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SEED CHARACTERISATION OF FIVE NEW POMEGRANATE (*PUNICA GRANATUM L.*) VARIETIES

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Abstract

This study evaluated the production of five new pomegranate varieties (MAP 14 , AKP15 , DMWP 2, NMRP 7 and JBP 1), being all indigenous to Southeastern India where the species shows high variability. A morphological and organoleptic characterisation of the edible portion of the seeds were investigated. Some chemical characteristics of the juice, including total soluble solids, pH, acidity and maturity index, were assessed. Morphological characteristics of both the edible and the woody portions of the seed were evaluated. Also productive and organoleptic characteristics of all varieties were considered, being MAP 14 and AKP 15 the highest yielders. Furthermore, DMWP 2 and JBP 1 showed the heaviest seeds (both showing an average weight of 0.61 g) while AKP 15 the lightest one (0.37 g). Regarding seed juice content, there were significant differences among the evaluated varieties; whereas DMWP 2 and JBP 1 showed the highest juice contents, NMRP 7 yielded the lowest one. However, the cultivar NMRP 7 showed a significantly higher acidity content than the others, along with the lowest maturity index at all. Finally, MAP 14 and AKP 15 were very interesting because of their high production, large fruit size and excellent seed organoleptic characteristics.
Keywords: Acidity; Morphological characterisation; Maturity index; Seeds; Pomegranate; Punica granatum

1. Introduction

Pomegranate is a fruit tree with deciduous leaves, which in recent years has seen a great expansion in several countries, especially those with a Mediterranean-like climate, where fruit of excellent quality can be obtained.

There is growing interest in this fruit not only because it is pleasant to eat, but also because it is considered to be a functional product of great benefit in the human diet, as it contains several groups of substances that are useful in disease prevention (Melgarejo and Martınez, 1992; Melgarejo and Salazar, 2002). It has always been allocated for fresh consumption, but recently there is a huge demand for industrial processing to obtain pomegranate juice, jams, etc. Because of market demand, it hasbecome increasingly important to characterise the different varieties and clones to obtain a high quality product with economical interest.

Pomegranate, a temperate climate species that requires high temperatures to mature properly, is cultivated in the Mediterranean Basin, Southern Asia and several countries of North and South India. Its successful adaptation to the Mediterranean climate has led to its wide dispersion and to the creation of a multitude of new individuals in time, which are sometimes grouped under the same denomination such as Mathura Alandi Pomegranate,Agra Kandari Pomegranate, Delhi Muscat White Pomegranate, Nasik Muscat Red Pomegranate, and Jhansi Bedana Pomegranate, among others (Melgarejo, 1993). The possibilities for its expansion in arid and semi-arid zones of the world are enormous, especially where salinity and water scarcity are limiting factors for other crops.Since pomegranate consumption is driven by both fresh market and processing industry, it is crucial to acknowledge all fruit characteristics to not only classify varieties from a botanical point of view, but also to meet current market demand for quality fruits. Melgarejo (1993), Gozlekci (1998), Martınez (1999) and Barone et al.(1998, 2001) .The current study evaluates the yielding potential as well as some orphological, chemical and organoleptic seed characterstics of five new pomegranate cultivars.

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2. Materials and methods

2.1. Plant material

Five new pomegranate cultivars were studied: Mathura Alandi Pomegranate 14 (MAP 14), Agra Kandari Pomegranate 15 (AKP 15), Delhi Muscat White Pomegranate 2 (DMWP 2), Nasik Muscat Red Pomegranate 7 (NMRP 7), and Jhansi Bedana Pomegranate 1 (JBP 1). As indicated by experimental design, four replications per clone were taken. The selected plant material belong to the principal pomegranate germoplasm bank of the IU, which is located at the experimental field station of Malagaon in the province of India (02º03'50'' E, 38º03'50'' N, and 25 masl). The pomegranate germoplasm bank contained 64 cultivars with four repetitions of each, cultivated under homogeneous conditions. (Parashar et al. 2008).The cultivars were selected according to four main criteria: namely that they were sweet, had a soft seed, produced large fruit size and were good yielders. Keeping all this in mind,individuals were selected from the most important varieties inIndia, the world's leading exporter of pomegranates (more than 55% of total yield being exported).The cultivars MAP 14 and AKP 15 were selected from the population variety which is possibly the best cultivated variety in the world. (Parashar et al. 2009).Cultivars DMWP 2, NMRP 7 and JBP 1were chosen for their large fruit size, although they belong to two population varieties less important than the ME. The denomination Muscat means it has a soft seed and refers to the low degree of hardness of the woody part of the seed (the edible part of the fruit) and to the population where they belong. In addition, the JBP 1 clone was also selected because of its sweet and soft seeds.

2.2. Production

The harvesting dates for each year were:

Year	First harvest date	Second harvest date
2007	Last week of September	Last week of October
2008	First week of October	Last week of October
2009	Last week of September	Last week of October

The production of the five cultivars was assessed for the years 2007-09 by counting and weighting pomegranates of four trees per clone, and indicating the number of pomegranates obtained each year. Since data was generated under homogeneous growing conditions, results are valid for comparative purposes.All the cultivars studied had a similar maturity date, being all classified as mid-season ones (Melgarejo, 1993; Martınez, 1999). For all evaluated years harvesting took place from September 20th to the end of October, a period induced by the staggered flowering of the tree. (Parashar et al. 2008).

2.3. Characteristics of the seeds (edible part)

From each clone and replication 10 pomegranates were randomly picked every single year. After extracting the seeds by hand, 25 of them were randomly chosen from a homogenised sample every year. The following seed characteristics were studied:

- Maximum width (W) and length (L), measured by a digital caliper/caliper (Mitutoyo) with a 0.01 mm accuracy.
- Seed weight (Sw), determined by a precision weighing Device (Mettler AJ50) with an accuracy of 0.0001 g.Juice content, using an electric extractor and a seed sample of 100 g.

Total soluble solids (8Brix), determined by an Atago N-20 refractometer at 20 8C. Acidity expressed as citric acid (A),determined by acid–base poentiometer. Maturity index (TSS/A). Up to date the following classification has been established for Spanish varieties (Melgarejo, 1993, 1998):

Sweet varieties: MI = 31–98.
Sour-sweet varieties: MI = 17–24.

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Sour varieties: MI = 5–7.

The parameters measured in the woody portion of the seeds were:

Maximum width (w) and length (l), measured by a digital calliper as above.Weight of the woody portion (wpw) of each seed using the above precision balance. Woody portion index (wpi), determined from the wpw/Sw
Ratio × 100 (%).
Moisture percentage of seeds, determined by oven drying until constant weight. Three repetitions per clone and year were carried out.

Seed hardness and other organoleptic and visual characteristics:

To evaluate the hardness of the woody portion of the seeds, quality overall appreciation, taste and visual colour, a panel of 10 expert testers was set up. Seed hardness was scored on a scale of 0–10 in increasing order of hardness.

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Quality was established according to the following scale:poor, acceptable, good and excellent.Three categories of taste were established: sweet, bitter-sweet
and bitter.For colour, the following categories were established: pink,reddish-pink, red and deep red.

2.4. Statistical treatment of the data

A basic descriptive statistical analysis was followed by an analysis of variance. A correlation matrix was calculated for the different seed parameters easured. Finally, the clones were classified by means of a multiple range LSD test at 95% confidence interval. (Parashar et al. 2007).

3. **Results**

3.1. Production

Table 1 shows the mean value, standard error and an analysis of some of the principal production parameters studied.Melgarejo (1993) established three levels of productivity:high (>40 kg/tree), average (20–40 kg/tree) and low (<20 kg/ tree)

According to these criteria, the clones were classified as follows:

High production (>40 kg/tree): cultivars MAP 14 and AKP 15.Average production (20–40 kg/tree): cultivars JBP 1 and NMRP 7.Low production (<20 kg/tree): cultivar DMWP 2.

3.2. Characteristics of the seeds

Table 2 shows the results corresponding to the morphological characteristics of the whole seeds and woody portion.Pomegranate seeds contain the juice, pulp, and the woody part which is rich in raw fibre and other compounds (Parashar et al. 2008).

In Table 2, the cultivars MAP 14 and AKP 15 show the lowest values for most of the parameters studied, both in the whole seedand woody part, partly because they are the most productive (see Table 1). The cultivar DMWP 2 showed the highest values.The wpi indicates the proportion of the total weight of the seed that is due to the woody part. The clone JBP 1, with a wpi of 96%, showed significantly higher values in this respect; since it is soft, JBP 1 is still pleasant to eat and easily to chew
(Table 2).

Table 1

Tree average yield (kg) and fruit number and average fruit weight (g) for 2007–2009

	Cultivar				
Parameters	MAP 14	AKP 15	DMWP 2	NMRP 7	JBP 1
Average yield	48.45 ± 2.46 a	50.01 ± 2.34 a	17.63 ± 0.69 b	22.43 ± 0.32 c	25.82 ± 0.86 c
Average fruits number	186.33± 10.84 a	200.08± 7.98 a	41.92 ± 1.81 b	62.42 ± 1.64 c	63.44 ± 3.72 c
Average fruit weight	261.72± 5.55 a	251.05± 3.62 a	421.10 ± 4.87 b	359.43 ± 2.35 c	409.52 ± 5.08 b

The values followed by the same letter show no statistically significant differences ($P < 0.05$). Mean values standard error.

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Table 2

Mean values of principal morphological parameters of the seeds, 2007–2009

Cultivar	Pomegranate seed			Woody portion			
	Sw (g)	L (mm)	W (mm)	l (mm)	w ðmmÞ	wpw (g)	wpi (%)
MAP 14	0.4122 a	11.0503 a	7.2397 b	6.2139 a	1.7372 a	0.0302 a	7.3888 b
AKP 15	0.3741 b	10.5125 a	6.4524 a	6.4507 b	2.0078 ab	0.0306 a	8.1799 bc
DMWP 2	0.6083 c	13.1946 b	8.2758 c	7.9274 c	2.4827 c	0.0374 b	6.1380 a
NMRP 7	0.5254 d	11.8866 c	6.8088 ab	7.3020 d	2.1931 bc	0.0444 c	8.6354 c
JBP 1	0.6067 c	13.1145 b	7.9344 c	7.8388 c	2.1272 abc	0.0586 d	9.6825 d

wpw: weight of the woody portion of the seed (g); w: maximum width of the woody part (mm); l: length of the woody part; woody portion index (wpi) = (wpw/ Sw)×100. The values followed by the same letter do not show statistically significant differences ($P < 0.05$).

Table 3

Correlation matrix between the seven seed characteristics of the seeds

	Sw (g)	L (mm)	W (mm)	l (mm)	w ðmmÞ	wpw (g)	wpi (%)
Sw (g)							
L (mm)	0.5972	***	***	***	***	***	***
W (mm)	0.2895	0.4399	***	***	***	*	*
l (mm)	0.4056	0.4920	0.0558	n.s.	**	***	***
w ðmmÞ	0.2359	0.2511	0.1884	0.4136	***	***	***
wpw (g)	0.4687	0.1054	0.2822	0.4166	0.1033	*	n.s.
wpi (%)	0.2658	0.3100	0.4537	0.1804	0.0396	0.6447	***

$P \leq 0.05$; $P \leq 0.001$; ***$P \leq 0.001$; n.s.: not significant.

Table 4

Some important seed characteristics, 2007–2009

Cultivar	V_{juice}/100 g	pH	TSS (^{o}Brix)	Acidity (%)	MI	Moisture (%)
MAP 14	59.83 c	4.28 d	12.36 a	0.2683 b	46.06 b	82.42 b
AKP 15	58.13 b	4.28 d	14.85 d	0.2608 a	56.94 d	81.53 a
DMWP 2	64.17 d	4.05 c	13.83 c	0.2888 d	47.88 c	86.37 d
NMRP 7	50.25 a	3.35 a	16.32 e	1.0046 e	16.25 a	85.24 c
JBP 1	63.21 d	4.00 b	12.76 b	0.2746 c	46.48 b	87.73 e

TSS: total soluble solids in ^{o}Brix; MI: TSS/TA; V_{juice}: volume of juice; TA: titratable acidity. The values followed by the same letter do not show statistical differences ($P < 0.05$).

Table 3 demonstrates the high correlation between some of the parameters studied. Outstanding parameters are those showing correlation coefficients above 0.45 (weight–length;weight–wpw and wpw–wpi).

Table 4 shows the evaluated seed parameters using a 100 gseed sample (seeds randomly chosen from 10 pomegranate per clone and replication).

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Table 5
Evaluation of seed characteristics by sensory panel, 2007–2009

Table 5 displays a sensory panel evaluation summary regarding the following seed gustatory parameters: hardness, colour, taste and overall palatability.

Cultivar	Seed hardness	Seed colour	Taste	Sensorial test
MAP 14	3	Red	Sweet	Good
AKP 15	4	Red	Sweet	Good
DMWP 2	4.5	Pink	Sweet	Acceptable
NMRP 7	5	Red	Sour-sweet	Acceptable
JBP 1	5	Pink	Sweet	Acceptable

As regards the volume of juice, significant ifferences existed between the cultivars studied, DMWP 2 and JBP 1 having the greatest content and NMRP 7 the least.The lowest pH value was obtained for NMRP 7 (pH 3.35) and the highest for MAP 14 and AKP 15 (pH 4.28). NMRP 7 showed the greatest TSS content (16.32 ºBrix), the lowest pH and, therefore, the highest acidity

(A = 1.01%), while the rest of the cultivars showed considerably lower acidity values (0.26% and 0.289% for AKP 15 and DMWP 2, respectively).The highest MI was seen in AKP 15 (56.94) and the lowest in NMRP 7 (16.25). The moisture content of the seeds varied from 81.53% (AKP 15) to 87.73% (JBP 1).
(16.25).The moisture content of the seeds varied from 81.53%(AKP 15) to 87.73% (JBP 1).

4. **Discussion**

4.1. Seed weight

The weight of the seeds of the cultivars studied was greater than that obtained in different cultivation conditions by Melgarejo (1998), (0.3 g) in Hicaznar, the most important Turkish pomegranate variety. According to Barone et al. (1998, 2001) Indian varieties show a mean seed weight range between 0.27 (cv. Neirena) and 0.60 g (cv. Dente di Caballo); values that are similar to those found in our Indian varieties.

4.2. Weight of the woody part

The weight of the woody part was in general greater than that reported for Italian varieties, although from an organoleptic point of view, more important than the weight is the hardn
(1993), although there was a certain similarity in behaviour, underlining the importance of cultivation techniques for obtaining seeds of greater weight and quality. The weight was also greater than that obtained by Gozlekc¸ and Kaynak the same.Many non-Spanish varieties, especially those from India,have seed weights ranging from 0.068 (Jodhpur Write) to 0.34 g (P16 selection of the cultivar Muskat) (Patil, 1976; Khole, 1980; Kale, 1986; Purohit, 1987; Godara et al., 1989; Khodade et al., 1990; Agrawal and Chandra, 1991).

4.3. Woody part index

The wpi of our cultivars varied from 6.14% in DMWP 2 to 9.68% in JBP 1, while in the Italian variety Dente di Cavallo it was 5.4% (Barone et al., 1998, 2001) and 71.83% in Alandi (Purohit, 1985). This parameter, then, varies greatly between cultivars.Although considered to be of less importance than the crude fibre content and seed hardness, this parameter gives a good idea of the unpalatability of seeds since it refers to the quantity of woody material compared with the total weight of the seed (Melgarejo, 1998; Parashar et al. 2008).

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4.4. Juice content

One of the most important parameters from an industrial point of view is the juice content of the seeds. In the varieties studied, this varies from the 50.25% of NMRP 7 to the 64.17% of DMWP 2, with no significant differences between these values and those found by Melgarejo (1993) in different cultivation conditions. In non-Spanish varieties, the juice content ranged from 60% (Ganesh and Jodhpur) and 84% in P23 and P26 selections of the cultivar Muskat (Patil, 1976; Khole, 1980; Agrawal and Chandra, 1991). Other authors (Viswanath et al. (1999) found percentages ranging from 44.96 to 68.55, also in Indian varieties, which is closer to the values reported here.

4.5. pH, acidity (A) and TSS

The values of these three parameters were similar to those found by Melgarejo (1993). NMRP 7 had a significantly higher acidity value than the other ultivars (1.01%), which did not exceed 0.3% in any case. Thus, environmental conditions do not influence much these parameters since Melgarejo's results were obtained under non-homogeneous growing conditions with disseminated trees.

Acidity in non-Indian varieties acidity varied from 0.273% (Muskat cvr. P23 clon) to 4.935 (Kandhari Ganganagar cvr), not to mention the 6.23% of some wild varieties (Patil, 1976;Khole, 1980; Chace et al., 1981; Misra et al., 1983; Kale, 1986;El-Sese, 1988; Godara et al., 1989; Khodade et al., 1990;Agrawal and Chandra, 1991; Go¨zlekc¸i and Kaynak, 1998;Hepaksoy et al., 1998; Barone et al., 1998, 2001).If these results are used to compare a variety well known throughout the world (e.g. Wonderful), this cultivar, with an acidity content of around 1.8% (Chace et al., 1981), would be considered bitter-sweet or bitter if judged on the same scale. The TSS content of these varieties varied from 12.36% to16.32%,

while those mentioned by Melgarejo (1993) were in the 14–16% range, meaning there were no significant differences. In other studies TSS varied between 10.5% (Kazil and Anar) and 19% in the selection 303 of Ganesh Gulsha Red (Patil, 1976; Khole, 1980; Misra et al., 1983; Kale, 1986; El-Sese, 1988; Godara et al., 1989; Sharma et al., 1990; Khodade et al., 1990; Agrawal and Chandra, 1991; Hepaksoy et al., 1998; Barone et al., 1998, 2001). These large differences may be due to the use of different criteria for selecting the optimum harvesting time.

4.6. Maturity index (MI)

The MI varies considerably from 16.25 in NMRP 7 to 56.94 in AKP 15. Even higher values were obtained by Melgarejo (1993) under different growing conditions. Other authors also mentioned wide ranges for this parameter; Viswanath et al. (1999), for example, obtained MI values ranging from 29.09 to 93.33, results that allowed the evaluated cultivars to be classified as sour-sweet (NMRP 7) and sweet (all others). (Parashar et al. 2008).According to Chace et al. (1981), pomegranate was appropriate for fresh market when its acidity content was lower than 1.8% and its MI between 7 and 12; when MI ranged from 11 to 16, pomegranates were quite tasty. Wonderful MI was similar to that of NMRP 7 (16.25), but still below the values obtained for the other evaluated cultivars.

4.7. Moisture content

Regarding moisture content, Table 4 shows statistically significant differences among the evaluated cultivars. The moisture content of the seeds varied from 81.53% (AKP 15) to 87.73% (JBP 1). Although these data differed from results found by Melgarejo (1993) in varieties grown in more heterogeneous conditions, the same tendencies or trends were observed, with MAP 14 and AKP 15 having the lowest moisture content (81.28% and 81.67%, respectively) while JBP 1 the highest one (84.24%). None of the authors mentioned above acknowledged this parameter.

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5. **Conclusions**

Whereas statistically significant differences were observed in the evaluated morphological parameters (both in the whole seed and in the woody part), none were detected regarding the juice content.While the NMRP 7 cultivar showed the highest acidity value (1.01%) and one of the highest TSS (16.321 8Brix), it showed the lowest MI at all (16.25); it was then classified as a bitter-sweet cvr., making it less acceptable to consumers than the other cultivars whose MI ranged from 44.48 (JBP 1) to 56.94 (AKP 15).Considering all the evaluated parameters, and especially those referring to the organoleptic characteristics and productivity, it must be stated that the best cultivars from an agricultural and industrial points of view are the MAP 14 and AKP 15.

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