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Characterization of hybrid pomegranate genotypes based on sunburn and cracking traits related to maturation time

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Summary

Sunburn and cracking are the most significant physiological problems in the region where pomegranate is grown. These problems cause yield loss of up to 50 % in some years. It is known that environmental and genetic factors have an effect on sunburn and cracking on pomegranates. In this study, the resistance of hybrid pomegranate genotypes against sunburn and cracking as well as their maturation time was determined. In addition, the relation between earliness and lateness and resistance against sunburn and cracking was investigated. The study was conducted in Western Mediterranean Agricultural Research Institute and 69 pomegranate genotypes were used as material. In the study, the break of wood buds, emergence of first flower buds, first blossoming, maximum blossoming, last blossoming, ripening, yellowing of leaves, and leaves' falling were detected with phenological observation. Moreover, upon harvest, sunburn and cracking ratios of each genotype were determined. Finally, it was found out that late types are more sensitive against sunburn and cracking compared to the types ripening in early and middle season.

Keywords: cracking, earliness, pomegranate, sunburn.

Introduction

Sunburn and cracking in pomegranates are common physiological disorders. Pomegranate damage due to sunburn and cracking may account for losses of up to 40-50 % of the total harvest in pomegranate production areas (Blumenfeld et al., 2000; Yazici and Kaynak, 2009a). The color of peels change from brown to black in pomegranate fruits when sunburn occurred. Also, water content depletion and drying occurs in fruit and this leads to less appeal in marketing and economic losses (Yazici and Kaynak, 2009b).

Sunburn and cracking in pomegranates generally start around ripening period and as the ripening goes on, cracking and sunburn ratios increase. It is a well-known fact that some fruits crack during the latter period of growth (Yazici and Kaynak, 2009b). Cracking and sunburn in pomegranate fruits may emerge separately and it is known that the ratio of cracking increase on fruits that are subjected to sunburn (Shulman et al., 1984).

The damage of sun on fruits increases in semi-arid and arid region. It has been reported that under these conditions, fruit and leaves temperatures go up to high levels and therefore sunburn occurs (Drake et al., 1991; Parchomlochuk and Meheriuk, 1996; Arndt, 1992; Schrader et al., 2002; Yazici and KAYNAK, 2006).

Sunburn in pomegranates is mostly caused by heat and solar radiation (Finkel and Holbrook, 2000; Desikan et al., 2001; Renquist et al., 1989). Cracking in pomegranates is caused by climatic factors such as irregular and over irritation during ripening period, rain during harvest period (Meshram et al., 2010; Mars, 2000), late harvest (Shulman et al., 1984; Hoda and Hoda, 2013), physical harms on peel and sunburn (Shulman et al., 1984), imbalance in plant nutrition (El-Kassas et al., 1992; Abd El-Rhman, 2010), temperature difference between day and night (Abd El-Rhman, 2010), warm winds blowing after an arid period, instant decrease of the temperature (Plamenac, 1972) and late harvest and genetic factors (Josan et al., 1979). It was reported that late harvest and genetic factors are the most significant factors (Yilmaz and Özgüven, 2009).

Resistance to fruit cracking: this is strongly affected by climate and orchard management, particularly water regime and irrigation scheduling. Some differences are observed between cultivars (Mars and Marrakchi, 1998).

It was noted that the resistance against cracking and sunburn of pomegranate types is also different (Kumar and Prohit, 1989; Abubakar et al., 2013). Precautions against cracking in pomegranates are taken and the most significant precaution is to use the resistant types that ripe early (Josan et al., 1979).

Ripening period of late pomegranate types in Turkey generally corresponds to the period when arid season is over and rain starts. During this period, the difference between day and night temperatures increase and relative humidity of the weather decreases. In this period, the pomegranate fruits are almost full ripe. The peel is tense in this period because of the aril formation. Following any long drought, the peel cannot resist the increasing internal pressure and split apart because of the reasons like irritation, rain or instant decrease of temperatures. Similarly, the peel of middle sized pomegranate types in subtropical climate conditions are sensitive to sunburn and damages occur on the peel. The damages starting at this period increase as the ripening goes on and decrease the appeal of the fruits. These reasons lead early pomegranate types which are not exposed to the climatic conditions to be more resistant to cracking and sunburn.

Ripening periods, sunburn, cracking resistance and sensitivity of 69 pomegranate genotypes that are hybrid and planted in the same trial parcel were identified in this study based on the idea that early pomegranate types that are not subjected to late period climate conditions are more resistant against sunburn and cracking. Moreover, it was shown if there is a relation between ripening periods and resistance and sensitivity.

Material and methods

This study was carried out at the West Mediterranean Agricultural Institute between the years of 2009-2010 in Antalya. The climate of the area is typically sub-temperate. The annual rainfall ranges between 800 to 1300 mm. The orchard soil was sandy in texture with pH 8.10, 397 µhos/cm electrical conductivity (EC) and 2.85 % organic carbon content. Uniform cultural practices were made and drip irrigation system was used in all plants grown under normal conventional production methods. In conventional production: ammonium sulphate (21 % N) was applied during the end of February, beginning of June, and beginning of August; triple super phosphate (43-45 % P_2O_5) was applied in November and potassium sulphate (50 % K_2SO_4) was applied in November. Soil moisture was provided regularly during the months of February-March and September-October from

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the break of wood buds to the ripening of fruits in the experimental plots. The irrigation was ended 15 days before harvest. Temperature, rainfall and solar radiation values of the experiment area were measured by the climate station (Mikro Metos Ag.).

Plant material

From the Hicaznar × Seedless IV (07N15), Hicaznar × Seedless VI (33N26), Hicaznar × Hicaznar (H×H), Hicazanar × Fellahyemez (H×F), Hicaznar × Ernar (H×E) crosses and Hicaznar open-pollination (OPH), which were done in 1998, 69 individual plants were preselected in 2006 and were used as research material. These genotypes exist on trial parcels which have same climate and soil conditions as well as same cultural applications are conducted. The analyses were conducted on 6 trees which were 7 years old and 414 trees were used in total. Six plants from each mentioned 69 genotypes, in total 414 plants, were evaluated at their bearing stage (2009-2010) for the following traits: the break of wood buds, emergence of first flower buds, first blossoming, maximum blossoming, last blossoming, ripening, yellowing of leaves, leaves' falling and cracking and sunburn ratios on fruits.

Phenological observations

The break of wood buds: the date when red-brown leaves emerge from wood buds among the brown flakes; Emergence of first flower buds: the date when blossom buds are seen on the ends of young shoots; First blossoming: the date when first blossoms emerge; Maximum blossoming: the date when blossomed flowers are seen most; Last blossoming: the date when last period blossoms completely emerge; Ripening: the date when the color of peel turns into red from yellow-green and calyx parts separate from each other; Leaves' growing pale: the date when more than half of the leaves grows pale; Leaves' falling: the date when 90 % of leaves fall (ONUR and TIBET, 1993).

Determination of fruit yield, sunburn and cracking

Sunburn rates of the fruit: at harvest time the fruit yield (kg) per tree was calculated, also the percentage of fruit cracking/tree at harvest time. Cracking rates of the fruit: at harvest time the fruit yield (kg) per tree was calculated, also the percentage of fruit cracking/tree at harvest time. Harvesting date of the individuals were classified as 'early' (13-23 Sept.), 'medium' (24 Sept.-04 Oct.), and 'late' (05-23 Oct.) based on methods described by ONUR and TIBET (1993).

Sunburn: The sunburn causes brownness and darkness in the fruit skin of pomegranates. In this study, the fruits that were browned and darkened during the ripening period were regarded as burned fruits (Fig. 1).

Cracking: Fruit cracking is basically caused by a rupture of skin because of internal developmental pressure. In this study, fruits that have a cracking and splitting skin were regarded as cracked fruits (Fig. 2).

Data analyses

Principal Component Analysis (Factor Analysis): Factor and cluster analysis were carried out according to BACKHAUS (1996). The software SPSS (20.0) was used to differentiate the given material due to the obtained characteristics.

Fig. 1: Sunburn in pomegranate fruits (original)

Fig. 2: Cracking in pomegranate fruits (original)

Box Plot: Obtained data are represented in Boxplot to display the present variation. If a different number of genotypes are present in investigated groups box plot is the best way to depict groups of numerical data through their quartiles. In Box plots lines extending vertically from the boxes (*whiskers*) indicating variability outside the upper and lower quartiles. Because of different number of genotypes in each group the middle line in the box plot represents the median, the underline the 25% quartile, the upper line the 75% quartile. Outliers are plotted as individual points. Box plots display variation in samples of a statistical population without making any assumptions of the underlying statistical distribution (McGill et al., 1978). The Box-Plots were created using SPSS (20.0) statistical package.

Results

Sixty-nine individual genotypes from different crosses were compared with each other regarding maturation time, sunburn and cracking ratios. Important differences were also determined between individuals.

The results of phenological observation

Two years of phenological observation means of pomegranate genotypes between 2009 and 2010 is demonstrated in Tab. 1. The break of wood buds in pomegranate genotypes started earliest at the end of January and continued until the first week of March. Emergence of first flower buds started earliest in the mid of March and continued until the mid of May. First blossoming phase started in almost all of the genotypes at the end of April or first half of May and continued until the end of May. In some genotypes, first blossoming period was completed at the beginning of June.

Full blossoming phase started at second half of May and was completed in the mid of June. In terms of last blossoming, generally one-month difference was observed among the genotypes. Last blossoming of genotypes started earliest at the second half of June and continued until the end of July, or the beginning of August.

In terms of fruit ripeness, significant differences were identified among the genotypes. Ripening started earliest at the first half of September and continued until the end of October. It has been identified through the data obtained that 25 types were early genotypes, 20 genotypes ripened in middle season and 26 genotypes were of late type. In majority of genotypes, leaves grew pale in November and fell in December.

Sunburn and cracking ratios of pomegranate genotypes

Sunburn and cracking ratios of early genotypes (Tab. 2), genotypes ripening in the middle season (Tab. 3) and late genotypes (Tab. 4) are stated below. Looking at tables, sunburn ratio at early genotypes in 2009 is 14.37%; it is 31.06% at the genotypes ripening in the middle season and 36.40% at the late genotypes. Cracking was determined consecutively 8.08%, 17.63%, 34.84% at early, middle season and late genotypes.

Similarly, in 2010 the highest sunburn and cracking were determined at late genotypes, and least at early genotypes. Sunburn ratios (%) of 2010 were determined 14.23 %, 36.02 %, 39.40 % at early, middle season and late genotypes, respectively. Cracking ratios (%) were determined as 7.07 %, 21.44 %, and 32.27 %, respectively. In terms of yearly comparison, both sunburn and cracking were higher in 2010.

Principal Component Analysis

The pomegranate genotypes grouped in early season, middle season and late season genotypes could be clearly differentiated using Principal Component Analysis. Especially the early season genotypes were different from the other two pomegranate groups. Some genotypes in the middle season group were similar to the early season group while some genotypes tend to be placed next to the late season group. The first two principal components corresponds totally 84,83% to the total variation present in the investigated material (Fig. 3).

Box Plot

As can be seen in Fig. 4, large variation exists regarding cracking and sunburn characteristics among investigated pomegranate genotypes grouped in terms of their maturing time. The lowest cracking and sunburn values were determined in the early season group in both years while the highest cracking and sunburn values were detected in the late season group. Also the biggest variation regarding the mentioned characteristics is presented in the same group.

Discussion

It was observed in the study that there is 24-34 days difference regarding the break of wood buds among pomegranate genotypes. This difference was identified as 18-20 days at the indigenous pomegranate cultivars in the studies of Onur and Tibet (1993) and Onur (1988).

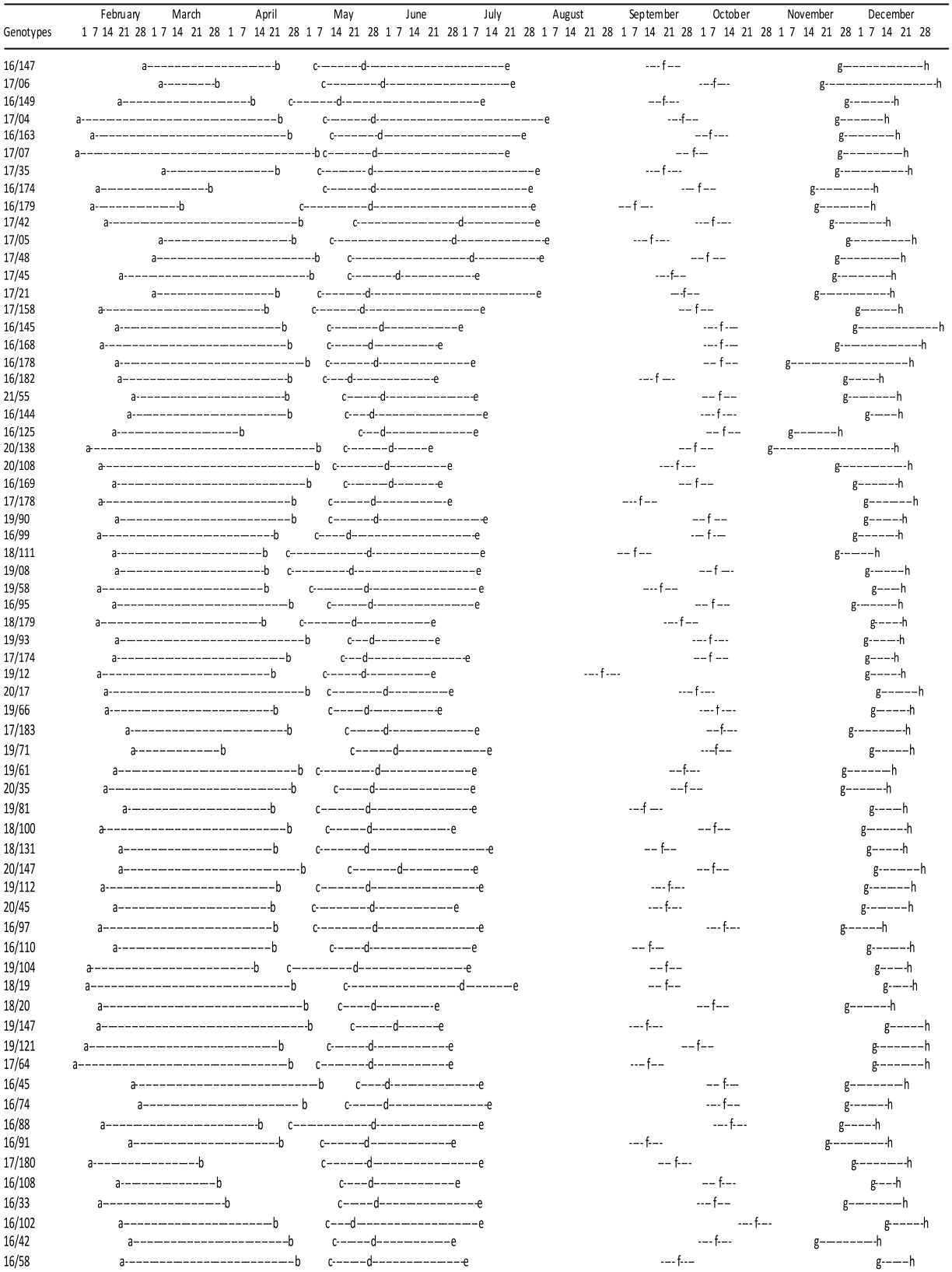
The whole blossoming period lasted 50-85 days at all evaluation parcels. Evreinoff (1953) found this period to be 50-70 days, Onur and Tibet (1993) 60-70 days, Onur et al. (1999) 70-80 days.

Normal flowering of pomegranate varieties occurs, in general, between March-April and July-August. It continues for up to 10-12 weeks or more depending on variety and geographical situation. The period of full bloom lasts about one month, and it was observed that flowering and fruit set occurs in about 3 or 4 distinct waves (Ben Arie et al., 1984; Hussein et al., 1994; El Sese, 1988).

Vegetative bud break and bloom of pomegranates in Oman begin at the end of March through April. The harvest of pomegranates in Oman takes place from July to September but peaks in August (Al-Yahya et al., 2009). In a study conducted in Turkmenistan, it was stated that early pomegranates ripen in September. In Iran, the pomegranates that ripen as of September are called early types, the ones that ripen as of October are called late types (Mohseni, 2009); it is stated that ripening time of Ashraf pomegranate is between September and October (Khodabakhshian et al., 2015). It is also stated that "Primosole", one of the types grown in Italy ripens on October 29 (Aquino et al., 2009). Wetzstein et al. (2011) said the ripening date of Wonderful pomegranate is October 11. It was noted that in California, mostly Wonderful type is commercially grown but as Granada ripens in August, it is more appealing to consumers and Foothill Early type ripens 1-2 weeks before Wonderful. In Spain, the harvest times of sweet types whose commercial value is high also differ as early, middle and late. It is evident that Mollar is a quality type grown in Spain (Manera et al., 2013); some other types ripen before Molar but their fruit quality is lower than Mollar. In a study conducted in Turkey (Polat et al., 2012); ripening time of the pomegranate cultivars varied between 19 September and 11 October. 'Çekirdeksiz' (19 Sep.) was the earliest and 'Kara Mehmet' was the latest (11 Oct.). Çekirdeksiz was mature about 10 to 15 days earlier than the other cultivars.

Hicaznar pomegranate cultivar which is mostly produced and exported in Turkey is a productive, quality, late season cultivar, and it ripens as of 15 October. Cracking at fruits is at a moderate level and it is a type which is very sensitive to sunburn. In this study some types which ripen one month before Hicaznar and are more resistant against cracking and sunburn were identified. Among the genotypes that were studied, ripening of fruits started generally around mid-September and were completed around mid-October with some types and at the end of October with other types.

Tab. 1: Phonological phases of pomegranate genotypes (data are means of 2009 and 2010).



a: the break of wood buds, **b:** the emergence of the first flower buds, **c:** first blossoming, **d:** maximum blossoming, **e:** last blossoming, **f:** ripening, **g:** yellowing of leaves, **h:** leaves' falling

Tab. 2: Fruit yield, sunburn and cracking amounts of early (13-23 Sept.) genotypes (kg/tree)

Early Genotypes	2009			2010		
	Fruit yield	Sunburn	Cracking	Fruit yield	Sunburn	Cracking
16/147	21.50	3.62	2.10	44.97	6.62	2.30
17/182	24.55	3.61	1.50	34.30	4.66	2.50
16/149	24.30	5.66	3.02	46.77	4.66	2.02
17/35	28.04	3.33	1.33	38.37	8.33	3.33
16/179	24.12	2.16	1.20	23.67	3.16	1.50
17/05	14.48	1.11	1.85	23.49	4.00	0.85
17/45	13.04	0.00	0.04	23.93	2.00	2.04
16/182	14.16	3.16	2.89	22.77	3.16	1.89
17/178	13.39	0.50	0.48	19.72	8.50	10.48
18/111	17.30	5.83	3.13	23.73	5.83	2.73
19/58	36.39	0.83	1.35	34.04	4.83	1.85
19/12	24.67	1.33	1.54	37.71	4.33	1.76
19/61	19.78	3.63	2.45	20.11	5.63	2.45
20/35	20.41	3.33	1.42	38.16	3.33	1.42
19/81	16.07	2.66	0.42	20.97	2.66	0.42
18/131	12.28	5.50	3.12	15.79	5.50	3.12
19/112	13.69	3.00	1.55	22.83	3.00	1.55
20/45	22.88	2.83	0.16	43.78	2.83	0.16
19/104	32.32	2.16	1.15	39.35	2.16	1.15
18/19	11.28	5.16	3.12	14.02	5.16	3.12
19/147	17.32	2.33	1.10	15.49	2.33	2.10
17/64	22.64	2.16	3.00	29.18	8.16	2.45
16/91	17.98	2.66	0.00	43.75	2.66	1.12
16/58	15.65	2.50	0.00	48.56	2.50	0.98
17/180	22.74	0.16	2.48	52.20	4.16	1.48
%	-	*14.37*	*8.08*	-	*14.23*	*7.07*
×	*20.04*	*2.88*	*1.62*	*30.97*	*4.41*	*2.19*
Max (×)	*36.39*	*5.83*	*3.13*	*52.20*	*8.50*	*10.48*
Min (×)	*11.28*	*0.16*	*0.00*	*14.02*	*2.00*	*0.16*
s	*6.37*	*1.55*	*1.07*	*11.82*	*1.94*	*1.91*

×: mean
s: Standard Deviation

Tab. 3: Fruit yield, sunburn and cracking amounts of middle season (24 Sept.-04 Oct.) genotypes (kg/tree)

Middle Season Genotypes	2009			2010		
	Fruit yield	Sunburn	Cracking	Fruit yield	Sunburn	Cracking
16/77	13.62	2.00	3.20	13.34	2.50	4.20
16/42	19.32	9.50	2.58	43.66	10.50	4.58
17/07	36.40	10.67	3.87	41.36	13.67	5.87
17/04	20.49	9.83	3.03	25.89	11.83	5.03
16/174	21.34	5.16	1.32	26.84	8.16	6.32
17/48	15.06	5.16	2.04	33.80	10.16	4.04
17/21	21.13	3.83	1.50	41.38	11.83	3.02
16/99	13.74	2.66	2.82	20.43	9.66	4.82
18/179	38.23	5.83	3.60	44.07	9.83	4.60
17/158	14.95	5.16	2.82	20.86	9.16	5.82
17/174	16.45	6.66	1.85	19.63	12.66	4.85
20/147	19.38	3.66	2.28	26.42	8.66	4.28
18/20	14.74	6.26	4.67	14.92	12.26	7.67
20/138	19.03	3.00	10.87	22.21	9.00	11.87
20/108	14.78	1.00	6.41	25.20	3.67	16.41
19/121	18.15	8.00	1.35	27.33	8.00	4.35
20/17	13.25	6.66	0.00	30.65	13.66	6.70
17/183	13.17	5.66	1.34	23.87	9.66	3.57
16/169	13.43	7.14	4.56	20.96	8.66	4.18
19/71	14.17	4.66	5.28	15.23	9.66	3.28
%	-	*31.06*	*17.63*	-	*36.02*	*21.44*
x	*18.54*	*5.76*	*3.27*	*26.90*	*9.69*	*5.77*
Max (x)	*38.23*	*10.67*	*10.87*	*44.07*	*13.67*	*16.41*
Min (x)	*13.17*	*1.00*	*0.00*	*13.34*	*2.50*	*3.02*
s	*7.01*	*2.59*	*2.36*	*9.52*	*2.91*	*3.17*

×: mean
s: standard deviation

Tab. 4: Fruit yield, sunburn and cracking amounts of late (05 - 23 Oct.) genotypes (kg/tree)

Late Genotypes	2009			2010		
	Fruit yield	Sunburn	Cracking	Fruit yield	Sunburn	Cracking
17/06	18,80	9,43	2,62	21,84	19,83	3,62
16/163	13,50	9,48	3,24	15,43	8,48	5,39
17/42	13,78	7,78	2,70	15,02	6,78	4,72
16/145	28,16	4,17	9,45	28,62	5,17	10,65
16/168	21,12	8,33	3,27	24,80	10,33	1,27
16/178	20,17	5,12	8,90	25,26	7,12	12,90
21/55	13,78	4,83	4,23	24,72	14,83	9,23
16/144	19,18	3,50	2,98	33,28	13,50	2,67
16/125	12,78	4,60	7,65	20,34	14,67	17,66
19/90	35,33	11,43	10,50	37,00	18,83	11,50
19/08	19,26	6,50	2,34	34,49	16,50	8,34
16/95	24,11	6,19	5,54	33,86	13,16	15,54
19/93	22,37	3,43	9,78	33,69	13,33	11,86
19/66	16,24	2,50	7,98	21,97	10,50	11,58
18/100	23,46	4,45	5,78	23,75	10,83	4,99
16/97	25,21	4,10	6,76	25,35	8,16	6,76
16/110	15,81	2,50	8,42	22,99	3,50	8,42
17/67	13,31	10,00	5,65	29,65	6,83	11,28
16/45	19,32	7,61	6,25	41,66	15,66	10,25
16/74	18,32	9,12	4,56	29,12	5,02	4,03
16/88	17,14	10,55	14,43	41,67	16,55	15,66
16/108	17,64	13,56	11,54	46,85	14,66	14,82
16/33	14,92	12,66	3,23	25,92	6,66	9,03
16/102	17,78	10,66	13,01	45,51	14,66	14,52
%		*36.40*	*34.84*		*39.40*	*32.27*
×	*19,23*	*7,19*	*6,70*	*29,28*	*11,48*	*9,45*
max (×)	*35,33*	*13,56*	*14,43*	*46,85*	*19,83*	*17,66*
Min (×)	*12,78*	*2,50*	*2,34*	*15,02*	*3,50*	*1,27*
s	*5,31*	*3,30*	*3,49*	*8,74*	*4,65*	*4,54*

×: mean
s: standard deviation

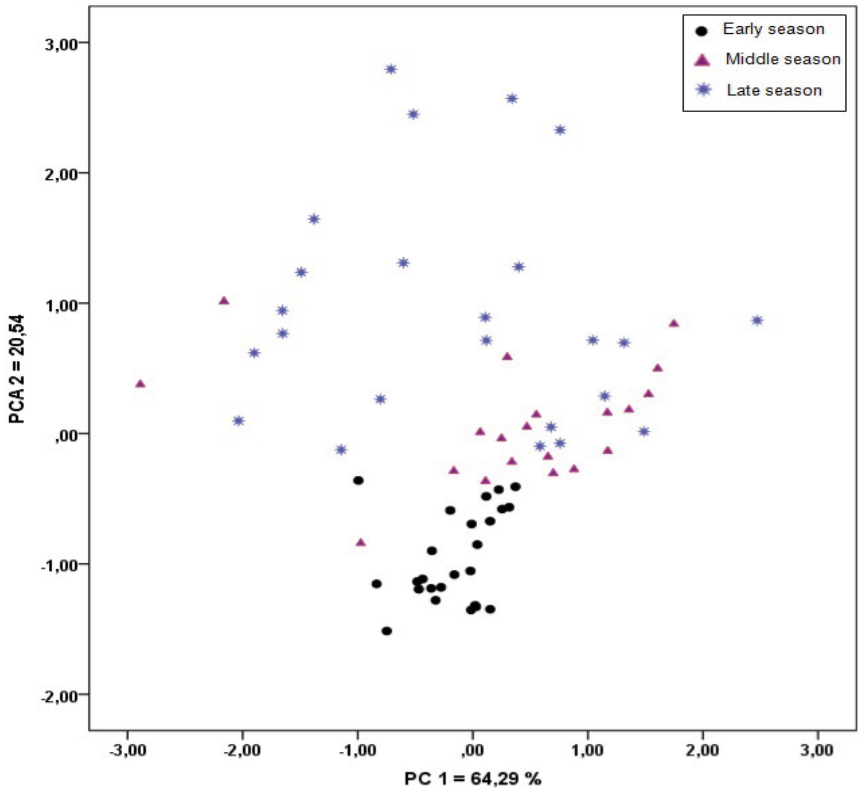


Fig. 3: 2D scatter diagrams of pomegranate genotypes based on maturing time during two years.

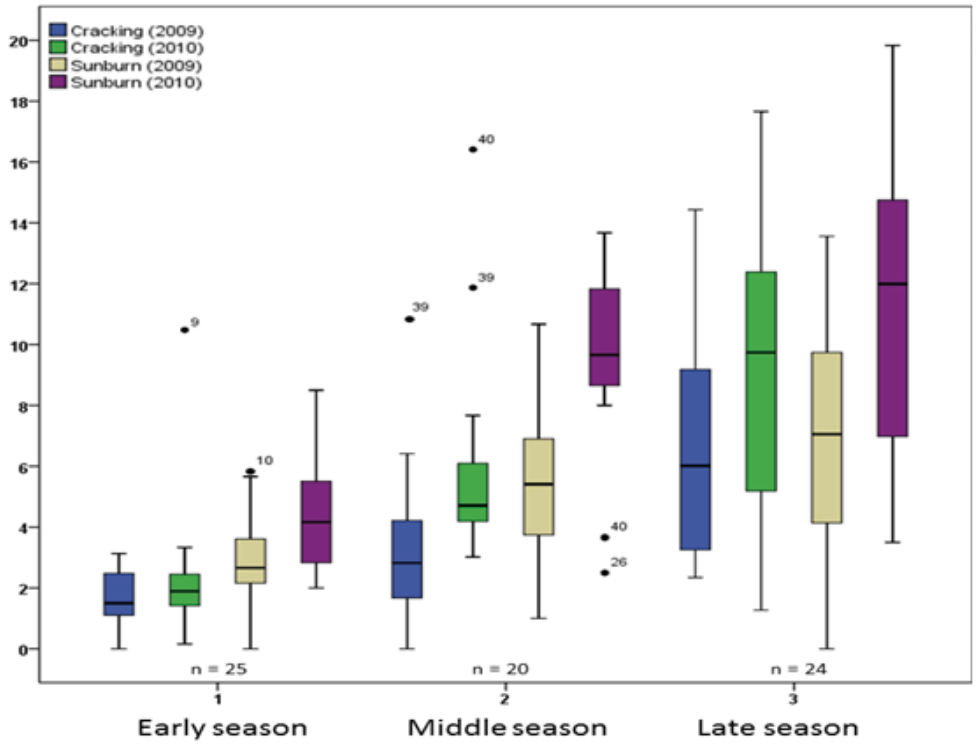


Fig. 4: Box-Plot diagram of genotypes based on cracking and sunburn values during two years (n= number of genotypes in every group)

Cracking in fruits is closely related to irrigation and nutrition situations (ONUR, 1988), sunburn is related to environmental factors like high temperature, light and radiation (YAZICI, 2006). In Turkey, the temperature in 2010 was 2,39 °C more than the normal rate, and mean rain was 82 mm over normal (ANONYMOUS, 2011). Higher sunburn and cracking ratio in 2010 than 2009 supports the idea that the increase of temperature and rain rise sunburn and cracking.

It has been reported that sunburn damages occur in fruits when the air temperature is between 28 and 32 °C or higher and solar radiation is higher than 600 cal/cm^2 × min (ARNDT, 1992; SCHRADER et al., 2002; YAZICI and KAYNAK, 2009b). In this study, due to the higher temperature and solar radiation in 2010 compared to that in 2009, the sunburn damages were higher. Finally, we have determined that the most risky months for sunburn damages are July and August in which the temperature and solar radiation values were higher for the tested pomegranate types. It has been determined that the highest temperatures in experimental parcels for 2009 and 2010 were in July and August. In 2009, the highest temperature, which was 38.3 °C in June increased to 41.8 °C in July. The highest temperature was measured as 40.90 °C in August and as 36.20 °C in September. In 2010, the highest temperature, which was 40.80 °C in June increased to 43 °C in July and 43.80 °C in August while it was 39.20 °C in September. In October, the highest temperature dropped to 32.00 °C. When the solar radiation data in the experimental parcels were examined, the highest average solar radiation in 2009 was measured as 620 cal/cm^2 × min in July. This was followed by August (600 cal/cm^2 × min), September (481 cal/cm^2 × min) and October (369 cal/cm^2 × min). In 2010, the solar radiation value was measured as 668 cal/cm^2 × min in July, 646 cal/cm^2 × min in August, 538 cal/cm^2 × min in September and 400 cal/cm^2 × min in October.

Cracking in pomegranates is caused by irregular and over irrigation during the ripening period and rain during the harvest period (MESHRAM et al., 2010; MARS, 2000). In this study, we determined that the most risky months for cracking are September and October, which is the harvesting time for middle-season ripening varieties and the ripening time for late season varieties. Additionally, the autumn rains begin during this period of season. In 2009, rainfall was detected as 119 mm during these months while in 2010, rainfall value was measured as 160 mm. It was determined that the increase in rainfall amounts in 2010 also increased the percentage of cracking in fruits. However, genetic features of pomegranate genotypes are also important factors for cracking and sunburn. It was observed in this trial that pomegranate genotypes that were grown under same climatic and soil conditions had different sunburn and cracking ratios. Especially, at the early types, sunburn and cracking were lower, while at the late types, sunburn and cracking were higher. Similarly; POLAT et al. (2012) identified that cracking ratio at two late types Hicaznar and Katırbaşı is higher than early seedless type.

Conclusions

In conclusion, in this study, a number of earlier and much late genotypes than current commercially important ones in Turkey have been determined. Moreover, it was identified that early genotypes are more resistant against sunburn and cracking than the genotypes ripening at middle season and late types.

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