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Genetic variability and correlation studies in grapes (*Vitis vinifera* L.) in Leh District of Jammu and Kashmir

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Abstract: The present investigations on genetic variability and correlation in wild grape accessions were carried out in the most favourable regions of Leh district of Jammu and Kashmir. Fifty wild grape accessions from five different villages of the district were marked and evaluated for important morphological traits i.e. yield and quality parameters. Data on various vegetative, fruit physical and fruit chemical characters were taken. Significant variations were observed for all the characters studied except number of seeds per berry. High genotypic coefficient of variance (GCV) and phenotypic coefficient of variance (PCV) were recorded for yield (21.73 and 22.81), yield efficiency (41.19 and 52.73), bunch weight (21.07 and 21.23), number of berries per bunch (22.31 and 25.28), berry length (21.69 and 22.07), berry weight (21.13 and 21.28) and total sugars (22.69 and 22.70). Out of twenty studied characters, thirteen characters registered high heritability estimates, while five recorded moderate heritability estimates and number of seeds per berry and acidity showed low heritability estimates. However, cane length (59.40), leaf area (31.43), bunch weight (43.16), number of berries per bunch (27.18) and TSS/acid ratio (25.81) exhibited high genetic advance as percentage of mean indicating additive gene effect. Fruit or berry yield was positively and significantly correlated with bunch length (0.652), bunch breadth (0.584), bunch weight (0.946), number of berries per bunch (0.672), berry breadth (0.363) and number of seeds per berry (0.612). This study revealed that the characters such as yield, bunch length, bunch weight, number of bunch per vine, berry weight, number of berries per bunch, total soluble solids and total sugars are the most important traits for selecting best grape accessions.

1. Introduction

Grape (*Vitis vinifera* L.) is an economically important and widely cultivated fruit crop in the world and is the first fruit crop to be cultivated by man to produce table fruits, dry fruits, juice and wine (Frederique *et al*., 2010). It is a fairly good source of minerals like calcium, phosphorus, iron and vitamins like B_1 and B_2. The area under grape cultivation in India is 118.700 hectares with production of 2585.300 kg (NHB, 2015). In Jammu and Kashmir, grapes are grown over an area of 315 ha with annual production of 1299 MT (Department of Horticulture, 2016). The grapes are

quite heterozygous and seedling off-springs exhibit wide genetic variability not only in fruit quality but also in vegetative vigour. Because of these variations, seeds are not used for propagation of vines meant for commercial purpose. More than 9,600 grape cultivars exist around the world (Galet, 2000) and as per international variety catalogue almost 16,000 prime names appear in the genus *Vitis* (Maul and Eibach, 2003). To preserve the current genetic pool and to use it judiciously, it is necessary to evaluate the extent of this diversity by identification and distinction of grape accessions, as well as the determination of genetic relationship between local cultivars and wild relatives (Negrul, 1973). Wild grapevines (*Vitis vinifera* L.) are heavily threatened in their natural habitats and high priority is given to the collection and preservation of this germplasm (Forneck *et al*., 2003). Indeed, the preservation of wild populations is considered essential for the maintenance of genetic variability and the resistance to genetic erosion (Cunha *et al*., 2009).

Grape is grown under a variety of soil and climatic conditions in three distinct agro-climatic zones namely mild humid tropical region, sub-tropical region and dry temperate region. Under dry temperate region of Jammu and Kashmir the maximum area is in lower belt of Leh district (Angchok *et al.*, 2009). During the early period, when Ladakh was the transit point on the Central Asian trade route, the traders, nomads and invaders from Yarkand, Baltistan, Punjab, Kashmir, China and Tibet used to pass through this region (Jolden, 2012) and the grape vines got disseminated or introduced in the lower belt of Leh district. The cultivation of grapes in Leh offers a greatest advantage by being ready for harvesting during the month of August-September which is an off season for the rest of the country and can therefore fetch higher remuneration. Keeping in view the economic importance of grapes and to boost its cultivation in the Leh District, the present investigation was carried out to generate the vital information on the existing germplasm of grape vine in the Leh district and selection of elite clones for further multiplication and distribution among the farmers.

2. Materials and Methods

Experimental material and area

Thorough surveys of different areas of Ladakh region was carried out during 2014 and out of a large population of wild grape only fifty accessions were selected from five different villages [Warseedo (4), Achinathang (21), Yokmathang (7), Hanuthang (5) and Dha (13)] of Leh district. The vines were marked on the basis of health, vigour, bearing habit and desirable berry characters. All the marked vines were of seedling origin ranging an age of between 20 to 60 years. The weather and geographical features of the studied location are represented in figure 1.

Fig. 1 - Weather and geographical features of the area surveyed.

Observations recorded

Observations were recorded on vegetative, foliage, fruit physical and chemical characters. Data was recorded on the various characters such as cane length (m), cane diameter (cm), internodal length (cm), leaf area (cm^2), yield (kg/vine). Yield efficiency was calculated as per Westwood (1993).

$$\text{Yield efficiency (kg/cm}^2\text{)} \frac{\text{Yield}}{\text{Trunk cross selectional area}}$$

Where, Trunk cross sectional area (TCSA) = $\text{girth}^2/4\ \pi$. With respect to bunch and berry physical characters i.e. bunch length (cm), bunch breadth (cm), berry length (cm) and berry breadth (cm) were recorded with the help of vernier caliper. For these characters randomly ten bunches and ten berries were taken from the vines. Randomly selected samples were subjected to bunch weight (g) and berry weight (g) with the help of digital weighing balance. All bunches from the vine were counted and number of bunches per vine were observed while for number of berries per bunch randomly ten bunches were taken and counted. Number of seeds per berry was also counted. Berry chemical characters i.e. TSS (°B), acidity (%), total sugars (%), TSS/acid ratio, and juice content (%) were observed as per the standard procedure as given in AOAC (1998).

Statistically analysis

Data collected on various parameters were statistically analyzed as per the procedure given by Snedecor and Cochran (1994). The genotypic coefficients of variation and heritability (in broad sense) were calculated (Singh and Chaudhary, 1979) while genetic advances were estimated as per the procedure of Johnson *et al*. (1955).

3. Results and Discussion

Wide range of variation was observed in all the studied characters among different accessions. The extent of variability was measured in terms of range, mean, standard deviation, coefficient of variation, PCV, GCV, heritability, genetic advance and genetic gain (Table 1). Cane length and cane diameter varied from 115.82 cm (GL-49) to 228.43 cm (GL-27) and 1.21 cm (GL-2) to 2.70 cm (GL-13) with a mean value of 156.27 cm and 1.67 cm, respectively. The standard deviation and coefficient of variation for cane length was 29.34 and 18.78 per cent whereas for cane diameter was 0.29 and 16.87 per cent. Maximum and minimum values for intermodal length were recorded in accessions GL-1 (29.93 cm) and GL-23 (10.50 cm) with a mean value of 23.76 cm. Accession GL-31 (124.67 cm^2) recorded minimum leaf area while GL-14 (184.00 cm^2) recorded maximum leaf area. Average mean value for leaf area recorded was 148.62 cm^2 and coefficient of variation was 10.89 per cent. Kadu *et al*. (2007) also reported variation in leaf area as well as in vine vigour among fifteen grape cultivars. Maximum yield was observed in accession GL-15 (23.16 kg/vine) whereas accession GL-39 (11.02 kg/vine) scored minimum yield with a average mean value of 13.33 kg/vine. Thakur *et al*. (2008) and Joshi *et al*. (2015) also reported similar results with respect to yield. Yield efficiency varied from 0.02 kg/cm^2 (GL-9, GL-42 and GL-43) to 0.19 kg/cm^2 (GL-33) however mean value for yield efficiency was 0.08 kg/cm^2 (Table 1 and Fig. 2). Standard deviation and coefficient of variation for yield and yield efficiency was 2.94 and 22.07 per cent and 0.04 and 42.85 per cent, respectively. The high coefficient of variation obtained in case of yield and yield efficiency may be due to variation in the age of vine and other yield attributes such as height of the vine and vine girth.

With respect to bunch and berry characters all the accessions had wide variation. Maximum bunch length (23.50 cm) and bunch breadth (13.07 cm) was registered in GL-1 accession whereas minimum bunch length was recorded in GL-9 (11.58 cm) and minimum bunch breadth in GL-32 (7.03 cm) (Table 1). Average mean, standard deviation and coefficient of variation for bunch length was 18.30 cm, 2.84 and 15.52 per cent, respectively and for bunch breadth these values were 9.68 cm, 1.70 and 17.56 per cent, respectively. Accession GL-37 recorded minimum (76.70 g) bunch weight whereas maximum bunch weight was recorded in GL-15 (155.50 g). Average mean value and coefficient of variation for bunch

Table 1 - Genetic variability components for major characters in various grape accessions selected in Leh district

Characters	Range	Mean	SD	CoV	Coefficient of variance (%)		Heritability (%)	Genetic advance	Genetic gain (%)
					GCV	PCV			
Cane length (cm)	115.82-228.43	156.27	29.34	18.78	18.69	18.94	97.4	59.4	38.01
Cane diameter (cm)	1.21-2.70	1.67	0.29	16.87	17.02	17.47	94.9	0.57	34.13
Internodal length (cm)	10.50-29.93	23.76	4.76	20	19.92	20.24	96.9	9.59	40.36
Leaf area (cm^2)	124.67-184.00	148.62	16.2	10.89	10.73	11.22	91.5	31.43	21.15
Yield (kg/vine)	11.02-23.16	13.33	2.94	22.07	21.73	22.81	90.8	5.68	42.61
Yield efficiency (kg/cm^2)	0.02-0.19	0.08	0.04	42.85	41.19	52.73	61	0.05	62.5
Bunch length (cm)	11.58-23.50	18.3	2.84	15.52	15.16	15.95	90.3	5.43	29.67
Bunch breadth (cm)	7.03-13.07	9.68	1.7	17.56	16.93	18.77	81.3	3.05	31.51
Bunch weight (g)	76.70-155.50	100.19	21.16	21.11	21.07	21.23	98.5	43.16	43.08
No. of bunches/vine	113.00-152.00	134.38	9.89	7.35	6.94	8.14	72.8	16.39	12.2
No. of berries/bunch	38.00-110.00	67.02	15.64	23.33	22.31	25.28	77.9	27.18	40.56
Berry length (cm)	0.81-2.06	1.12	0.24	21.42	21.69	22.07	96.5	0.49	43.75
Berry breadth (cm)	0.80-1.64	1.05	0.17	15.23	15.96	16.31	95.7	0.34	32.38
Berry weight (g)	0.92-1.92	1.37	0.29	20.59	21.13	21.28	98.6	0.59	43.07
Number of seeds/ berry	1-feb	1.21	0.3	21.7	19.83	32.74	36.7	0.3	24.79
TSS (^oB)	13.70-23.10	20.15	2.03	10.01	9.95	10.25	94.2	4.01	19.9
Acidity (%)	0.15-0.27	0.21	0.03	9.52	11	16.25	45.9	0.03	14.29
Total sugars (%)	5.81-15.62	10.93	2.48	22.7	22.69	22.7	99.9	5.11	46.75
TSS/acid ratio	62.48-137.33	97.35	17.75	17.97	16.53	21.23	60.6	25.81	26.51
Juice content (%)	60.00-93.33	77.7	8.7	11.18	11.09	11.4	94.7	17.27	22.23

weight was 100.19 g and 21.11 per cent. Havinal *et al.* (2008) and Mukhtar *et al*. (2011) also reported similar results for bunch weight while studying twelve grape cultivars, however Kamiloglu and Polat (2009) observed much higher bunch weight which might be due to the age and cultural practices adopted. Number of bunches per vine and number of berries per bunch ranged between 113 (GL-10) and 152 (GL-1) and 38 (GL-18) and 110 (GL-1) with a mean value of 134.38 and 67.02, respectively. Coefficient of variation for number of bunches per vine and number of berries per bunch was 7.35 and 23.33 per cent, respectively. The difference in the yield per vine in different grape cultivars might be due to differences in weight of the bunch, number of bunches, weight of the berries and age of the vines besides their successful adoption to the varying agro-climatic conditions under which they are cultivated (Havinal *et al*., 2008).

GL-11 recorded maximum berry length (2.06 cm) whereas GL-32 and GL-33 recorded minimum berry length (0.81 cm) with a mean value of 1.12 cm and coefficient of variation was 21.42 per cent. GL-29 registered maximum berry breadth (1.64 cm) however minimum was registered in GL-32 (0.80 cm) with average mean value and coefficient of variation of 1.05 cm and 15.23 per cent. Berry weight varied from 0.92 g (GL-4 and GL-33) to 1.92 g (GL-45) (Table 1 and Fig. 2). Average mean value and coefficient of variation for berry weight was 1.37 g and 20.59 per cent. Similar values for berry characters were also reported by Al-Shawish (2010). Number of seeds per berry ranged between 1 and 2 with mean value of 1.21. Out of fifty studied accessions, forty accessions were with one seed and only ten accessions had two seeds. Coefficient of variation for number of seeds per berry was 21.70 per cent.

Total soluble solids ranged between 13.70°B (GL-41) to 23.10°B (GL-43) whereas acidity varied from 0.15 (GL-40) to 0.27 per cent (GL-18). Average mean value for total soluble solids and acidity was 20.15°B and 0.21 per cent whereas coefficient of variation was 10.01 per cent and 9.52 per cent (Table 1). Thakur *et al*. (2008) and Jiang *et al*. (2012) also reported similar range for TSS in the commercial cultivars of grape. Maximum total sugar was recorded in GL-30 and GL-31 (15.62%) and minimum was recorded in GL-42 (5.81%) with a average mean and coefficient of variation of 10.93 per cent and 22.70 per cent. GL-41 (62.48) recorded minimum TSS/acid ratio whereas GL-13 (137.33) recorded maximum TSS/acid ratio. Juice content ranged between 60 per cent (GL-32) to 93.33 per cent (GL-1, GL-12 and GL-29). Mean values and coefficient of variation for TSS/acid ratio was 97.35 per cent and 17.97 per cent whereas these values for juice content was 77.70 per cent and 11.18 per cent. Sharma and Bist (1993) and Ghosh *et al.* (2005) also reported similar results for TSS, total sugars and juice content while evaluating eight local accessions of dry temperate areas of Himachal Pradesh.

A perusal of the data revealed that the magnitude of the PCV was higher than GCV for all the characters. The estimates of PCV and GCV were high for yield (21.73 and 22.81), yield efficiency (41.19 and 52.73), bunch weight (21.07 and 21.23), number of berries per bunch (22.31 and 25.28), berry length (21.69 and 22.07), berry weight (21.13 and 21.28) and total sugar (22.69 and 22.70) indicated the presence of adequate genetic variation among the genotypes and suitability of these attributes for further improvement by selection. Bist and Sharma (1995) and Gupta *et al*. (2015) also reported high phenotypic and genotypic coefficient of variance for bunch weight, berry weight and yield characters. PCV was high and GCV was moderate for number of seeds per

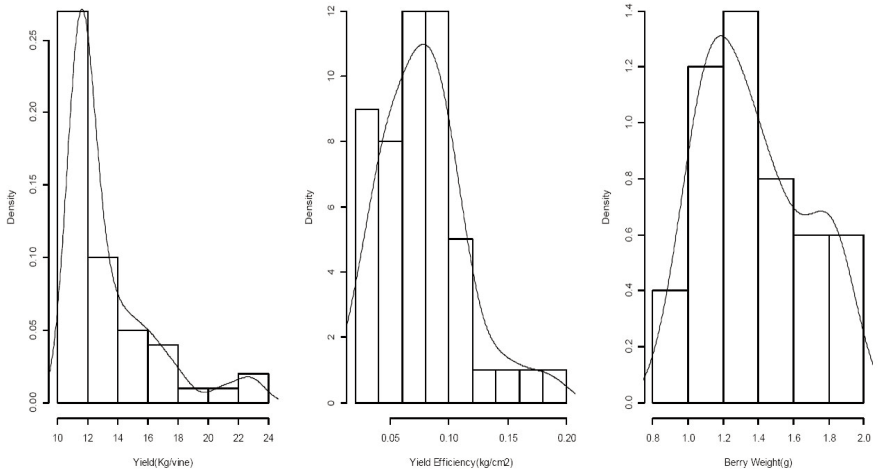

Fig. 2 - Yield, yield efficiency and berry weight in various grape accessions selected in Leh district.

berry. GCV in general, were lower than the PCV (Table 1) which indicated close association between genotype and phenotype. High value of PCV and GCV indicated the existence of substantial variability, ensuring ample scope for their improvement through selection. These results further confirmed with the findings of earlier researchers for Kumar *et al*. (2002) and Wei *et al*. (2003). Low GCV and PCV were recorded for leaf area (10.73 and 11.22), number of bunch per vine (6.94 and 8.14) and total soluble solids (9.95 and 10.25). The estimates of PCV and GCV for leaf area, number of bunch per vine and total soluble solids were low in magnitude yet these were close to each other indicating little effect of environment in the inheritance of these traits.

Heritability is a parameter of huge importance to the breeders as its magnitude indicates the reliability with which a genotype can be recognized through its phenotype expression (Table 1). Most of the characters studied had high heritability estimates, however they are moderate for yield efficiency (61.0%), number of bunches per vine (72.8%), number of berries per bunch (77.9%), and TSS/acid ratio (60.6%) and low for number of seeds per berry (36.7%) and acidity (45.9%). The heritability of highest magnitude was noticed for total sugar (99.9%) closely followed by berry weight (98.6%) and bunch weight (98.5%). High estimates of heritability in broad sense indicate that substantial improvement can be made using standard selection procedures. High heritability estimates for yield, bunch weight, berry weight, TSS were observed by Kumar *et al*. (2002), Wei *et al.* 2003 and Gupta *et al*. (2015) and are in consonance with the present study. Heritability estimates alone are not an ideal parameter for predicting the effect of selecting the desired individual. Heritability estimates along with genetic advance are more useful than heritability value alone in predicting the selection of best individuals. In the present investigations cane length (97.4 and 59.40), leaf area (91.5 and 31.43) and bunch weight (98.5 and 43.16) exhibited high genetic advance as a percentage of mean along with high heritability. These results indicated the influence of additive gene action and hence these characters are likely to respond to selection. High heritability and low genetic advance were observed for yield (90.8 and 5.68), berry length (96.5 and 0.49), berry breadth (95.7 and 0.34), berry weight (98.6 and 0.59) and TSS (94.2 and 4.01) which may be attributed to the non additive gene effects and these traits can be improved through hybridization and use for hybrid vigour. Number of seeds per berry (36.7 and 0.30) and acidity (45.9 and 0.03) showed low heritability associated with genetic advance indicating the role of non additive gene for these traits suggesting thereby that their improvement could be achieved through heterosis breeding.

A highly significant positive correlation was recorded between bunch length and bunch breadth (0.953), bunch weight (0.727) and number of berries per bunch (0.421) resulting in getting high yields (Table 2). Cane length was highly significant and positive correlated with yield (0.356), bunch length (0.356) and bunch weight (0.447). Yield registered

Table 2 - Correlation coefficients (Genotypic) in different characters in various grape accessions selected in Leh district

Characters	Cane lenght (cm)	Cane diamter (cm)	Inter-nodal lenght (cm)	Leaf area (cm^2)	Yield (kg/ vine)	Yield effi-ciecency (kg/cm^2)	Bunch lenght (cm)	Bunch breadth (cm)	Bunch weight (g)	No. of bunches/ vine	No. of berries/ bunch	Berry lenght (cm)	Berry breadth (cm)	Berry weight (g)	No. of seeds/ berry	TSS (°B)	Acidity (%)	Total sugar (%)	TSS/ acid ratio	Juice content (%)
Cane lenght (cm)	1.000	0.272	0.122	0.244	0.356**	-0.520**	0.356**	0.254	0.447**	-0.174	0.156	0.202	0.287*	0.274*	0.224	-0.01	0.268	-0.224	-0.225	0.409**
Cane diameter (cm)		1.000	0.001	0.389**	0.353*	-0.336*	0.135	0.052	0.359**	0.163	0.318*	0.262	0.266	0.023	0.428**	-0.067	-0.144	-0.226	0.099	0.465**
Internodal lenght (cm)			1.000	0.309*	0.333*	-0.052	0.328*	0.353*	0.315*	0.092	0.177	0.219	0.227	0.13	0.336*	0.027	0.056	0.154	-0.04	0.12
Leaf area (cm2)				1.000	0.315*	-0.106	0.286*	0.197	0.326*	0.071	0.172	0.222	0.198	0.137	0.26	-0.025	0.04	-0.288*	0.008	0.326*
Yield (kg/vine)					1.000	0.049	0.652**	0.584**	0.946**	0.289*	0.672**	0.337*	0.363**	0.173	0.612**	-0.024	0.052	-0.148	-0.058	0.535**
Yield efficiency (kg/cm^2)						1.000	-0.025	-0.011	-0.094	0.377**	0.202	-0.201	-0.278*	-0.308*	-0.233	-0.07	-0.101	0.115	0.039	-0.284*
Bunch lenght (cm)							1.000	0.953**	0.727**	-0.196	0.421**	0.144	0.219	0.254	0.342*	0.159	-0.012	-0.255	0.096	0.435**
Bunch breadth (cm)								1.000	0.639**	-0.206	0.294*	0.196	0.299*	0.309*	0.404**	0.163	0.151	-0.248	-0.035	0.408**
Bunch weight (g)									1.000	-0.018	0.647**	0.383**	0.430**	0.263	0.648**	0.021	0.013	-0.293*	-0.004	0.583**
Number of bunches/vine										1.000	0.209	0.173	0.035	-0.26	0.091	-0.302*	0.048	0.234	-0.23	-0.066
Number of berries/bunch											1.000	0.261	0.301*	-0.603**	0.530**	-0.129	0.031	-0.129	-0.11	0.282*
Berry lenght (cm)												1.000	0.945**	0.064	0.389**	0.008	0.144	-0.24	-0.109	0.396**
Berry breadth (cm)													1.000	0.08	0.465**	0.031	0.147	-0.242	-0.107	0.456**
Berry weight (g)														1.000	0.089	0.162	-0.055	-0.156	0.141	0.264
Number of seeds/berry															1.000	0.13	0.274*	-0.214	-0.166	0.566**
TSS (°B)																1.000	-0.102	0.323*	0.665**	-0.086
Acidity (%)																	1.000	-0.097	-0.808**	0.266
Total sugar (%)																		1.000	0.255	-0.305*
TSS/acid ratio																			1.000	-0.22
Juice content (%)																				1.000

highly significant and positive correlation with bunch length (0.652), bunch breadth (0.584), bunch weight (0.946), number of berries per bunch (0.672), berry breadth (0.363) and number of seeds per berry (0.612) while showed simple positive correlation with number of bunches per vine (0.289) and berry length (0.337) depicting that all these characters are yield contributing characters. Kliewer and Dokoozlia (2000) and Gupta *et al*. (2015) also reported positive and significant correlation between yield and bunch length, bunch breadth, bunch weight. Bunch weight showed positive and highly significant correlation with number of berries per bunch (0.647), berry length (0.383), berry breadth (0.430) and number of seeds per berry (0.648). A highly significant but negative correlation was observed between number of berries per bunch and berry weight (-0.603). Berry length and berry breadth showed highly significant and positive correlation with number of seeds per berry (0.389 and 0.465) and juice content (0.396 and 0.456). Acidity was highly but negatively correlated with TSS/acid ratio (-0.808). These results are in conformity with those reported by Kumar *et al*. (2002) and Gupta *et al*. (2015) who advocated that the importance should be given to bunch length, bunch breadth, number of bunches per vine, number of berries per vine, berry weight during selection process because these characters contribute towards the yield.

4. Conclusions

Most of the traits under study showed significant variations from low to high magnitude to heritability and genetic advance. These can facilitate selecting and utilizing the most preferred traits of interest and also hint the potential of grape for further improvement. Some traits with high phenotypic and genotypic coefficient of variation those are detrimental which make possible grape improvement. A significant positive correlation of economic traits like bunch length, bunch weight, number of berries per bunch, berry breadth, number of seeds per berry with yield was recorded suggesting that selection for these characters would lead to crop improvement.

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