

Assessment of phenotypic variability, its heritable components and character association in pomegranate (*Punica granatum*) genotypes

DINESH SINGH¹, NIRMAL SHARMA² and K KUMAR³

Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh 173 230

Received: 4 December 2009; Accepted: 14 May 2010

ABSTRACT

A study was conducted during 2007 and 2008 among 16 pomegranate (*Punica granatum* L.) genotypes to estimate the genetic variability in respect of various quantitative and qualitative traits and their association with each other. Wide range of phenotypic variability and genotypic variability was observed in almost all the tree and fruit characters, particularly plant height, plant spread, plant volume, fruit weight, aril size, aril content, TSS, acidity, sugar content and yield/plant. High variability exists for fruit yield-contributing traits, offering opportunity for improvement through selection. Individual plant selection for yield, aril percentage, fruit weight, number of arils and aril : rind ratio would be satisfactorily effective in pomegranate as these characters exhibited high heritability as well as high genetic advance.

Key words: Character association, Heritability, Pomegranate, Variability

Pomegranate (*Punica granatum* L.) is an important fruit of tropical and subtropical regions of the world and has originated in Persia, Afganistan and Baluchistan (De Candolle 1967). In India, its cultivation is scattered all over the country especially in Maharashtra, Rajasthan, Gujarat, Karnataka and Andhra Pradesh. Pomegranate fruits have high nutritive and therapeutic value, excellent keeping quality and high market demand. Therefore, its cultivation is most lucrative and remunerative. In India, pomegranate cultivation is dependent upon the seedling selections from open pollinated varieties and few hybrids. Though the pomegranate improvement work started as early as 1905 but it took long time to start with concentrated efforts on genetic improvement and still exploration for a better cultivar is going on, as most of the commercial cultivars lack one or the other desirable traits. The assessment of variability is the first step in any breeding programme and the progress depends on the extent of genetic variability present in various biometric characters in the gene pool. But few reports are available pertaining to the extent of variability in pomegranate on various quantitative characters. Since, most of the plant characters of economic importance are polygenic in nature and are highly influenced by environmental fluctuations, therefore, it is difficult to judge whether the observed variability is due to environment or genetics of an individual.

¹Assistant Scientist (email: dinesh_hort@yahoo.com), ²Research Associate (email: sharmanirmal.77@gmail.com), ³Professor and Head, (email: fruitbreeding@gmail.com), Department of Fruit Breeding and Genetic Resources

This suggests the imperative need of partitioning the phenotypic variation into its heritable and non-heritable components. For a successful hybridization programme with efficient utilization of the resources, knowledge of association of different characters is the most useful prerequisite. This will help to screen the progeny at early stage which is substantially large in case of pomegranate. The present studies were therefore undertaken to estimate the genetic variability in respect of various quantitative and qualitative traits with the hope that such information may be useful for further crop improvement programmes.

MATERIALS AND METHODS

A study was undertaken at the experimental farm of the Department of Fruit Breeding and Genetic Resources, Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh during 2007 and 2008. Three replicates of 16 pomegranate genotypes, viz 'Anar Shirin Muhammad Ali', 'Bush Dwarf', 'Bush Large', 'Ganesh', 'G-137', 'Alok', 'Suni Bedana', 'China Seedling', 'Muskat White', 'Gula Shah', 'Mridula', 'Chawla', 'Jodhpur Red', 'Kandhari Hansi', 'PS 75-K-5' and 'Afghan Kandhari' consisted of the base material for the present study. Detailed observations were recorded for 20 tree and fruit characters, viz plant height (m), plant spread (m), plant volume (m³), average stem girth (cm), fruit weight (g), fruit length (cm), fruit diameter (cm), rind thickness (cm), number of arils, aril percentage (%), aril rind ratio, aril length (cm), aril breadth (cm), 100 aril weight (g), Juice per cent (%), TSS

(°B), acidity (%), reducing sugar (%) and non-reducing sugar (%) as per the standard procedures suggested by Ranganna (1986). The data were statistically analyzed for each character by analysis of variance as suggested by Panse and Sukhatme (1961) from which different variance components estimated. Heritability estimates (broad sense) were computed by the formula suggested by Hanson *et al.* (1956). The coefficients of genetic variation were estimated by the methods described by Burton (1952). The expected genetic advance resulting from selection of top 5% individuals from the population was computed by the formula suggested by Johnson *et al.* (1955) and the genetic gain was expressed as per cent of genetic advance over the population mean. Co-relationship of the characters was worked out as described by Panse and Sukhatme (1961) and the direct and indirect effects of independent traits on fruit yield/plant was estimated by the method of Dewey and Lu (1959).

RESULTS AND DISCUSSION

Assessment of the phenotypic variability is a prerequisite of any breeding programme as to select desirable genotypes. A wide range of phenotypic variability was observed in almost all the characters studied particularly plant height, plant spread, plant volume, fruit weight, aril size, aril per cent, TSS, acidity, sugar content and yield. Analysis of variance (Table 1) revealed significant varietal differences for all the 16 characters. The estimates of range in variation, average mean performance, genotypic and phenotypic

coefficients of variation, heritability. Genetic advance and genetic gain are presented in Table 2. The genotypic coefficient of variability measures and compares the range of genetic variability present in various characters. Maximum variation was observed in yield/plant, followed by fruit weight, acidity, non-reducing sugars, number of arils, aril : rind ratio, plant spread, reducing sugars, plant height and plant volume both at phenotypic and genotypic levels. The genotypic coefficient of variation ranged from 5.51% in TSS to 71.98% for fruit yield/plant and characters, such as plant spread, number of arils, aril : rind ratio, acidity, reducing sugars and non-reducing sugars showed comparatively high genotypic coefficient of of variation, whereas the remaining characters exhibited low to medium genotypic coefficient of variation (Table 2). Similarly, Prasad and Bankar (2000) recorded considerable phenotypic variability in characters like plant height, plant spread, fruits/plant, fruit weight, fruit size, aril content, acidity and sugar contents while studying different pomegranate genotypes. In the present study, in general the estimates of phenotypic coefficient of variation (PCV) were higher than genotypic coefficient of variation (GCV) in all the characters. The highest estimates of PCV and GCV were shown by the character yield/plant and the estimates were moderate for the yield-contributing characters, ie fruit weight, fruit length, number of arils, aril percentage and fruit diameter. Thus it may be concluded that high variability exists for fruit yield-contributing traits, offering opportunity for improvement through selection. The results are in consonance with the findings of Samadia and Pareek (2006).

As it is not possible to authenticate the heritable amount of variation with the help of genotypic coefficient of variation, it was further assessed with the help of heritability (broad sense) estimates. Heritability ranged from 43.91 (average stem girth) to 94.30% (acidity). The highest heritability estimate was observed for acidity (94.30%), followed by 93.21% (fruit weight), 91.50% (number of arils) and 91.05% (yield/plant). Low to moderate heritability was observed for plant height (74.21%), plant volume (70.58%), fruit length (62.05%), fruit diameter (69.82%), rind thickness (55.72%), aril length (65.21%), TSS (52.70%), reducing sugars (80.40%) and non-reducing sugars (61.85%). Mishra *et al.* (1983) reported 34.89 to 96.81% heritability in different biometric traits of pomegranate. The high estimates of heritability are helpful as it enables the breeders to base the selection programme on phenotypic performance. Earlier Samadia and Pareek (2006) suggested that heritability estimates in conjunction with genetic advance are usually more helpful in predicting its resultant effect from selecting the best individuals. Heritability in broad sense, as it includes both additive as well as epistatic gene effects shall be reliable only if accompanied by high genetic advance (Singh *et al.* 2009)). In the present study, genetic advance expressed in percentage of mean ranged from 0.11% in rind thickness and

Table 1 Analysis of variance for tree and fruit characters

Character	Mean squares		
	Replication	Treatment	Error
d.f.	2	15	30
Plant height (m)	0.02	1.158*	0.05
Plant spread (m)	0.086	1.10*	0.19
Plant volume (m ³)	15.46	29.76*	8.13
Average stem girth (mm)	13.78	290.32*	4.87
Fruit weight (g)	501.75	25991.0*	58.28
Fruit length (cm)	7.06	13.21*	6.15
Yield (kg/plant)	29.68	106.77*	12.78
Fruit diameter (cm)	1.98	9.23*	1.82
Rind thickness (cm)	0.01	0.02*	0.002
Number of arils	429.02	83942. 2*	9.30
Aril content (%)	15.52	636.71*	11.45
Aril : rind ratio	0.11	0.80*	0.05
Aril length (cm)	0.06	0.10*	0.06
Aril breadth (cm)	0.04	0.03*	0.013
100 aril weight (g)	6.20	91.22*	0.53
Juice percentage	22.34	311.56*	20.43
TSS (°B)	2.44	6.37*	1.25
Acidity (%)	0.39	0.47*	0.32
Reducing sugars (%)	3.46	23.73*	1.69
Non-reducing sugars (%)	0.88	1.70*	0.57

*P=0.05

Table 2 Estimates of range, mean, phenotypic coefficient of variation, genotypic coefficient of variation, heritability, genetic advance and genetic gain in different pomegranate genotypes

Character	Range	Mean	Coefficient of variation (%)		Heritability (%)	Genetic advance	Genetic gain (%)
			Phenotypic	Genotypic			
Plant height (m)	1.60 – 3.33	2.37	25.52	18.94	74.21	1.44	21.96
Plant spread (m)	1.02 – 2.20	1.57	35.20	28.97	82.29	0.24	15.29
Plant volume (m ³)	0.16 – 15.65	6.93	38.75	27.35	70.58	1.91	27.56
Average stem girth (mm)	11.28 – 43.5	31.65	30.82	13.53	43.91	4.70	14.85
Fruit weight (g)	104.67 – 465.33	214.92	43.26	40.32	93.21	82.71	38.48
Fruit length (cm)	5.14 – 9.63	7.14	21.48	13.33	62.05	3.76	52.66
Yield (kg/plant)	1.84 – 24.60	7.08	79.06	71.98	91.05	8.20	115.82
Fruit diameter (cm)	5.62 – 9.88	7.31	21.49	15.00	69.82	3.44	47.06
Rind thickness (cm)	0.16 – 0.45	0.29	27.55	15.35	55.72	0.11	37.93
Number of arils	280 – 719	466.96	35.82	32.78	91.50	42.09	9.01
Aril content (%)	35.87 – 71.96	60.94	23.69	20.86	88.07	30.55	50.13
Aril: rind ratio	1.42 – 2.28	1.74	28.78	23.73	82.46	0.62	35.63
Aril length (cm)	0.95 – 1.16	0.99	12.64	8.24	65.21	0.28	28.28
Aril breadth (cm)	0.58 – 0.80	0.65	10.89	9.12	83.77	0.11	16.92
100 aril weight (g)	19.72 – 40.68	29.56	18.60	8.20	44.10	11.23	37.99
Juice percentage	59.67 – 75.67	68.84	14.31	9.91	69.26	10.32	14.99
TSS (°B)	10.10 – 14.13	12.50	10.45	5.51	52.70	1.40	11.20
Acidity (%)	0.16 – 1.13	0.56	38.92	36.70	94.30	0.28	50.00
Reducing sugars (%)	7.95 – 10.28	8.76	30.94	24.88	80.40	2.61	29.79
Non-reducing sugars (%)	0.87 – 2.85	1.53	40.13	24.82	61.85	0.32	20.92

aril breadth to 82.71% in fruit weight. Mishra *et al.* (1983) reported 7.14–59.26% genetic advance in different biometric traits of pomegranate. High heritability was associated with high genetic advance for most of the characters. Fruit weight, yield/plant, number arils, aril content, aril: rind ratio, acidity and reducing sugars had high heritability along with high genetic advance which indicated that high heritability obtained for these characters was probably due to additive gene effects (Panse and Sukhatme 1961). While studying the phenotypic and genotypic variability among different pomegranate genotypes, Samadia and Pareek (2006) also concluded that characters, viz fruit weight, acidity, fruits/plant, arils/fruit and yield possessed high heritability along with high genetic advance. Other characters exhibited comparatively lower heritability and/or low genetic advance, indicating that dominance or epistatic effects are of considerable value for these characters and hence little improvement in these characters is possible through selection (Panse 1957). Genetic advance as percentage of mean (genetic gain) was very high for yield/plant (115.82%), followed by fruit length (52.66%), aril percentage (50.13%), acidity (50.00%), fruit diameter (47.06%), fruit weight (38.48%), 100 aril weight (37.99%), rind thickness (37.93%) and aril: rind ratio (35.63%). Thus, individual plant selection for yield/plant, aril percentage, fruit weight, number of arils, aril: rind ratio and acidity may be effective to a considerable extent in pomegranate as these characters exhibit high heritability as well as high genetic advance. Samadia and Pareek (2006) also reported high estimates of GCV,

heritability and genetic advance for number of arils, aril weight, fruit weight, number of fruits/plant and yield/plant and suggested that improvement in these characters could be brought about by selection.

Correlation: For a successful hybridization programme with efficient utilization of the resources, knowledge of association of commercially important traits is of most useful pre-requisite. This helps in screening the progeny at an early stage, which is substantially large as in case of pomegranate. Genotypic correlation coefficients in general were higher than the corresponding phenotypic correlation coefficients (Table 3) implying inherent association among different characters and lower values of phenotypic coefficients, indicating the environmental influence lowering the value of genotypic correlation (Samadia and Pareek 2006). Plant height was positively and significantly correlated with plant volume but exhibited no significant co-relationship in either way with yield characteristics but plant spread was found to be positively correlated with yield and number of characters. Similarly, Meena *et al.* (2009) also observed no correlation of plant height with plant volume and yield. However plant spread was positively and significantly correlated with plant volume, fruit weight, fruit length, fruit diameter, fruit yield, fruit diameter, number of arils, aril percentage and 100-aril weight, thus, emphasis needs to be given on this character in selection of parents and progeny screening. Plant volume was positively and significantly associated with plant height, plant spread, fruit weight, fruit length, fruit diameter, yield/plant, aril length and aril breadth (yield attributes). Fruit yield/

Table 3 Correlation coefficients at genotypic (G) and phenotypic (P) levels with respect to yield and its component traits in different pomegranate genotypes

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19	X20	
X1	G	0.000																			
X2	P	0.000																			
X3	G	0.229-	0.000																		
X4	P	0.205	0.000																		
X5	G	0.885	0.611**	0.000																	
X6	P	0.246	0.590	0.000																	
X7	G	0.132	-0.217	-0.265	0.000																
X8	P	0.112	-0.196	-0.246	0.000																
X9	G	-0.156	0.478**	0.440*	0.283	0.000															
X10	P	-0.138	0.446	0.431	0.256	0.000															
X11	G	-0.104	0.451**	0.454**	0.270	0.661**	0.000														
X12	P	-0.091	0.436	0.439	0.245	0.643	0.000														
X13	G	0.312	0.697**	0.607**	0.257	0.618**	0.498**	0.000													
X14	P	0.291	0.670	0.590	0.238	0.601	0.480	0.000													
X15	G	0.135	0.491**	0.531**	0.192	0.776**	0.521**	0.773**	0.000												
X16	P	0.110	0.473	0.518	0.176	0.754	0.508	0.748	0.000												
X17	G	-0.171	0.085	0.173	-0.256	0.481**	0.272	0.149	0.275	0.000											
X18	P	-0.126	0.059	0.161	-0.233	0.460	0.258	0.131	0.236	0.000											
X19	G	-0.278	0.442	0.139	-0.193	0.710**	0.699**	0.465**	0.443*	-0.128	0.000										
X20	P	-0.228	0.434	0.125	-0.178	0.707	0.671	0.456	0.429	-0.101	0.000										
X21	G	-0.126	0.241	0.216	-0.288	0.742**	0.469**	0.631**	0.478**	-0.240	0.481**	0.000									
X22	P	-0.108	0.225	0.208	-0.259	0.734	0.441	0.618	0.452	-0.208	0.443	0.000									
X23	G	-0.250	0.063	0.198	0.111	0.258	0.219	0.431*	0.315	-0.371	0.149	0.595**	0.000								
X24	P	-0.221	0.049	0.174	0.103	0.235	0.102	0.404	0.292	-0.334	0.131	0.547	0.000								
X25	G	-0.152	-0.139	0.466**	0.204	0.231	0.335	0.180	0.121	0.294	-0.444*	0.555**	0.228	0.000							
X26	P	-0.127	-0.134	0.451	0.187	0.209	0.319	0.159	0.101	0.273	-0.432	0.522	0.196	0.000							
X27	G	-0.306	-0.144	0.454*	0.203	0.321	0.241	0.241	0.165	0.146	-0.491**	0.637**	0.372	0.271	0.000						
X28	P	-0.281	-0.121	0.444	0.184	0.296	0.228	0.228	0.134	0.115	-0.465	0.606	0.348	-0.216	0.000						
X29	G	0.233	0.243	0.276	-0.202	0.510**	0.255	0.539**	-0.263	-0.152	0.276	0.390*	0.163	0.259	0.1466	0.000					
X30	P	0.210	0.220	0.252	-0.194	0.507	0.231	0.511	-0.229	-0.121	0.242	0.341	0.131	0.214	0.134	0.000					
X31	G	0.192	0.162	0.478**	0.225	0.275	0.181	0.397*	0.391*	0.218	0.301	0.578**	0.449	0.382*	0.381*	0.205	0.000				
X32	P	0.169	0.143	0.459	0.198	0.248	0.162	0.363	0.352	0.184	0.263	0.541	0.433	0.338	0.342	0.189	0.000				
X33	G	0.144	-0.103	0.188	0.199	0.147	0.226	0.134	0.127	0.110	0.279	0.256	0.244	0.256	-0.135	0.517**	0.000				
X34	P	0.116	-0.088	0.161	0.178	0.107	0.210	0.110	0.098	0.087	0.230	0.201	0.210	0.221	-0.114	0.501	-0.083	0.000			
X35	G	0.098	0.304	0.215	-0.105	-0.329	-0.182	-0.115	0.207	-0.216	-0.320	0.278	-0.114	-0.199	-0.140	0.092	-0.138	0.356	0.000		
X36	P	0.072	0.289	0.202	-0.094	-0.315	-0.163	-0.091	0.186	-0.172	-0.281	0.226	-0.082	-0.156	-0.103	0.059	-0.109	0.321	0.000		
X37	G	0.146	0.182	0.166	0.156	0.219	0.286	-0.144	0.181	0.195	0.205	0.101	-0.145	-0.105	0.186	0.126	0.272	0.492	-0.188	0.000	
X38	P	0.101	0.169	0.152	0.144	0.204	0.240	-0.102	0.142	0.147	0.178	0.079	-0.111	-0.086	0.131	0.091	0.231	0.463	-0.154	0.000	
X39	G	0.158	0.182	0.166	0.247	0.199	0.123	-0.210	0.157	0.119	0.108	0.092	-0.119	-0.164	0.130	0.096	0.210	0.302	-0.106	0.176	0.000
X40	P	0.126	0.141	0.131	0.228	0.176	0.091	-0.186	0.128	0.086	0.088	0.036	-0.088	-0.128	0.116	0.072	0.191	0.271	-0.089	0.111	0.000

*P=0.05; **P=0.01

X1, Plant height; X2, plant spread; X3, plant volume; X4, average stem girth; X5, fruit weight; X6, fruit length; X7, yield/plant; X8, fruit diameter; X9, rind thickness; X10, number of arils; X11, aril content; X12, aril rind ratio; X13, aril length; X14, aril breadth; X15, 100 aril weight; X16, juice percentage; X17, TSS; X18, acidity; X19, reducing sugars; X20, non-reducing sugars

Table 4 Direct (in diagonal) and indirect (others) effects of various tree and fruit characters on yield/plant in different pomegranate genotypes

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19	Correlation
X1	-0.255	-0.705	1.453	-0.241	0.048	0.001	0.000	-0.001	-0.018	0.009	0.120	0.007	0.099	0.016	0.005	0.023	0.173	-0.002	-0.020	0.312
X2	-0.202	0.887	1.508	-0.234	0.129	0.000	-0.015	0.046	-0.001	0.017	0.030	-0.002	0.078	0.011	0.003	0.034	0.254	-0.051	-0.023	0.697
X3	-0.226	-0.815	1.641	-0.211	0.120	0.000	-0.011	0.040	-0.002	0.016	0.047	0.003	0.086	0.014	0.006	0.012	0.158	-0.053	-0.021	0.607
X4	-0.135	-0.458	0.763	-0.453	0.249	-0.002	-0.038	0.248	0.012	0.050	-0.005	-0.019	0.095	0.009	0.011	0.013	-0.053	0.026	-0.057	0.257
X5	-0.024	-0.222	0.384	-0.219	0.515	-0.004	-0.075	0.446	0.045	0.032	0.076	-0.034	0.127	0.024	-0.014	-0.020	-0.216	-0.087	-0.064	0.618
X6	0.026	0.059	-0.108	-0.213	0.451	0.405	-0.070	0.414	0.050	0.023	0.000	-0.034	0.084	0.011	-0.011	-0.013	-0.320	-0.048	-0.054	0.498
X7	-0.001	-0.175	0.229	-0.223	0.503	-0.005	-0.077	0.438	0.047	0.030	-0.056	-0.039	0.120	0.019	-0.013	-0.004	-0.205	-0.080	-0.071	0.773
X8	0.000	-0.075	0.120	-0.207	0.423	-0.004	-0.062	0.043	0.027	0.028	-0.156	-0.033	0.097	0.012	-0.011	-0.038	-0.260	-0.049	-0.053	0.149
X9	0.073	0.017	-0.063	-0.087	0.366	-0.004	-0.057	0.233	0.063	0.015	0.015	-0.023	0.024	0.004	-0.005	-0.017	-0.262	-0.085	-0.027	0.465
X10	0.032	0.214	-0.355	0.311	-0.228	0.002	0.032	-0.214	-0.013	0.172	0.240	0.015	-0.080	-0.013	-0.006	0.005	0.140	-0.022	0.048	0.631
X11	-0.064	-0.056	0.161	0.005	-0.082	0.000	0.009	-0.177	0.002	-0.036	0.479	0.011	-0.014	0.008	0.017	0.008	0.009	-0.008	-0.002	0.431
X12	0.039	-0.030	-0.108	-0.183	0.372	-0.004	-0.063	0.377	0.30	0.023	-0.109	-0.048	0.091	0.004	-0.007	0.021	-0.100	-0.068	-0.072	0.180
X13	-0.133	0.367	0.745	-0.228	0.345	-0.002	-0.049	0.278	0.008	0.031	-0.036	-0.023	0.190	0.032	-0.017	0.018	-0.020	-0.040	-0.068	0.341
X14	-0.085	-0.216	0.501	-0.091	0.263	-0.001	-0.032	0.134	0.005	0.20	0.078	-0.004	0.128	0.110	-0.005	-0.029	-0.074	-0.033	-0.059	0.539
X15	0.023	0.055	-0.207	0.102	0.142	-0.001	-0.020	0.118	0.006	-0.008	-0.165	-0.007	0.063	0.005	-0.050	0.042	0.019	-0.012	0.023	0.397
X16	-0.044	-0.227	0.145	-0.045	-0.076	0.000	-0.002	-0.153	-0.008	0.002	0.029	-0.008	0.026	-0.010	0.016	0.134	0.279	0.041	-0.034	0.134
X17	0.088	0.446	-0.516	-0.048	0.221	-0.003	0.031	0.281	0.033	0.020	-0.009	-0.009	0.008	0.007	0.002	-0.074	-0.054	-0.012	-0.013	0.115
X18	0.003	0.269	-0.522	-0.071	-0.267	0.001	0.037	-0.160	-0.032	0.009	-0.022	0.019	-0.046	-0.009	0.004	0.033	0.036	0.167	0.006	0.144
X19	-0.040	-0.161	0.273	-0.202	0.257	-0.002	-0.043	0.227	0.013	0.027	0.009	-0.027	0.101	0.022	0.009	0.036	-0.053	-0.007	-0.128	0.210

Residual effects: 0.0136

Italic figures represent direct effects

X1, Plant height; X2, plant spread; X3, plant volume; X4, average stem girth; X5, fruit weight; X6, fruit length; X7, fruit diameter; X8, rind thickness; X9, number of arils; X10, aril content; X11, aril : rind ratio; X12, aril length; X13, aril breadth; X14, 100 aril weight; X15, juice percentage; X16, TSS; X17, acidity; X18, reducing sugars; X19, non-reducing sugars

plant was positively and significantly correlated with plant spread, plant volume, fruit length, fruit weight, fruit diameter, number of arils, aril content, aril : rind ratio and 100 aril weight. Thus, these characters are most important yield contributing components and yield could be improved through selection based on these characters. Fruit weight was positively and significantly associated with plant spread, plant volume, fruit length, fruit diameter, number of arils, aril content, aril length, aril breadth, 100 aril weight and juice percentage whereas it was negatively correlated with acidity. Similar trend of characters association was observed by Samadia and Pareek (2006) between yield-contributing components in pomegranate. Juice percentage was positively correlated with plant volume, yield, fruit diameter, aril : rind ratio, aril percentage and aril length, but was negatively correlated with TSS, acidity and aril percentage, aril percentage in turn was positively correlated with fruit weight, fruit length, yield, fruit diameter, number of arils, aril : rind ratio, aril length, aril breadth, 100 aril weight and juice percentage. These results are in consonance with those reported by Samadia and Pareek (2006). Thus, it may be concluded that characters such as plant spread, plant volume, fruit length, fruit weight, fruit diameter, number of arils, aril content, aril : rind ratio and 100 aril weight deserve due attention while deciding selection strategy for improvement of pomegranate.

Path analysis: For path analysis, 19 different tree and fruit characters were considered as variables and fruit yield/plant was taken as a dependent variable. The direct and indirect effects of different characters were worked out and are presented in Table 4. Plant height, plant spread, plant volume, fruit weight, aril : rind ratio and aril content were positively associated with fruit yield. The procedure provides information about the cause and effect situation and helps in understanding the cause of relationship between variables. The direct and indirect effects of different characters on plant yield have been studied by different workers on different fruit crops like pecan nut (Kaushal 2000) and walnut (Singh *et al.* 2009).

REFERENCES

Burton G W. 1952. Quantitative inheritance in grasses. *Proceedings of 6th International Congress* 1: 277-83.
 De Candolle A. 1967. *Origin of Cultivated Plants*, pp 237-41. Hafner Pub. Co. New York.
 Dewey D R and Lu K H. 1959. A correlation and path coefficient analysis of components of crested wheat grass seed production. *Agronomy Journal* 51: 515-8.
 Hanson C H, Robinson H F and Comstock R E. 1956. Biometric studies of yield in segregating population of Korean leopedeza. *Agronomy Journal* 46: 286-92.
 Johnson H W, Robinson H F and Comstock R E. 1955. Estimates of genetic and environmental variability in soyabeans. *Agronomy Journal* 47: 314-8.
 Kaushal R. 2000. 'Studies on variability and selection of superior

- seedling trees in Himachal Pradesh'. Ph D thesis. Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh.
- Mishra R S, Srivastva R P and Kuksal R P. 1983. Evaluation of some pomegranate cultivars for valley areas of Garhwal hills. *Progressive Horticulture* **15** (1-2): 24–6.
- Panse V G and Sukhatme P V. 1961. *Statistical Methods for Agricultural Workers*. ICAR, New Delhi.
- Panse V G. 1957. Genetics of quantitative characters in relation to plant breeding. *Indian Journal of Genetics and Plant Breeding* **17**: 318–28.
- Prasad R N and Bankar G J. 2000. Evaluation of pomegranate cultivars under arid conditions. *Indian Journal of Horticulture* **57**(4): 305–8.
- Ranganna S. 1986. *Handbook of Analysis and Quality Control for Fruit and Vegetable Products*, 2nd edn. Tata Mc Graw Hill, New Delhi.
- Samadia D K and Pareek O P. 2006. Fruit quality improvement under hot arid environment. *Indian Journal of Horticulture* **63** (2): 126–32.
- Singh D, Singh M and Kumar K. 2009. Manifestation of genetic variability and correlation studies in seedling tree of walnut (*Juglans regia* L.). *Advances in Horticultural Sciences* **23**(1): 29–32.