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in

Melgarejo P. (ed.), Martínez-Nicolás J.J. (ed.), Martínez-Tomé J. (ed.).
Production, processing and marketing of pomegranate in the Mediterranean region: Advances in research and technology

Zaragoza : CIHEAM
Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 42

2000
pages 87-92

Determination of relationship between fruit cracking and some physiological responses, leaf characteristics and nutritional status of some pomegranate varieties

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SUMMARY – Pomegranate *(Punica granatum* L.) is a drought resistant fruit species and is well adapted to the Mediterranean conditions. The differences among the cultivars in respect to fruit cracking, an important physiological disorder, seems to be significant. The researchwork is conducted on six pomegranate varieties: two classified as sensitive to cracking, Koycegiz and Siyah, two as resistant to cracking, Kadi and Lefon and two as intermediate, Cekirdeksiz (Seedless) and Feyiz. Primary nutrients (leaf and fruit), leaf gas exchange properties, leaf water potential and fruit characteristics were investigated and correlated with the ratio and tendency of cracking.

Key words: Pomegranate, *Punica granatum*, cracking, gas exchange, primary nutrients.

RESUME – *"Détermination de la relation entre les crevasses du fruit et certaines réponses physiologiques, les caractéristiques foliaires et le statut nutritionnel chez quelques variétés de grenade". Le grenadier (*Punica granatum *L.) est une espèce fruitière résistante à la sécheresse et bien adaptée aux conditions méditerranéennes. Les différences entre les cultivars en ce qui concerne les crevasses du fruit, qui est un trouble physiologique important, semblent être significatives. Le travail de recherche est mené sur six variétés de grenades : deux classées comme sensibles aux crevasses, Koycegiz et Siyah, deux comme résistantes aux crevasses, Kadi et Lefon, et deux comme intermédiaires, Cekirdeksiz (sans graines) et Feyiz. Les nutriments primaires (feuille et fruit), les propriétés d'échange foliaire de gaz, le potentiel hydrique des feuilles et les caractéristiques du fruit, ont été étudiés et mis en corrélation avec le ratio et la tendance aux crevasses.*

Mots-clés : *Grenadier,* Punica granatum*, crevasses, échange de gaz, nutriments primaires.*

Introduction

Pomegranate is widely distributed in the tropical and subtropical regions of the world, even if its importance in the world-wide trade is still very limited. The medicinal properties of pomegranate, especially in traditional systems, is known from time immemorial (Roy and Waskar, 1997). It is accepted as a holy fruit together with olive and fig. Its high adaptability to versatile conditions especially to stress conditions (Haggag and El-Shamy, 1987) make it a favourable fruit for marginal land. It is recommended for resource-poor farmers. Pomegranate fruits and trees can be utilized in various ways and is expected to become an important raw matter for industrial use (Onur, 1988).

In nature, wild pomegranate trees are reproduced by seed and thus there is a vast population in the regions where pomegranate is found. Pomegranate can be easily grown by cuttings and suckers and this has enabled to pass over the valuable genetic materials for centuries. The pomological and chemical properties of pomegranate varieties reveal significant variations (Dokuzoguz and Mendilcioglu, 1978; Sharma and Sharma, 1990).

In Turkey, pomegranate is among the under-utilised fruit species. The total number of trees is reported as 2,729,000 and the production as 55,000 tonnes (SIS, 1995). Among different geographical regions, the Mediterranean and the Aegean regions provide nearly 71% of the national production. For the south-eastern Turkey, pomegranate is recommended as a promising species. Although pomegranate is generally grown as a low input culture, varietal differences and some physiological disorders exert a major impact on fruit quality and consequently marketability. Fruit

splitting due to irregular irrigation practices or excessive rain during the maturation period is accepted as a major fruit defect (Onur, 1988). Previous research work on different species have revealed significant effects of plant nutrients and transpiration rates on fruit splitting (Aksoy and Akyüz, 1993). Kumar (1990) reports fruit cracking as a pre-harvest disorder which may result from the fluctuation of soil moisture and relative humidity, dry wind, rain or heavy irrigation following a dry spell, and states that the potential to develop crack resistant varieties still exit.

The present study was undertaken to examine the possible factors which may have impact on fruit cracking of pomegranates with the aim of developing pre-selection criteria that will be of further help to the breeders and producers. Besides, these parameters may contribute to determine drought tolerance of pomegranate varieties.

Material and methods

The experiment was conducted in 1998 at the collection orchard of Ege University Faculty of Agriculture Department of Horticulture (Bornova-İzmir/Turkey). Six pomegranate varieties reported by Dokuzoguz and Mendilcioglu (1978) presenting varying tendencies in terms of fruit splitting were selected for investigations (Table 1). Among the examined varieties, Kadi, Lefon and Seedless (soft seeded varieties are named as seedless in Turkey) are accepted in the Turkish standards for pomegranate as standard varieties (TS, 1986). The pomegranate trees are 28 years old and are grown under rain-fed conditions and without any additional fertilization.

Table 1. Pomegranate varieties examined in the trial

Split tendency	Variety
Resistant	(1) Lefon
	(2) Kadı
Intermediate	(3) Feyiz
	(4) Seedless
Susceptible	(5) Siyah
	(6) Koycegiz

During the fruit development period, leaf samples were taken at intervals on July 9, July 25, August 25 and September 22, 1998 and analysed for their primary nutrient content. Nitrogen was analysed by Kjeldahl method, P colorimetrically and K, Ca and Mg flamephotometrically (Kacar, 1972). In September, fruit samples were harvested, separated as the peel and pulp and analysed for the macro nutrient content. As fruit quality attributes, average fruit weight (%), dry matter content of the peel and pulp, ratio of split (crack) fruits and the soluble solids (%) and titratable acidity (% as citric acid) contents of the juice were determined.

Leaf samples were taken monthly to measure some physiological parameters. Leaf area was determined by a digital planimeter. Leaf photosynthesis and transpiration rates were measured by a portable photosynthesis system (CID, CI 301) using a closed chamber (volume = 1 litre) and calculated per leaf. Leaf water potential was measured by a pressure chamber (PMS Instruments Inc., Model 1003). Leaf succulence was found as mg/cm^2 according to Romero-Aranda and Syvertsen (1996).

Results

Fruit quality

The fruit sizes of the analysed pomegranate varieties ranged between 144.15 and 252.15 g and

the varieties were grouped into two, Koycegiz (6) and Lefon (1) being in the top ranking group. The soluble solids content of the juice changed between 13.9 to 17.1%. Kader *et al*. (1984) state that within each season soluble solids content increased, whereas, titratable acidity of the juice decreased with ripening. The highest soluble solids content was found in cultivars Siyah (5) and Seedless (4). The lowest levels were determined in Koycegiz and the other varieties were placed in between. In terms of peel dry matter content, varieties Kadi, Koycegiz and Feyiz (3) made up the first group (Table 2). Siyah (5) and Lefon (1) formed the top ranking group together with Kadı (2) in respect to dry matter content of the pulp (flesh).

Pomegranate fruits are known to differ according to their acidity contents and varieties are identified as sweet, acidic or semi-acidic. Acidity of the juice determines the area of utilization (Onur, 1983). Among the six varieties only Lefon seems to have a strong acidic taste. Seedless cultivar ranked the second. The other four cultivars were placed in the same statistical group.

Pomegranate fruits were harvested on September 22, 1998 and cracking was first observed 1 to 2 weeks prior to harvest. The statistical analysis of split ratios were parallel to the previous work of Dokuzoguz and Mendilcioglu (1978) revealed three significant groups. Koycegiz (24.54%) and Siyah (19.04%) had the highest incidences and grouped together. Lefon had the lowest ratio of splitting, but its difference with Feyiz and Seedless was not significant at statistical level (Table 2).

Table 2. Fruit quality characteristics of the analysed pomegranate varieties

Variety	Fruit weight (g)	TSS (%)	Dry matter (%)		Acidity (% citric acid)	Fruit split (%)
			Pulp	Peel		
Lefon (1)	240.53	15.8	25.20	32.55	3.539	10.280
Kadi (2)	144.15	15.1	23.50	41.30	0.320	17.275
Feyiz (3)	180.90	15.7	22.70	38.60	0.627	13.080
Seedless (4)	158.05	16.1	23.25	34.30	0.269	16.609
Siyah (5)	159.45	17.1	25.25	35.15	0.352	19.040
Koycegiz (6)	252.15	13.9	21.75	40.00	0.378	24.540
F	13.494**	8.865**	4.526*	6.417*	987.168**	5.304**
LSD (0.05)	43.276	1.24	2.259	4.754	0.142	6.361

*F significant at alpha level 5%; **F significant at alpha level 1%.

Leaf characteristics

As could be seen in Table 3, the average leaf area ranged between 4.50 and 6.97 cm^2 but the differences among the varieties sampled at intervals were not marked. In the net photosynthesis values of the six pomegranate varieties, date and date × variety interaction was statistically significant On July 9, Lefon had the highest photosynthetic rate (Pn) followed by Seedless and Kadı, whereas, Siyah had the lowest. All the other four varieties were found similar. On July 25, Lefon and Seedless, the two top ranking on July 9 had the lowest rate. Pn values obtained in August 25 were similar to those of July 25 except cv. Siyah. In general, the highest Pn and E (transpiration rate) values were measured on July 25. The date × variety interaction was important on the leaf transpiration rate of pomegranate cultivars. The transpiration rates of cv. Seedless and Koycegiz were found to be higher on August 25.

In terms of water-use efficiency calculated as Pn/E, varietal differences created a marked effect. Lefon and Seedless were grouped together. Koycegiz had the lowest performance and the other varieties had minor differences.

The leaf water potential did not vary at a significant level among the examined varieties. The leaf potential values were higher on July 25, followed by August 25 and July 9 in the decreasing order (Table 3). A similar trend was found for the leaf succulence. Neither the varietal differences nor the

sampling dates had a significant impact on leaf succulence, however, the most succulent leaves were found in cultivar Lefon and the least was in Siyah.

Table 3. Leaf area and the analysed physiological parameters of pomegranate varieties

Date	Variety	Leaf area (cm^2)	Succulence index (mg/cm^2)	Pn ($\mu mol/m^2/s$)	E ($mmol/m^2/s$)	WUE (Pn/E)	Leaf water potential (-bar)
July 9	1	4.880	8.00	13.543	8.043	1.682	21.350
	2	5.055	7.75	11.510	11.175	1.034	21.850
	3	4.880	7.75	10.631	9.302	1.142	17.600
	4	5.160	8.06	11.517	8.701	1.331	20.250
	5	5.105	6.38	8.363	9.838	0.851	19.150
	6	6.055	8.00	10.893	11.821	0.921	20.200
	Mean	5.189	7.66	11.076	9.813	1.160	20.067
July 25	1	5.960	9.38	12.537	10.083	1.245	22.650
	2	5.465	9.06	15.095	13.368	1.135	25.900
	3	5.135	8.50	14.540	13.531	1.082	23.000
	4	5.980	7.81	12.531	10.959	1.147	24.850
	5	6.085	6.94	15.941	16.417	0.971	26.700
	6	5.505	7.44	15.630	17.263	0.905	21.215
	Mean	5.688	8.19	14.379	13.603	1.081	24.053
Aug 25	1	6.970	8.19	9.411	6.803	1.388	20.600
	2	6.730	7.50	11.304	10.212	1.107	21.950
	3	4.850	7.31	9.817	8.478	1.279	23.800
	4	4.495	8.25	11.183	11.709	1.455	21.400
	5	5.495	8.56	10.455	13.582	0.789	20.850
	6	4.880	8.38	11.518	18.555	0.621	24.250
	Mean	5.570	8.03	10.614	11.556	1.106	22.142
LSD (0.05)	Date	ns	ns	1.603**	**	ns	2.157**
	Variety	ns	ns	ns	**	0.246**	ns
	Date × Var.	ns	ns	1.603**	2.392**	Ns	ns

**F significant at alpha level 1%; ns: F value not significant.

Primary plant nutrients

The leaf nitrogen content was the highest in samples taken on July 9 (0.829%) but decreased within the season to 0.789% on July 25, 0.755% on August 25 but again increased to 1.112% at harvest in September (Table 4). Haggag and El-Shamy (1987) report the primary nutrient content of the leaf (sampled in May and August 17) in Higazi and Arabi pomegranate cultivars fertilised at different levels of N, P and K as 1.48-2.19% N, 0.12-0.13% P, 0.72-0.93% K, 1.25-1.66% Ca and 0.18-0.25% Mg. In the analysis of leaves sampled in September from six pomegranate varieties, the results obtained are 1.19% N, 0.860% P, 0.219% K, 2.012% Ca, and 1.106% Mg. The slight differences may be due to sampling time or soil and climatic conditions prevailing in the orchards (Table 4).

The nitrogen content of the fruit flesh was the highest in Lefon. All the other varieties were statistically similar and formed the second group. On the other hand, K content was the lowest in Siyah and together with Koycegiz it was significantly different than the other cultivars. In terms of pulp-P, Ca and Mg varietal differences were not significant.

The peel-N, P, K and Mg contents of different cultivars were statistically similar. The peel-Ca content of the varieties decreased in the order of Lefon (8.4%); Kadi (6.34%); Koycegiz (4.85%); Feyiz (4.81%); Seedless (4.62%); and Siyah (2.69%). Lefon and Kadi were statistically grouped together (Table 5).

Table 4. Leaf primary nutrient content of the analysed pomegranate varieties

Date	Variety	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
July 9	1	0.77	0.114	3.31	1.484.	0.750
	2	0.76	0.086	3.01	1.781	1.050
	3	0.81	0.103	3.11	2.069	1.050
	4	0.85	0.111	3.51	1.288	0.650
	5	0.90	0.106	3.54	1.269	0.600
	6	0.88	0.099	3.39	1.425	0.700
	Mean	0.83	0.103	3.31	1.553	0.800
July 25	1	0.71	1.193	3.07	2.070	1.100
	2	0.72	0.805	3.04	1.777	1.050
	3	0.77	0.985	2.77	1.936	1.050
	4	0.85	1.023	3.11	1.386	0.800
	5	0.86	0.966	3.34	1.308	0.850
	6	0.83	0.871	3.44	1.562	0.950
	Mean	0.79	0.974	3.13	1.673	0.966
August 25	1	0.73	0.956	2.27	2.206	1.250
	2	0.73	3.876	2.87	2.167	1.350
	3	0.78	0.919	3.04	1.855	1.200
	4	0.78	0.852	3.04	1.503	0.850
	5	0.76	0.852	2.94	1.816	1.200
	6	0.76	0.767	3.07	2.089	1.250
	Mean	0.76	1.370	2.87	1.939	1.183
September 22	1	1.09	0.878	1.66	2.110	0.750
	2	1.06	0.573	1.71	2.288	1.050
	3	1.13	0.925	1.71	2.192	1.050
	4	1.20	0.823	1.20	1.865	0.650
	5	1.09	0.993	2.02	1.519	0.600
	6	1.57	0.968	2.08	2.019	0.700
	Mean	1.19	0.860	1.73	2.012	0.800
LSD (0.05)	Date	0.501**	ns	2.18**	0.159**	0.1439**
	Variety	0.614*	ns	2.67**	0.195**	0.176**
	Date × Var.	ns	ns	ns	ns*	ns

*F significant at alpha level 5%; **F significant at alpha level 1%; ns: F value not significant.

Table 5. Primary nutrient content of pomegranate fruits (as peel and pulp)

Varieties	Pulp (% dry matter)					Peel (% dry matter)				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg
Lefon (1)	1.435	1.110	0.334	3.461	0.040	0.511	0.462	0.426	8.461	0.028
Kadi (2)	0.889	1.674	0.313	3.654	0.033	0.490	0.425	0.389	6.346	0.023
Feyiz (3)	0.924	1.822	0.318	3.846	0.038	0.511	0.989	0.405	4.808	0.025
Seedless (4)	1.106	1.785	0.322	3.654	0.043	0.497	0.463	0.389	4.615	0.020
Siyah (5)	0.868	1.318	0.278	4.423	0.033	0.427	0.314	0.266	2.692	0.017
Koycegiz(6)	0.833	1.267	0.308	3.654	0.035	0.413	0.435	0.334	4.846	0.027
F	8.45**	ns	4.52**	ns	ns	ns	ns	ns	4.7**	ns
LSD 0.05	0.273		0.031						3.096	

**F significant at alpha level 1%; ns: F value not significant.

Discussion

The correlations among the analysed parameters displayed significant relationships between fruit crack or splitting and transpiration rate (split ratio × E; r = 0.513**) and water use efficiency (split ratio × WUE; r = -0.428**). The varieties selected as crack resistant had the highest WUE, whereas, the lowest in susceptibles. The leaf water potential has marked impact on leaf Pn (r = 0.412*) and E (r = .371*). Among the primary nutrients, nitrogen seems to be the most effective on fruit cracking. Increasing levels of N favoured the ratio of split fruits. The correlation coefficient of this relationship is calculated as r = 0.475**. N has an adverse effect on leaf succulence (r = -0.407*). The N nutrition of different organs in the pomegranate tree is also correlated. Fruit peel N content is also significantly affected by leaf N.

Leaf succulence was found to increase with increasing levels of leaf Ca (r = 0.333*) and decreasing levels of K (r = -0.278). The negative impact of K/Ca (r = -0.420**) and K/Ca + Mg ratios (r = -0.404*) in the leaves was more prominent compared to leaf Ca. The data related to physiological parameters reveal that the highest stress was observed in samples taken on July 25, during the hot and dry period of the Mediterranean summer and during the rapid fruit development period. The correlation coefficients obtained for July 25 data were greater than the average of three months. Possibly the onset of the cracking coincided with this period, as well. Leaf succulence is an important parameter showing the availability of internal air spaces in the leaf tissues which is necessary for gas exchange (Romero-Aranda and Syvertsen, 1996).

Among the analysed parameters, leaf N and K/Ca ratio seem to be highly correlated with the leaf succulence and gas exchange properties of the leaf tissue and thus, with fruit cracking. These parameters can be further investigated and tested in screening for crack or drought resistance.

Acknowledgement

This research is partially supported by the funds provided by FONDEF project No. 1062.

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