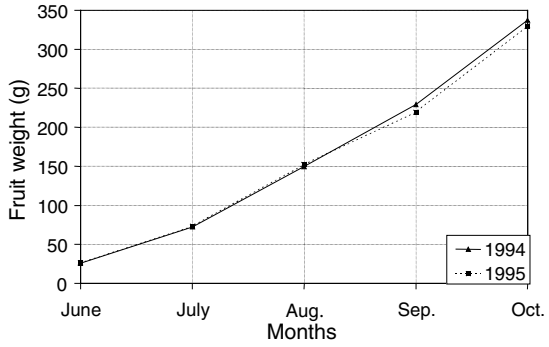

Fig. 3. Variation in fruit weight during fruit growing period.

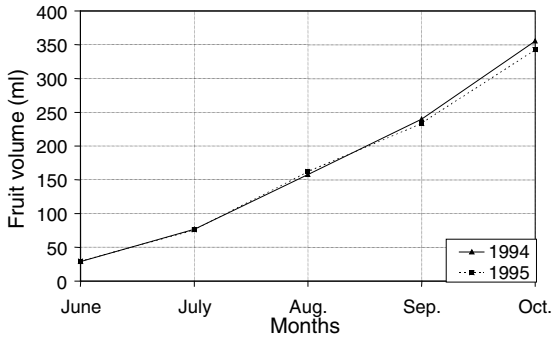

Fig. 4. Variation in fruit volume during fruit growing period.

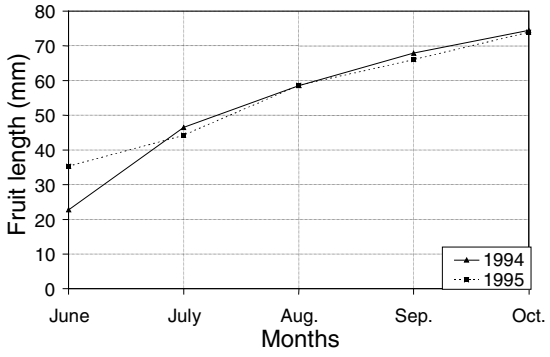

Fig. 5. Variation in fruit length during fruit growing period.

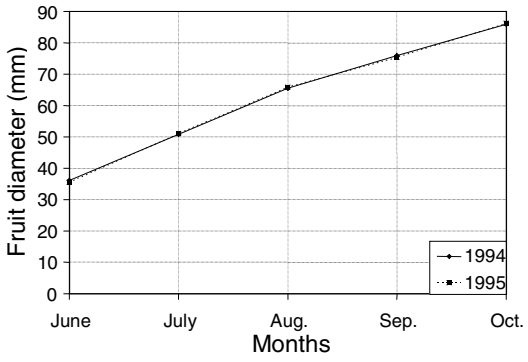

Fig. 6. Variation in fruit diameter during fruit growing period.

Skin thickness

While the fruit skin thickness in 1994 from June to October were 5.19%, 4.40%, 4.29%, 4.27% and 4.23%, respectively, these values were 5.42%, 4.52%, 4.34%, 4.32% and 4.25%, respectively in 1995 (Fig. 7). As can be seen from Fig. 7, increment in skin thickness slowed down from small fruit stage (in June) to maturation (in October). It was assumed that this decrement was due to increase in fruit growth speed.

Skin amount

While the percentages of fruit skin amount in 1994 from June to October were 78.30%, 47.44%, 47.30%, 43.43% and 41.63%, respectively, these values were 78.95%, 54.00%, 49.73%, 46.29% and 41.90%, respectively in 1995 (Fig. 8). As can be seen in Fig. 8, while the skin amount was about 80% during small fruit period in both years, it decreased down to about 40% in accordance with fruit size and maturation stages. As fruits became more and more mature, aril size also increased. As a consequence of these developments, skin development and percentage skin amount slowed down.

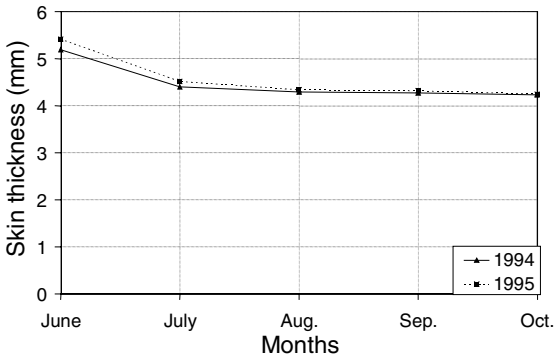

Fig. 7. Variation in skin thickness during fruit growing period.

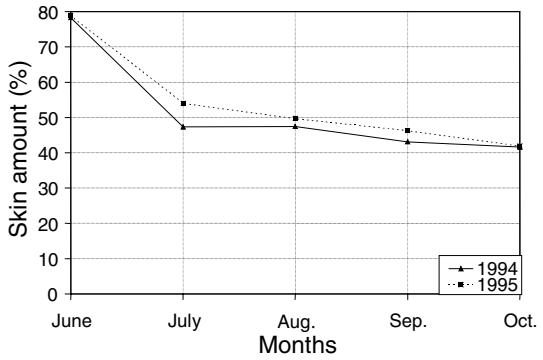

Fig. 8. Variation in skin amount during fruit growing period.

Juice yield

While the percentages of juice yield in 1994 from June to October were 14.99%, 28.02%, 30.36%, 42.11% and 48.04 %, respectively, these values were 14.93%, 28.97%, 31.86%, 40.08% and 48.38%, respectively in 1995 (Fig. 9). As can be seen from Fig. 9, changes in juice yield were similar in 1994 and 1995. Increment occurred in June during small fruit period was higher than the increment occurred in other months. Increment in juice yield occurred in accordance with fruit size and maturation stages. Juice yield increased as fruits became more and more mature. Similarly, in a study conducted in Israel, it was reported that, while the juice yield was around 25% in mid-July, it reached 40-45% in harvest time (Shulman *et al*., 1984).

Aril yield

While the aril yield in 1994 from June to October were 21.70%, 52.56%, 52.70%, 56.88% and 58.43%, respectively, these values were 21.05%, 46.00%, 50.26%, 53.71% and 58.10%, respectively in 1995 (Fig. 10). As can be seen from Fig. 10, as fruits got more mature, aril yield increased. While the increment in June was fast, it slowed down in other months. About half of the total fruit weight during many stages of fruit development consisted of the aril. Similar findings were also reported by Shulman *et al*. (1984). Increment in aril yield was higher than the increment in skin. It was assumed that increment in aril yield occurred due to fruit maturation.

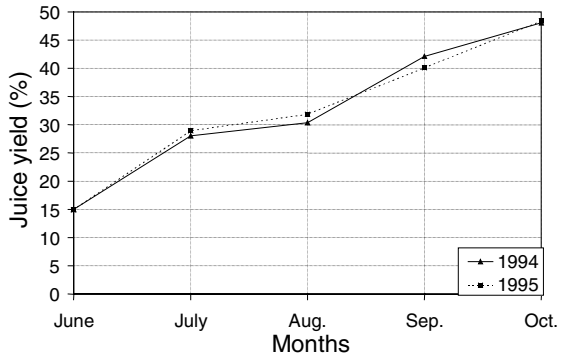

Fig. 9. Variation in juice yield during fruit growing period.

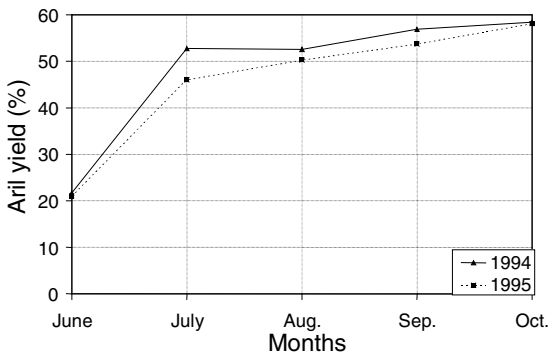

Fig. 10. Variation in aril yield during fruit growing period.

100-aril weight

While the average 100-aril weight in 1994 from June to October were 1.10 g, 7.53 g, 11.49 g, 20.67

g and 31.52 g, respectively, these values were 1.07 g, 6.78 g, 12.13 g, 18.54 g and 22.89 g, respectively in 1995 (Fig. 11). As can be seen in Fig. 11, increment in 100-aril weights occurred in accordance with fruit development and increment in aril size. No comparison was made since there was no literature available on this subject.

Soluble solid contents

While percentages of soluble solid contents in 1994 from June to October were 6.74%, 9.37% 10.90%, 12.64% and 15.94%, respectively, these values were 6.72%, 8.52%, 9.38%, 12.15% and 15.88%, respectively in 1995 (Fig. 12). Soluble solid content steadily increased during fruit development period as can be seen in Fig. 12. The increment was quite high especially in September and October when fruits were about to harvest. Similarly, it was reported that in Israel's conditions soluble solid content of Wonderful cultivar steadily increased until the second half of September. In another study, soluble solid content increased gradually during fruit development and reached 11-14% and 13-14% in mid-August for Mule's Head and Wonderful cultivars respectively. Afterwards these values reached 14-15% for Mule's Head cultivar and 15-16% for Wonderful cultivar at the end of September. Increment in soluble solid content could be explained by the increment in sugar content (glucose and fructose) of arils as a consequence of fruit development and maturation, as was reported by Shulman *et al*. (1984).

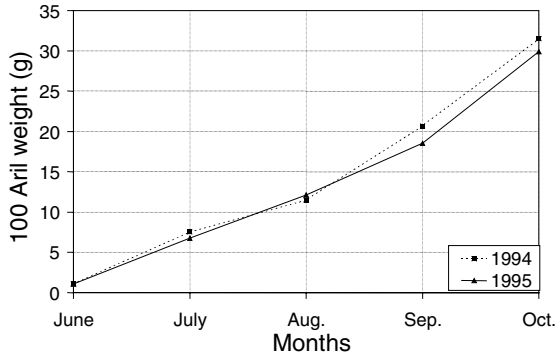

Fig. 11. Variation in 100-aril weight during fruit growing period.

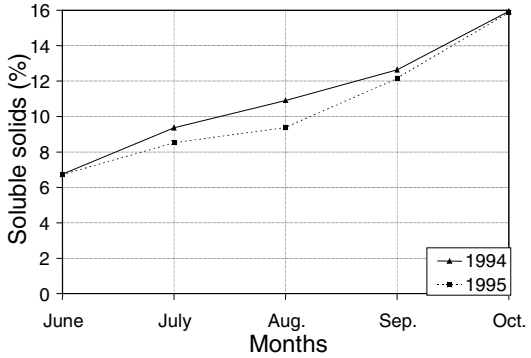

Fig. 12. Variation in soluble solid contents during growing period.

Juice pH

While juice pH in 1994 from June to October were 4.30, 2.40, 2.81, 2.90 and 3.18, respectively, these values were 4.40, 2.43, 2.82, 2.86 and 2.95, respectively in 1995 (Fig. 13). As can be seen from Fig. 13, while the juice pH was quite high at the beginning, it rapidly decreased in July. A slight increment in juice pH was observed in August, September and October, due to fruit maturation. These results are in agreement with Ben-Arie *et al.* (1984) and Kumar and Purohit (1989).

Titratable acidity

Percentages of titratable acid contents were taken from June to October in the years of 1994 and 1995. While percentage titratable acid contents in 1994 from June to October were 0.67%, 2.09%, 2.89%, 2.60% and 1.71%, respectively, these values were 0.67%, 2.58%, 2.94%, 2.56% and 1.91%, respectively in 1995 (Fig. 14). While titratable acidity was low at the beginning of both years, it was increased in July then decreased in other months due to maturation (Fig. 14). Shulman *et al*. (1984) also reported similar results in their study. In another study conducted with Wonderful cultivar, while the titratable acidity gradually decreased, the soluble solid content increased until the second half of September and then both titratable acidity and soluble solid content became stable (Ben-Arie *et al.*, 1984). Chace *et al.* (1981) stated that titratable acid content of 1.8% and soluble solid content of 17% could be used as the signs of maturation on some pomegranate cultivars grown in California. These results are in accordance with the findings of this present study. Decrement in titratable acidity can be used as a standard criteria to decide on maturation like increment in soluble solid content.

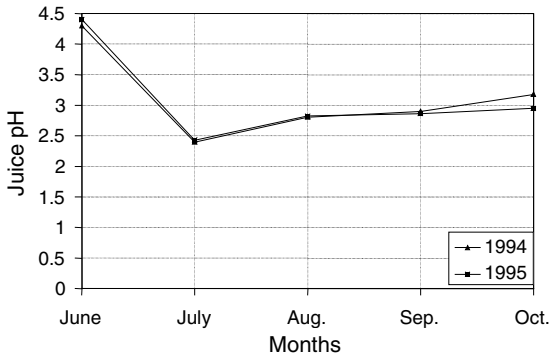

Fig. 13. Variation in juice pH during fruit growing period.

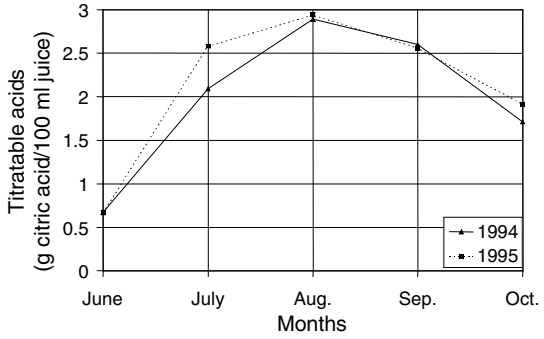

Fig. 14. Variation in titratable acids during fruit growing period.

Conclusions

A single sigmoid curve was obtained for fruit growing. In Hicaznar cultivar, 77.68-86.20% of total flowers on examined trees were A type flowers, and 13.80-22.32% were B type flowers. The fruit setting of total flowers was 7.59-16.07% and 44.0-71.99% in B type flowers.

While fruit diameter, length, volume, weight, 100-aril weight, juice and aril yield, pH, total soluble solid content showed a regular increment, titratable acidity and percentage skin amount had a decrease from first fruit setting to maturity.

Results showed that there was a correlation between physical and chemical changes occurred during fruit development and optimal harvesting time. Especially correlation between total soluble solid content and titratable acidity can be used in practice to determine optimal harvesting time.

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