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Determination of Fruit Growth in Some Apple Varieties

Ersin ATAY^a, Lütfi PIRLAK^b, Ayşe Nilgün ATAY^a

^aEğirdir Horticultural Research Institute, 32500, Isparta, TURKEY

^bSelçuk University, Faculty of Agriculture, Department of Horticulture, 42030, Konya, TURKEY

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Corresponding author: Ersin ATAY, e-mail: atayersin@yahoo.com, Tel: +90(246) 313 24 20

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ABSTRACT

This study was carried out in order to examine the fruit development in some apple varieties which are grafted on MM 106 rootstock and reach the harvesting maturity in various periods under Isparta (Eğirdir) conditions. Changes in diameter of the fruits were regularly measured, beginning from the time when they reached about 1 cm diameter size until the harvesting time so that we could create fruit growth curves in Jersey mac, Galaxy Gala and Braeburn apple varieties that are grafted on MM 106 rootstock. All varieties grew with a regular single sigmoid curve from fruit set time to harvest. During grow and development periods average fruit weight, soluble solids content, pH value of the fruit juice increased, and fruit firmness, titratable acidity decreased. Moreover, it was found out that the values L and b decreased while the value a increased during harvest times of the varieties when compared to the first samples taken right after the color broken ($P < 0.01$ for Braeburn and $P > 0.05$ for other varieties).

Keywords: Apple varieties; Growth curves; Fruit growth

Bazı Elma Çeşitlerinde Meyve Gelişiminin Belirlenmesi

ESER BİLGİSİ

Araştırma Makalesi — Bitkisel Üretim

Sorumlu Yazar: Ersin ATAY, e-posta: atayersin@yahoo.com, Tel: +90(246) 313 24 20

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ÖZET

Bu çalışma, Isparta (Eğirdir) koşullarında MM 106 anacı üzerine aşı ve farklı tarihlerde hasat olgunluğuna ulaşan bazı elma çeşitlerinde meyve gelişiminin incelenmesi amacıyla yapılmıştır. MM 106 anacı üzerine aşı Jersey mac, Galaxy Gala ve Braeburn elma çeşitlerinde meyve büyüme eğrilerinin oluşturulması için çap değişimleri meyvelerin yaklaşık 1 cm çap değerine ulaştığı tarihten hasat tarihine kadar düzenli olarak ölçülmüştür. Elde edilen sonuçlara göre, tüm çeşitlerde meyve tutumundan hasada kadar meyvelerin sürekli olarak tek sigmoid eğri oluşturacak şekilde büyüdükleri belirlenmiştir. Meyvelerin büyüme ve gelişimi sırasında ortalama meyve ağırlığı, suda çözünebilir toplam kuru madde miktarı ve meyve suyunun pH değerinde artış, meyve eti sertliği ve titre edilebilir asitlikte ise azalma olduğu tespit edilmiştir ($P < 0.01$). Meyvelere renk düşümünden sonra alınan ilk örneklerle nazaran, çeşitlerin hasat tarihlerinde L ve b değerlerinin azaldığı, a değerlerinin ise arttığı tespit edilmiştir (Braeburn için $P < 0.01$ ve diğer çeşitler için $P > 0.05$).

Anahtar sözcükler: Elma çeşitleri; Büyüme eğrileri; Meyve gelişimi

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1. Introduction

Growth is described as an irreversible increase in weight and volume. The same meaning is also true for the cellular level (Kocaçalışkan 2006). Parameters such as elongation, enlargement and thickening of the organs and cells of the plants in a

certain period of time, increase in number of plants and increase in weight of plants in both dry and wet forms are used in measuring the growth (Eriş 1990).

In most of the drupe fruits, as well as in some of the fruits like berries, growth of fruits shows a double sigmoid curve from pollination to the

harvesting time. However peach, apricot, sour cherry, sweet cherry and plum (drupe fruits) form a dual sigmoid curve whereas strawberry (berry fruits), apple and pear (pome fruits) form a single sigmoid curve (Miller et al 1987; Westwood 1995).

Genetic factors (variety, rootstock, age, biennial bearing, the position of the flower on spur etc.), cultural factors (pruning, defending against diseases and pests, thinning, irrigation and nutrition, exogenous hormone applications etc.) and environmental factors (temperature, light, soil, moisture, wind and gases etc.) affect the sizes of apples (Lakso et al 1995; Rom 1996; Stern & Flaishman 2004).

Development, also stating the meaning of growth, is a word explaining differentiation, organizing and advancing towards complexity (Kocaçalışkan 2006).

Understanding fruit development helps also understanding the use of fertilizers, pruning, growth regulators, fruit thinning and size prediction (Westwood 1995). For many practical reasons, it is desirable to know the growth progress of apple fruit under orchard conditions in real time. While on the one hand growers may better fine-tune management practices, on the other hand, the ability to forecast average fruit weight at harvest is of great value for marketers (Costa et al 2004). In this study, development of Jersey mac, Galaxy Gala and Braeburn varieties, which mature in various times and grafted on MM 106 rootstock in Eğirdir, were examined.

2. Materials and Methods

2.1. The site and the plant materials

This study was carried out over 2 consecutive years (2006-2007) in Eğirdir Horticultural Research Institute in Isparta, Turkey (latitude 37° 49' N – longitude 30° 52' W – altitude 940 m). Climate and soil properties of the location are indicated in Table 1 and Table 2 respectively.

Experiment were carried out on adult trees (7-8 years old in 2006) of the three apple varieties (Jersey mac, Galaxy Gala, and Braeburn), planted with 4 m × 3 m distances and grafted onto MM 106 rootstock. Trees were trained to central leader system and they were fertilized with mineral nutrients together with drip irrigation water at regular intervals in the vegetation period. The soil was fertilized with ammonium nitrate (400 g/tree,

440 g/tree in 2006 and 2007 respectively), monoammonium phosphate (400 g/tree, 440 g/tree in 2006 and 2007 respectively) and potassium nitrate (800 g/tree, 880 g/tree in 2006, and 2007 respectively).

Table 1-Mean monthly climate data of Eğirdir, 2006-2007 (Anonymous 2008)

Çizelge 1-Eğirdir'in 2006 ve 2007 yıllarına ait aylık ortalama iklim verileri (Anonim 2008)

MF	Temp., °C		RH, %		ST, °C	
	2006	2007	2006	2007	2006	2007
Year						
March	6.8	7.0	70.2	65.1	7.8	8.2
April	12.2	9.7	61.2	54.9	13.1	11.0
May	16.0	17.7	58.9	55.6	16.5	17.8
June	21.5	21.9	53.7	51.6	22.8	22.6
July	23.6	24.3	53.4	43.0	26.4	26.0
Aug.	25.3	24.2	53.2	51.4	27.8	26.9
Sep.	19.0	18.7	62.1	50.4	23.6	23.3
Oct.	13.6	14.0	73.5	66.0	17.8	18.5

MF = Meteorological factors, RH = Relative humidity, ST=Soil temperature (50 cm depth)

Table 2-The soil properties of the research area (0-30 cm)

Çizelge 2-Deneme alanının toprak özellikleri

pH (1:2.5)	7.91
Lime, %	6.15
Salinity, mS cm ⁻¹	0.17
Sand, %	38
Clay, %	18
Silt, %	44
Organic matter, %	1.9

2.2. The phenological observations

Bud swelling, bud burst, first bloom, full bloom, end of bloom, and harvesting times of the fruits were determined.

2.3. The fruit growth curves

The diameter values of the fruits were examined in order to form growth curves. Beginning from the date when the fruits reached about 1 cm diameter till the harvesting time, they were measured in mm value twice a week in 2006 and once a week in 2007 by means of a digital caliper in the vertical large equatorial part which combined the stalk cavity and flower cavity. For this reason, a tree for each variety was appointed and 16 flower cluster from various directions were signed on each tree. After fruit set, only king fruit was left behind and

the other fruits in the cluster were thinned with hand.

2.4. Some chemical and physical changes during the growth and development of fruits

Two trees from each variety were used. A total of eight fruits were taken randomly from four directions of trees (north-south-east-west). Average fruit weight and the skin color were measured beginning from June drop period to the harvesting time (measurement started right after the fruits were color broken). The analyses of fruit firmness, soluble solids content (SSC), titratable acidity (TA) and pH measurement were made. Titratable acidity and pH analyses were made only in 2006, while the measurements of fruit skin color were made only in 2007. The analyses were carried out once in two weeks until a month before the expected harvesting time, however after that time they were done once a week. It was noticed that sample taking dates except harvesting times were same in both experimental years and that the average values of both years were used. Sample taking dates are given in Table 3. In order to determine the average fruit

weight, the samples were weighted after every harvesting one by one. The skin colors of the fruits were found out by using Minolta CR-300 model color device. Firmness was measured using hand penetrometer with 11 mm probe. Color and firmness measurements were done through two different areas of the equatorial part of the fruits in a way that forms an angle of 180° between them. The mean of the two measurements was taken as the mean of a fruit. The measurements of fruit firmness got started to make beginning from the date when pressure scale was able to be applied. The rates of SSC were measured by refractometer, and TA by titration with 0.1 N NaOH and expressed in percent of malic acid per 100 ml of juice, and pH values were measured with a digital pH meter in three parallel ways.

2.5. Statistical analysis

The regression equations of the obtained data were analyzed by using the “SAS 9.0” statistical computer package. Analyses of regression were performed using least squares method. Linear and quadratic model was used in the analyses.

Table 3-Sampling dates

Çizelge 3-Örnek alma tarihleri

Date	Variety	Date	Variety
19.06.2006	Jerseymac	19.06.2007	Jerseymac
29.06.2006	Jerseymac, Galaxy Gala, Braeburn	29.06.2007	Jerseymac, Galaxy Gala, Braeburn
13.07.2006	Jerseymac, Galaxy Gala, Braeburn	13.07.2007	Jerseymac, Galaxy Gala, Braeburn
21.07.2006	Jerseymac	21.07.2007	Jerseymac
27.07.2006	Jerseymac, Galaxy Gala, Braeburn	27.07.2007	Jerseymac, Galaxy Gala, Braeburn
03.08.2006	Jerseymac (The last harvest)	03.08.2007	Jerseymac (The last harvest)
10.08.2006	Galaxy Gala, Braeburn	10.08.2007	Galaxy Gala, Braeburn
17.08.2006	Galaxy Gala	17.08.2007	Galaxy Gala
24.08.2006	Galaxy Gala, Braeburn	24.08.2007	Galaxy Gala, Braeburn
28.08.2006	Galaxy Gala (The last harvest)	31.08.2007	Galaxy Gala (The last harvest)
07.09.2006	Braeburn	07.09.2007	Braeburn
21.09.2006	Braeburn	21.09.2007	Braeburn
28.09.2006	Braeburn	28.09.2007	Braeburn
05.10.2006	Braeburn	05.10.2007	Braeburn
12.10.2006	Braeburn	12.10.2007	Braeburn
17.10.2006	Braeburn (The last harvest)	22.10.2007	Braeburn (The last harvest)

3. Results and Discussion

3.1. Phenological observations

In Eğirdir in years 2006 and 2007, the phenologic observation results of the samples used in the experiment as well as the number of days, a time period beginning from full bloom to harvesting, are given in Table 4. In both experimental years the periods of bud swelling, bud burst, first bloom and

full bloom were coincided with each other in Jerseymac and Braeburn varieties. On the other hand, in Galaxy Gala variety, these periods took part 1-4 days later. However, at the end of bloom it was observed that they occurred in almost the same periods for all varieties. In Jerseymac and Galaxy Gala varieties, harvesting expanded to a longer time period because all fruits on the trees did not mature at the same time. The phenologic periods of all the

varieties occurred later in 2007 than they did in 2006. Also DAFB occurred in a shorter time interval in 2007 than in 2006. In Jersey mac and Galaxy Gala varieties, harvesting expanded to a longer time period because all fruits on the trees did not mature at the same time. Burak et al (1994) suggested that for Jersey mac variety, grafted to seedling rootstock, in Yalova (Turkey) conditions, the dates of bud swelling, bud burst, first bloom, full bloom, and end of bloom for the years 1990-1994 were respectively 15/3-29/3-16/4-19/4-30/4. Öztürk (2005) suggested that for Royal Gala variety, grafted to MM 106 rootstock, in Eğirdir (Turkey) conditions, the dates of bud swelling, bud burst, first bloom, full bloom, and end of bloom for 2004 were respectively 21/3-28/3-17/4-26/4-4/5 while these dates were respectively 17/3-29/3-16/4-24/4-4/5. Rom & Allen (1999) suggested that in Arkansas (USA) the date of full bloom for Gala

Supreme variety, grafted to M 9 rootstock was 6/4 and this date was 10/4 for Braeburn. The time of full bloom and blooming duration change according to varieties, species, ecology and years. Parallel latitudes, sea level, vectors, hot and cold winds, rootstock and to some extent maintenance processes affect blooming (Karaçalı 2004). In apple varieties, blooming observed at different times is an expected result (Kaynaş 1987).

3.2. Fruit growth curves

Fruit diameters were regularly measured from the date of fruit set to the harvesting time in order to find out the physical growing dynamics of the fruits in some apple varieties involved in the experiment. The changes in the fruit diameters of Jersey mac, Galaxy Gala and Braeburn apple varieties are given in Figure 1.

Table 4-The phenologic observation results of the varieties used in the experiment

Çizelge 4-Denemede yer alan çeşitlerin fenolojik gözlemleri

Variety	Jersey mac		Galaxy Gala		Braeburn	
	2006	2007	2006	2007	2006	2007
Year						
Bud swelling	17/3	21/3	19/3	24/3	17/3	21/3
Bud burst	30/3	3/4	1/4	5/4	30/3	3/4
First bloom	16/4	20/4	18/4	24/4	16/4	20/4
Full bloom	20/4	28/4	22/4	1/5	20/4	28/4
End of bloom	3/5	5/5	2/5	6/5	2/5	5/5
Harvesting time	27/7 - 3/8	30/7 - 3/8	24/8 - 28/8	27/8 - 31/8	17/10	22/10
DAFB	98 -105	93 -96	124 - 128	118 - 122	180	177

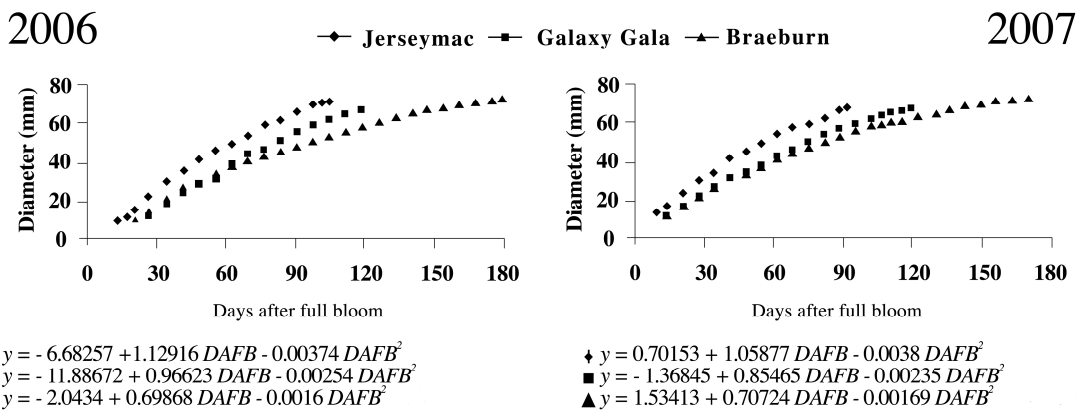


Figure 1-Time-dependent diameter change of the varieties from full bloom to harvest time in 2006 and 2007 ($R^2 = 0.99$, $P < 0.01$)

Şekil 1-Çeşitlerin 2006 ve 2007 yıllarında tam çiçeklenmeden hasada kadar olan dönemde zamana bağlı çap değişimi ($R^2 = 0.99$, $P < 0.01$)

Jerseymac variety, beginning to grow at an early period because of its being genetically early season, indicated higher diameter values than the other varieties during both years from the beginning of the growth period till the harvesting time. Galaxy Gala variety indicated smaller diameter values than Braeburn varieties till the first week of June during these two years, but it had higher diameter values than Braeburn variety till the harvesting time, because its cellular growth was genetically much more than the other one as from that date. Braeburn variety, maturing at the latest time, on the other hand grew fast in the period of cell division during both years, however in the period of cell expansion it went on growing more slowly than the other varieties. It was suggested that fruits in all varieties grew in a way to form a single sigmoid curve from the time of fruit set to their maturation. Various researchers suggested that the growth in apple fruits constituted a single sigmoid curve (Garriz et al 1993; Hirst & Flowers 2000). The results we obtained from the experiment are consistent with the studies conducted earlier.

3.3. Average fruit weight

The values of average fruit weight were found as 35.79 g (19/6) in Jerseymac, 38.87 g (29/6) in Galaxy Gala and 33.49 g (29/6) in Braeburn variety. As sampling dates moved along, the values of remaining fruit weight were measured on 13th July as 96.01 g, in Jerseymac, 64.27 g in Galaxy Gala and 47.56 g in Braeburn variety. During the harvesting times (given in Table 3) on the other hand, the values of fruit weights were stated as 135.71 g, Jerseymac, 150.14 g. in Galaxy Gala and 222.84 g in Braeburn variety (Figure 2). It was found that the weight values of the experimental samples increased in a linear manner throughout the sampling dates ($P < 0.01$).

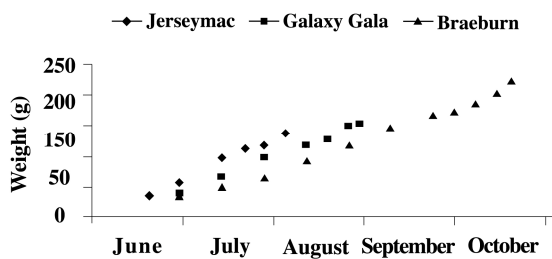


Figure 2-Time-dependent changes in weights from full bloom to harvest time

Şekil 2-Tam çiçeklenmeden hasada kadar zamana bağlı ağırlık değişimi

Similarly, Garriz et al (1993) suggested that the values of average fruit weight of Granny Smith apple variety, increased as the sampling dates moved along. Jerseymac had heavier fruits during the same sampling times (29th June, 13th July, and 27th July) since it is a summer variety. Galaxy Gala, maturing during the mid season, and Braeburn variety, a temporary one, respectively followed this. However, the varieties' being in direct proportion to the length of growth season in harvesting times, Braeburn variety produced heavier fruits and Galaxy Gala and Jerseymac respectively followed this. It is considered that this situation roots from the fact that as the temporariness in the maturing period of the varieties increase, all the cell division period and most of the cell growth period are completed and the first slow growing and rapid growing phases spread through a long time. As a matter of fact, it was reported that there was a linear relationship between the harvesting time and fruit weight, and that fruit weight in apples depend on cell number, size and the width of the gaps between the cells (Karaçalı 2004). The obtained results are consistent with the literature data.

3.4. Fruit firmness

As the measurements of fruit firmness were carried out in order to the date on which pressure scale could be applied to fruit flesh, sampling dates of the varieties showed great differences. In the first sampling dates, the values related to the fruit firmness were found as 11.46 kg (19/6) in Jerseymac, 11.80 kg (27/7) in Galaxy Gala and 12.01 kg (24/8) in Braeburn variety. As the sampling dates moved along, the values related to the decreasing firmness of fruit were stated as 7.22 kg on 21st July in Jerseymac, 10.4 kg on 10th August in Galaxy Gala and 10.79 kg on 21st September in Braeburn variety. During the harvesting times (given in Table 3) on the other hand, the values of fruit firmness were stated as 6.01 kg in Jerseymac, and 8.90 kg in Galaxy Gala and 8.60 kg in Braeburn variety (Figure 3). It was suggested that values related to the fruit firmness in all varieties of the experiment decrease with a linear speed and they dropped to the lowest levels in the harvesting time ($P < 0.01$). Respectively Galaxy Gala (8.90 kg) and Jerseymac (6.01 kg) followed Braeburn variety (8.60 kg), which had the highest firmness value during harvesting time. Ingle et al (2000) discovered that in the USA conditions of

York Imperial apple variety decreased as the sampling dates moved along.

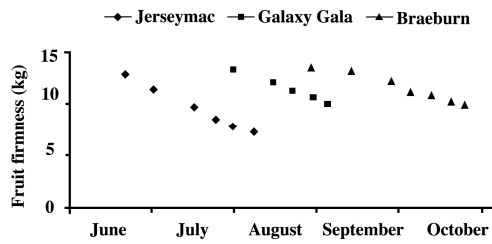


Figure 3-Changes in the firmness of fruit during the development of fruits

Şekil 3-Meyvelerin gelişimi sırasında meydana gelen meyve eti sertliği değişimleri

3.5. Fruit skin color

Color values were found out on the first sampling dates as $L=55.09$, $a=0.04$, $b=20.64$ (13/7) in Jerseymac, $L=55.89$, $a=8.68$, $b=18.94$ (10/8) in Galaxy Gala and $L=53.60$, $a=4.46$, $b=19.85$ (21/9) in Braeburn variety. In the harvesting times (Table 3), on the other hand, color values of the fruits were stated as $L=44.90$, $a=14.23$, $b=13.99$ in Jerseymac, $L=48.81$, $a=24.47$, $b=15.01$ in Galaxy Gala and $L=41.76$, $a=20.25$, $b=13.89$ in Braeburn variety (Figure 4). It was determined that L and b values of the varieties decreased in harvesting times while a values increased when compared with the first samples taken right after they were skin colored. Together with some differences based on the varieties, it was also suggested that all the values between the dates on which first analyses were carried out and harvesting times didn't continue linearly, that is there were some descents and ascents ($P < 0.01$ for Braeburn and $P > 0.05$ the other varieties). The fact that skin color changes in apple fruits before and after harvesting didn't continue linearly was discovered by various researchers (Eren 2002; Rocha & Morais 2003).

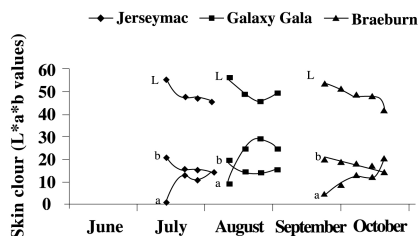


Figure 4-Color changes during the development of fruits

Şekil 4-Meyvelerin gelişimi sırasında meydana gelen renk değişimleri

3.6. Soluble solids content (SSC)

SSC in the research were found out on the first sampling dates as 8.13 % (19/6) in Jerseymac, 8.31 % (29/6) in Galaxy Gala and 7.04 % (29/6) in Braeburn variety. As the sampling dates moved along, increasing values of SSC were stated on the date of 13th July as 10.18 % in Jerseymac, as 9.63 % in Galaxy Gala and as 9.25 % Braeburn variety. In the harvesting times on the other hand, SSC were stated as 12.36 % in Jerseymac, 13.19 % in Galaxy Gala and 13.75 % Braeburn variety. Braeburn variety, with relatively low SSC on the same sampling dates (29th June, 13th July, 27th July), reached higher values than the other varieties in harvesting times (Figure 5). In Jerseymac, increasing speed of the SSC, ascended linearly throughout the sampling dates and it reached the highest level in the harvesting time ($P < 0.01$). The increase of the SSC in Galaxy Gala on the other hand, descended in the measurements done on the dates of 13th July and 27th July, and after these dates the values remained almost at the same level, but they reached the highest level in the harvesting time. In Braeburn variety, the SSC, which increased with a slow acceleration, reduced their increasing speed in the measurements done on the dates of 24th August, 7th September and 21st September, but they increased almost in the same speed beginning from 28th September to the harvesting time and they reached the highest level in the harvesting time. Ingle et al (2000) suggested that in USA conditions, as the sampling dates moved along in York Imperial apple variety, SSC increased. Similarly, Özdemir et al (2002) suggested that in Niğde conditions, as the sampling dates moved along in Red Chief and Super Chief apple varieties, SSC increased. The obtained results are consistent with the literature data. The increase or slow down of SSC on some sampling dates is thought to be resulted from the changes in water rates within cells.

3.7. Flesh pH

Flesh pH in the research was found out on the first sampling dates as 3.04 (19/6) in Jerseymac, 3.39 (29/6) in Galaxy Gala and 2.83 (29/6) in Braeburn variety. As the sampling dates moved along, the increasing pH values of fruit juice were observed on 13th July as 3.09 in Jerseymac, 3.41 in Galaxy Gala and 2.91 in Braeburn variety. Galaxy Gala was the variety which had the highest pH values in

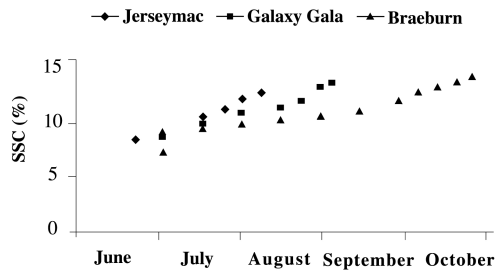


Figure 5-Changes SSC during the development of fruits

Şekil 5-Meyvelerin gelişimi sırasında meydana gelen SÇKM değişimleri

harvesting times and on the same sampling dates (29th June, 13th July and 27th July) (Figure 6). It was suggested that the increasing speed of pH values in Jersey mac, measured on 13th July and 21st July, together with the Galaxy Gala, measured on 27th July, 10th August and 17th August, slowed down. However, the increasing speed of pH values did not slow down in any certain period for Braeburn. Moreover, its pH values increased almost at the same speed ($P < 0.01$). Eren (2002) suggested that as the sampling dates moved along in Golden Delicious, Starking Delicious, Idared, Imperatore and Granny Smith apple varieties, the pH values of fruit juice increased. The obtained results are consistent with the literature data.

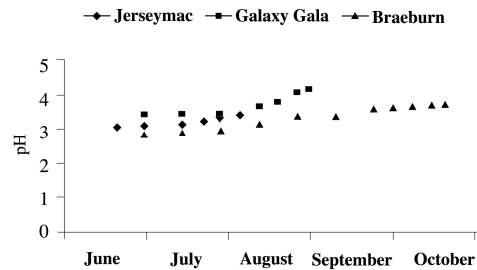


Figure 6-pH changes during the development of fruits

Şekil 6-Meyvelerin gelişimi sırasında meydana gelen pH değişimleri

3.8. Titratable acidity (TA)

TA in the research was found as 1.44 % (19/6) in Jersey mac, 0.59 % (29/6) in Galaxy Gala and 1.26 % (29/6) in Braeburn variety on the first sampling dates. As the sampling dates went by, decreasing TA amounts were noticed on the date of 13th July as 0.82 % in Jersey mac, 0.58 % in Galaxy Gala and 1.21 % in Braeburn variety. TA in the measurements made during the harvesting time was stated as 0.55 % in Jersey mac, 0.38 % in Galaxy

Gala and 0.66 % in Braeburn variety. Braeburn variety with the highest TA amounts on the same sampling dates (29th June, 13th July and 27th July) was followed respectively by Jersey mac and Galaxy Gala varieties (Figure 7).

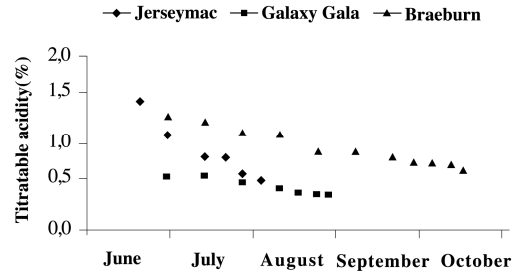


Figure 7-Changes in titratable acidity (TA) during the development of fruits

Şekil 7-Meyvelerin gelişimi sırasında meydana gelen titre edilebilir asit miktarı değişimleri

It was found that the decreasing speed of TA slowed down a bit for Jersey mac on the dates of 29th June and 13th July. However, it was suggested that for Galaxy Gala and Braeburn varieties decrease in a linear speed throughout the sampling dates ($P < 0.01$). Kaya (1995) suggested that in apples, Pırlak and Güteryüz (1997) in cornelian cherries, Kurnaz (1989) in peaches and nectarines titratable acid amounts decreased in parallel to the sampling dates. The obtained results are consistent with the literature results.

4. Conclusion

In apple cultivation, it is necessary to consider both efficiency and quality at the same time. Therefore, the fruit quality parameters (diameter, average fruit weight, fruit firmness, soluble solids content, pH, titratable acidity etc.) must be well understood. This study was conducted with the aim of evaluating the fruit development and determining fruit quality in some apple varieties. Likewise, the most important subject is the fruit quality in commercial apple production.

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