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Fruit quality improvement in pomegranate under hot arid environment

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ABSTRACT

The extent of genetic variability, heritability and genetic advance with respect to growth, fruit yield and quality traits in 25 pomegranate hybrids/open-pollinated progenies were studied. Fruit yield per plant, number of fruits per plant, fruit weight and weight of 100 arils were recorded high heritability parameters along with large amount of genetic advance. Thus, selection of progenies based on performance would be effective for these characters. The number of fruit per plant, fruit weight, diameter and length were positively and significantly correlated with fruit yield per plant both at phenotypic and genotypic levels. Fruit weight had highly significant and positive correlation with fruit diameter, fruit length and weight of 100 arils. Therefore, emphasis should be given to these characters while selecting a genotype for enhancing yield and fruit size in pomegranate. On the basis of desirable parameters, best individuals were identified from the heterozygous progenies and compared for fruit quality and yield components in respect of popular cultivar Jalore Seedless for further testing under hot arid agro-climate after clonal propagation.

Key words: Fruit quality, genetical studies, pomegranate.

INTRODUCTION

Pomegranate is an important fruit of arid and semi-arid tropical and subtropical regions. It has high nutritive and therapeutic values. The fruits have excellent keeping quality. Therefore, its cultivation is most lucrative and remunerative. Pomegranate is grown in India, Afghanistan, Pakistan and Iran. In India, it is extensively grown in Maharashtra, Rajasthan, Gujarat, Karnataka and Andhra Pradesh. Until 1980's, the types such as Alandi, Dholka, Jalore Seedless, Jodhpur Red, Bedana, Musket, Madhuguri, Chawla, Nabha and Country Large Red were commonly cultivated in different regions of India. They lacked in one or the other fruit quality characters since they were developed through selection from the open pollinated seedlings on the basis of phenotypic attributes like fruit size, sweetness, mellowness and colour of aril (Pareek and Samadia, 12). The popular cultivar Ganesh was developed in 1971 at Ganeshkhind Gardens, Pune. During the 1990's, few selections were made from seedlings or clonal progenies of Musket (P 23 and P 26) and Ganesh (G 137). During this period, exotic pomegranate genotypes were also evaluated under AICRP on Arid Zone Fruits and consequently promising cultivars like Jalore Seedless, Ganesh, G 137 and P 26 were identified. Some more Russian and Iranian cultivars were also introduced and evaluated but these did not perform well under arid and semi-arid regions of India. But these cultivars had the desirable dark red aril colour and high TSS. Therefore, attempts to infuse blood red aril colour of these exotic types into the popular soft seeded cultivars were made at MPKV, Rahuri and IIHR, Bangalore. As a result, two hybrids having soft seed and blood red aril, Mridula (MPKV) and Ruby (IIHR) were developed for commercial cultivation particularly in Maharashtra and Karnataka (Vashishtha *et al.*, 13).

The prevalence of extremely high temperature for long period (April to September) and very high vapour pressure deficit in the atmosphere in the Indian arid zones during fruit development period results in fruit cracking. Therefore, improvement in pomegranate is required to develop cultivar suited to such regions, besides improvement in aril size and colour. Keeping this in view, the present work was undertaken to study the variability in the developed progenies/hybrids to identify suitable genotypes for the arid environment.

MATERIALS AND METHODS

Twenty-five progenies under the study consisted of 13 F_1 hybrids of desirable parental combinations, 11 open pollinated seedling progenies of exotic (Iran) and indigenous material (Jalore Seedless) and one clonal progeny from seedling-originated orchards of cv. Jalore Seedless. Field planting of these progenies was completed in two years, *i.e.* 1998 and 1999 at CIAH, Bikaner. The agro-climate of Bikaner is characterized by extremes of temperature (as low as -4 °C in winter and as high as 48 °C in summer), low rainfall (100-350 mm) in short spells during July to September, high vapour pressure deficit (30 mb during May-June), intense solar radiation and sandy soils having poor soil fertility and water holding capacity. High density planting was done at 2 m x 1 m spacing. Irrigation was done through 0.75 m wide channels keeping the plants in

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centre. Uniform cultural practices were adopted. On establishment, the number of plants in each progeny ranged from 6 to 42. There were more than 25 plants in 20 progenies and 6 to 12 plants in the remaining five progenies. For study, the plants of each progeny were divided into three groups and marked for recording group-wise observations. The observations were started in 1999 for phenological, flowering and fruiting behaviour, and fruit quality traits.

Observations for quantitative and qualitative component were made on 2 to 5 plants per group in each progeny (three groups/progeny) during July 2002 to February 2003. Crop was retained for *Mrig Bahar* flowering in July to September and fruiting in December to February and observations on plant growth, fruit yield and quality attributes were made. A mean growth and fruit character in each group was considered as a replication mean of the progeny. In this way, three group mean of a progeny was used to analyze the ANOVA and also for biometrical components of variability following standard statistical procedures as suggested by Panse (10), Panse and Sukhatme (11), Burton and De Vane (2) and Dewey and Lu (4). On the basis of assessment of fruit quality components in the plants within the progenies, individual plants of desirable characters were observed for two years during 2001-02 and 2002-03. Fruits from the identified plants of the potential progenies were harvested regularly from December to February during both the years to record observations on fruit quality. Three to five fruits/plant/month were harvested and the monthly mean of fruit characters was used to compare the individual plants of the progenies.

RESULTS AND DISCUSSION

The analysis of variance indicated high and significant differences in quantitative attributes, *viz.*, fruit weight (g), fruit length (cm), fruit diameter (cm), weight of 100 arils (g), aril length (cm), aril width (cm), [illegible] number of fruits/plant, fruit yield/plant (kg), plant height (cm) and plant spread (cm). Data on fruit quality characters of the progenies (Table 1) revealed wide variation in mellowness of aril (very hard to soft), colour of aril (white to blood red), taste of aril (slightly sweet to very sour) and fruit rind colour (yellowish, greenish, whitish, reddish tinge or their combinations). The fruit of F_1 progeny (DKS/H/97/003) and open pollinated progenies of Jalore Seedless (AHP/OP/JS/98/10 and AHP/OP/JS/98/15) possessed better table quality in comparison to that of the popular cultivar Jalore Seedless. These results are in general agreement with the findings of Karale (7).

The bio-metrical components of genetic variability measured in terms of genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability (h^2 broad sense), genetic advance (GA) as percentage of mean (genetic gain) based on quantitative characters of the progenies are given in Table 2. The results indicate a wide range of variability in fruit weight, fruit length, fruit diameter, weight of 100 arils, aril length, aril width, TSS, number of fruits/plant, fruit yield/plant, plant height and plant spread. The coefficient of variation (CV %) ranged from 0.84 percent in weight of 100 arils to 5.39 percent in number of fruits per plant.

The mean performance of the progenies depicted wide range of variation and that is not only for quantitative traits but also in qualitative characters including colour of fruit rind, mellowness, colour and taste of aril and TSS. It reveals that the phenomenon of transgressive segregation seems to be present in the progenies. This shows that the parents and source population from which open pollinated progenies are evolved heterozygous. In the present studies, parental combination (cross) generated several individuals consisting progeny of that combination. The average performance of a progeny was utilized for deriving the genetic behaviour of the progeny. The most promising individuals were selected considering the important commercial characters, *viz.*, fruit size, rind colour, high content of aril, boldness, red to dark red colour, soft to very soft aril and high TSS. The response of open pollinated progenies developed from fruits of seedling originated population (Jalore and Jodhpur areas of Rajasthan) were highly variable. This might be because of seedling originated orchard in heterozygous conditions, mixed seedling population of Jalore Seedless and Jodhpur Red in the orchards and cross pollination behaviour (attractive and heterostyle flower).

Absolute variability in different characters does not permit on deciding as to which character is showing the highest degree of variability. Therefore, estimates of [illegible] variance and coefficient of [illegible]. Maximum [illegible] was shown in fruit weight followed by plant height, plant spread, weight of 100 arils, and number of fruits per plant both at genotypic and phenotypic levels. In the present study, in general, the estimates of PCV were higher than GCV in all the characters but showed narrow differences (Table 2) implying that variability was due to genetic factors. The highest estimates of PCV and GCV were shown by fruit yield per plant and number of fruits per plant, respectively. Both the estimates were moderate for fruit weight. These results indicate that high magnitude of genetic variability existed for the fruit yield contributing traits, offering a good opportunity for improvement through selection. This is in consonance with the findings of Karale and Desai (8).

Table 1. Genotypic means for important traits of F_1 and open pollinated pomegranate progenies.

Progeny code	Fruit weight (g)	Weight of 100 arils (g)	Number of fruits/ plant	Fruit yield/ plant (kg)	Taste of aril	Mellowness of aril	Colour of aril	Fruit rind colour	Plant growth behaviour
DKS/H/97/001	115.29	24.68	18.12	2.14	Very sour	Very hard	Blood red	Y-R tinged	D
DKS/H/97/002	109.51	25.42	6.17	0.64	Very sour	Very hard	Red	Y-R tinged	D
DKS/H/97/003	142.30	24.53	14.75	1.91	Sweet	Soft	Dark red, red, pink	R-Y tinged	EG
DKS/H/97/004	84.35	20.91	4.27	0.36	Slightly sweet	Medium soft	Dark pink, pink	R tinged	Intermediate
DKS/H/97/005	55.48	17.02	7.44	0.42	Slightly sweet	Medium hard	Pink	R tinged	EG
DKS/H/97/007	114.27	23.11	9.46	1.06	Very sour	Hard	White, pink, red	Y-G	D
DKS/H/97/008	124.68	24.84	10.60	1.27	Sour	Hard	Red, dark pink	Light red-pink tinged	D
DKS/H/97/009	79.48	22.33	11.56	0.89	Slightly sweet	Hard	Light pink	Y-W-R tinged	D
DKS/H/97/010	115.12	32.97	11.23	1.29	Sour	Hard	Red, white pink	Y-W-R tinged	D
DKS/H/97/011	116.16	23.61	9.33	1.08	Very sour	Medium hard	Blood red, dark pink	R-Y	D
DKS/H/97/012	113.22	23.76	8.21	0.89	Sour	Hard	Light pink	Y-W-R tinged	EG
DKS/H/97/013	87.16	13.74	7.41	0.67	Slightly sweet	Hard	Light pink	Y tinged	EG
DKS/H/97/014	114.72	24.09	9.20	1.12	Slightly sweet	Medium soft	Blood red, red	Y-W-R tinged	EG
DKS/OP/97/006	126.16	26.51	13.72	1.66	Very sour	Hard	Red	Light red tinged	D
AHPG/OP/98/S_3	86.04	21.34	7.45	0.58	Very sour	Very hard	Red, pink	Y-G	D
AHPG/OP/98/S_{4A}	92.34	22.13	5.46	0.49	Very sour	Hard	Light red, pink	Y-G	D
AHPG/OP/98/S_{4B}	75.21	22.41	3.38	0.23	Very sour	Hard	Red	Y-G	D
AHP/OP/JS/98/01	69.17	22.55	7.45	0.48	Slightly sweet	Hard	Dark pink, pink	Y-G-R tinged	EG
AHP/OP/JS/98/02	60.22	22.75	9.44	0.55	Sour	Hard	Red	Y-G-R tinged	EG
AHP/OP/JS/98/04	58.84	22.44	8.41	0.49	Slightly sweet	Hard	Pink	Y-G-R tinged	EG
AHP/OP/JS/98/09	89.25	22.44	6.61	0.53	Slightly sweet	Hard	Pink	Y-G-R tinged	EG
AHP/OP/JS/98/10	115.42	25.15	11.36	1.25	Sweet	Soft	Red	Y-G-R tinged	EG
AHP/OP/JS/98/11	86.38	21.11	9.45	0.75	Slightly sweet	Medium hard	Pink	Y-G-R tinged	EG
AHP/OP/JS/98/15	111.35	22.84	11.94	1.18	Sweet	Soft	Red	Y-G-R tinged	EG
AHP/C/JS/98/1-9	133.66	25.69	11.35	1.48	Sweet	Soft	Light pink	Y-G-R tinged	EG
Mean	99.03	23.13	9.35	0.94	-	-	-		
CV (%)	1.35	0.84	5.40	5.72	-	-	-		
CD (P = 0.05)**	2.20	0.32	0.83	0.09	-	-	-		

Y - Yellowish; P - Pinkish, D - Deciduous; G - Greenish; R - Reddish, EG - Evergreen; W - Whitish.

Table 2. Biometrical components of genetic variability in pomegranate progenies.

Character	Range		Mean	CV (%)	CD (5%)	Vp	Vg	PCV (%)	GCV (%)	h^2 (%)	GA	GA as percent of mean
	Min.	Max.										
Fruit weight (g)	58.84	142.30	[illegible]9.03	1.35	2.20	591.86	590.06	24.56	24.52	99.7	49.96	50.45
Fruit length (cm)	4.18	6.85	5.41	1.76	0.16	0.85	0.84	17.01	16.92	98.9	1.87	34.57
Fruit diameter (cm)	4.32	6.34	5.29	1.73	0.15	0.61	0.60	14.78	14.67	98.6	1.59	30.03
Weight of 100 arils (g)	13.74	32.97	23.14	0.84	0.32	11.45	11.41	14.62	14.60	99.6	6.94	30.03
Aril length (cm)	0.83	1.05	0.93	2.39	0.04	0.003	0.003	6.39	5.93	85.9	0.11	11.34
Aril width (cm)	0.81	0.97	0.87	2.07	0.03	0.002	0.001	4.86	4.40	81.8	0.07	8.20
TSS (°Brix)	13.45	20.24	17.49	1.13	0.32	1.45	1.41	6.89	6.80	97.3	2.42	13.82
Number of fruits/plant	3.38	18.12	9.35	5.39	0.82	11.04	10.78	35.51	35.10	97.6	6.68	71.47
Fruit yield/plant (kg)	0.23	2.14	0.93	5.72	0.09	0.25	0.25	53.71	53.41	98.8	1.02	109.38
Plant height (cm)	93.87	135.03	[illegible]6.25	4.54	8.67	106.80	78.90	8.89	7.64	73.8	15.73	13.53
Plant spread (cm)	109.04	142.33	[illegible]29.77	4.24	9.05	83.22	52.82	7.03	5.60	63.4	11.93	9.19

Table 3. Genotypic and phenotypic correlation coefficient among fruit yield characters in pomegranate progenies.

Character		Fruit weight	Fruit length	Fruit diameter	Weight of 100 arils	Aril length	Aril width	TSS	Fruits/ plant	Fruit yield/ plant
Fruit weight	G	**1.000**	0.743	0.739	0.568	0.357	0.250	[illegible]	0.567	0.817
	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fruit length	G		**1.000**	0.944	0.273	0.137	0.051	0.085	0.477	0.678
	P			0.932**	0.272	0.134	0.038	0.081	0.469*	0.674**
Fruit diameter	G			**1.000**	0.407	0.165	0.107	0.263	0.581	0.743
	P				0.406*	0.148	0.086	0.256	0.565**	0.735**
Weight of 100 arils	G				**1.000**	0.379	0.394	0.771	0.418	0.520
	P					0.350	0.352	0.760**	0.410*	0.516**
Aril length	G					**1.000**	0.825	0.242	0.327	0.385
	P						0.682**	0.217	0.299	0.344
Aril width	G						[illegible]	[illegible]	[illegible]	[illegible]
	P							0.288	0.318	0.294
TSS	G							**1.000**	0.366	0.376
	P								0.355	0.369
Fruits/plant	G								**1.000**	0.931
	P									0.913**
Fruit yield/plant	GP									**1.000**

*, ** Significance at 5 and 1 percent, respectively.

Although GCV helps to measure the genetic variability in a character, it is not possible to partition the heritable variation with this alone. Burton (1) suggested that GCV together with heritability estimates would give the best results of the amount of genetic advance to be expected from a selection. The magnitude of heritability indicated the reliability of the genotypes with which they can be identified for their phenotypic expression. High estimates of broad sense heritability was obtained for fruit yield and quality components, whereas it was moderate for plant growth characters. The heritability was very high for fruit weight (99.7) followed by weight of 100 arils (99.6), number of fruits per plant (97.6) and fruit yield per plant (98.8). In the present studies, high heritability in fruit yield and quality characters may be due to low influence of non-genetic factors on the expression of the traits. Hanshe *et al.* (5) in peach, and Karale and Desai (8) in pomegranate also observed similar trends. Thus, selection of genotypes for these characters can be done on the basis of its own phenotypic performance.

The heritability variation can be estimated with greater degree of accuracy when heritability is studied along with genetic advance. A high heritability coupled with high genetic advance gives the most effective criteria for selection (Johnson *et al.*, 6). Genetic advance as percentage of mean (genetic gain) was very high for fruit yield per plant (109.38) followed by number of fruits per plant (71.47) and fruit weight (50.42), whereas it was moderate for fruit length and breadth and weight of 100 arils. Low estimates of genetic gain were recorded for TSS and aril length and width. Manohar *et al.* (9) also reported high estimates of GCV, heritability and genetic advance for arils per fruit, rind weight, fruit weight, number of fruits per tree and fruit yield per tree and suggested that improvement in these characters can be brought about by selection.

In the present study, high heritability estimates coupled with high genetic advance as percentage of mean were observed for fruit yield and number of fruits per plant and fruit weight indicating that the heritability for these characters might be due to additive gene effects. Further, these characters could be considered reliable selection indices. The characters with high heritability coupled with low genetic advance were recorded for fruit size, aril size and weight of 100 arils indicating that these characters are controlled by non-additive gene action. Thus, the reliability of improvement in these characters through selection would be relatively low and may require higher selection pressure.

Genotypic correlation coefficient, in general, were greater in magnitude than the corresponding phenotypic ones (Table 4), indicating that there was an inherent association among various characters and that phenotypic expression of correlation was lessened under the influence of environment. Fruit yield per plant showed highly significant positive correlation both at genotypic and phenotypic levels with respect to fruits per plant, fruit weight, fruit diameter and fruit length suggesting that these characters are the most important

Table 4. Fruit quality characters of elite plants of selected Pomegranate progenies.

Progeny code	Fruit weight (g)	Percent aril	Percent rind	Percent juice	Percent seed aril waste	Aril length (cm)	Aril width (cm)	TSS (°Brix)	Acidity (%)	Juice colour
DKS/H/97/003/3	84.28	60.35	38.07	43.74	13.43	1.16	0.756	17.56	0.55	Dark Red
DKS/H/97/003/16	122.35	61.26	36.44	42.26	12.72	1.02	0.766	18.44	0.58	Blood Red-Red
DKS/H/97/003/21	118.47	60.86	34.82	43.03	17.35	1.03	0.768	17.65	0.40	Red
DKS/H/97/003/17	90.73	57.41	40.89	36.35	14.64	1.11	0.759	17.53	0.40	Dark Red
DKS/H/97/003/22	149.31	66.75	30.71	38.30	16.21	1.02	0.779	17.60	0.58	Red
AHP/OP/JS/98/10/45	130.88	59.60	36.04	36.43	17.59	1.04	0.786	16.41	0.38	Dark Pink
Range	83.5-152.3	56.5-67.4	30.2-41.2	35.6-44.6	11.9-17.6	1.0-1.2	0.74-0.79	16.2-18.6	0.34-0.59	
Mean	112.65	61.04	36.24	40.02	15.3	1.06	0.77	17.53	0.478	
SD	23.15	3.00	3.20	3.22	1.95	3.05	0.014	0.62	0.10	
CV (%)	20.00	4.90	8.90	8.00	12.80	5.10	1.80	3.60	20.90	

yield contributing components and that effective improvement in fruit yield can be achieved through selection based on these traits. Fruit weight had highly significant and positive correlation with fruit diameter, fruit length and weight of 100 arils. Desai *et al.* (3) observed similar trends for character association between fruit yield components in pomegranate. Interestingly, the fruit number and fruit size were also positively correlated. It indicates that in pomegranate the progenies producing more fruits have also genetical potential to give bigger fruits.

On the basis of the analysis of quantitative characters for component of variability, it is evident that number of fruits per plant, fruit yield per plant, fruit weight and weight of 100 arils deserves due weightage while formulating selection strategies for improvement in pomegranate. Thus, selection of superior types based on fruit yield components would be effective after ensuring the acceptable fruit quality components in the breeding material. For selection of desirable individuals within a heterozygous progeny/population developed through combination of heterozygous parents/population, selection of desirable individuals can be done on the basis of deviation from the mean of the progeny population. Therefore, the best individuals under heterozygous progeny/population having better fruit quality and yield performance could be identified for further clonal evaluation to select the most promising types.

The mean, CV and standard deviation for fruit yield and quality components of desirable plants of the two progenies is presented in Table 4. Six selected isolates excelled in fruit quality and also considered more potential for economic attributes than the population mean of the progeny under study as well as the fruit quality of popular cv. Jalore Seedless. Data revealed that a considerable range of variations exits in all the fruit quality characters among the individuals. This type of situation suggests that the best performing individuals having excellent fruit quality can be further tested under arid environment for high yield potential after clonal multiplication.

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