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Genetic variability and association among colour and white seedless genotypes of grape (*Vitis vinifera*)

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ABSTRACT

Twenty three genotypes (11 colour seedless and 12 white seedless) of grape (*Vitis vinifera* L.) were investigated during 2015-16 to evaluate qualitative and quantitative traits to explore its existing gene pool and identify the selection indices important for grapevine improvement. Traits like acidity, days to ripening, heat unit requirement, total sugars, number of berries per bunch and TSS had least variation among the coefficients both at phenotypic and genotypic level. High estimates of heritability (broad sense) and genetic advance were observed for some traits signifying high potential for improvement of grape through selection and are governed by additive gene action. Highest heritability was recorded for acidity (99.95) and low for days (33.57) taken to 50% panicle appearance. Correlation coefficients at phenotypic and genotypic level envisaged that fruit yield per vine was having significant and positive correlation with number of bunch and number of fruitful canes. These are the most important characters contributing towards fruit yield and can be strategically used to improve the yield of grape.

Key words: Correlation, Genetic variability, Genotypes, Grape, Heritability

A wide range of natural genetic variability exists in grape (*Vitis vinifera* L.) which may be exploited for the crop improvement. For a successful breeding programme, the knowledge of genetic variability of desirable characters is very important. The breeding methodology for genetic improvement of fruit yield and its components depends upon the nature and magnitude of variability available for these traits.

The estimation of genetic parameters such as phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability (broad sense) and genetic advance (GA) is helpful in making selections effective for improving base population. Effectiveness of selection will increase if the nature of interrelationship among different characters is understood. Varieties play a very important role in boosting up production, therefore, it is advisable to select best variety which can fit into achieving vertical growth and can sustain the impact of climate change, biotic and abiotic stresses and also to meet the consumers' requirement.

Existence of sufficient level of genetic variability is a prerequisite for variety development and therefore detailed evaluation of the accessions for different qualitative and quantitative traits is necessary in order to identify accessions with useful traits for improvement programme. Information on extent of variation, estimates of heritability and expected genetic advance in respect of yield and yield contributing traits constitute the basic requirement for crop improvement programmes. Lerner (1958) stressed the importance of correlation of the various characters with yield. Correlation provide an estimate of inherent association between genes controlling any two characters.

Keeping in view the economic and dietary importance of the fruit, the present study was undertaken to investigate the genotypic evaluation of some coloured seedless and white seedless grape (*Vitis vinifera* L.) germplasms for evaluation and selection of the promising cultivars.The aim of this work was to assess the qualitative and quantitative traits and selection of elite genotype for further breeding work.

MATERIALS AND METHODS

The present experiment was conducted at horticulture farm, College of Horticulture, RVSKVV, Mandsaur (Madhya Pradesh) during the season of 2015-16 with twenty three treatments. Experiment was laid out in randomized block design (RBD) with three replications. A six years old vineyard was established by procuring uniform grape genotypes, budded on dogridge rootstock and trained on 'Y' trellis system of training at a spacing of 3 m × 2 m. These budded trees were maintained with uniform

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horticulture practices. The experiment involved twenty three grape varieties of which eleven coloured seedless (Sharad Seedless, Krishna Seedless, Flame Seedless, A 18-3, Fantasy Seedless, Kishmish Moldowsky, Black Seedless, Kishmish Red, Crimson Seedless, Ruby Seedless, Kishmish Chernyi) and twelve white seedless (Thompson Seedlless, 2A-clone, Superior Seedless, Manjri Naveen, Merbein Seedless, H-5, Sonaka, New Perlette, Sultanin-2, Pusa Seedless, Pusa Urvashi, Kishmish Rozavis White). Continous visits were conducted during investigation to determine the growth parameters such as pruning weight (kg/vine), number of mature canes (recorded by counting the retained mature canes per vine after the October pruning), number of fruitful canes (recorded by counting the number of fruitful canes per vine of each treatment) and girth of main trunk (cm) (recorded with the help of vernier calipers). Data pertaining to phenological parameters were assessed by selecting ten canes randomly on each vine in every treatment. Data recorded for fruit yield parameters such as number of bunches and weight of bunch (g) was worked out on the basis of observations from a composite sample of five canes and five bunches chosen at random from every vine of each variety, number of berries per bunch (recorded by counting the number of fruits per five bunches per vine and averaged), 100 berry weight (g) (recorded by selecting hundred berries randomly at harvest from each treatment), berry length (cm) and berry diameter (mm) (recorded with the help of Vernier calipers at harvest by selecting five berries randomly in each treatment), berry weight (g) was derived by averaging the weight of five berries. The number of days taken for fruit ripening from pruning was recorded in each treatment after the winter (October) pruning to know earliness or lateness of the variety. Five bunches on each vine of each cultivar were tagged and observed for recording the days required for fruit ripening. The heat units or growing degree days (GDD) was calculated using the following formula described by Rai *et al.* (2002).

$$GDD = \sum_{ts}^{tm} \{[(Tmax + Tmin)/2]\text{-}Tb\}$$

where, ts and tm are the time of fruit setting and fruit maturity, respectively. Tmax and Tmin are the maximum and minimum temperatures, respectively. Tb is the base temperature below which fruit growth is arrested. The base temperature for grapes is taken as 10°C (Brar *et al.* 1992). The total soluble solids (TSS) were determined with the help of hand refractrometer and acidity was estimated as per the methods in AOAC (1970) and total sugar was estimated by volumetric method as suggested by Lane and Eynon (1986).

The mean plot data were subjected to analysis of variance following standard statistical method (Gomez and Gomez 1983). The phenotypic and genotypic coefficients of variation (PCV and GCV) were obtained by the method suggested by Burton and Devane (1953) and Johnson *et al.* (1955). Heritability in broad sense and genetic advance (GA) were estimated as per the formulae described by Johnson *et al*. (1955) respectively. The coefficients of correlation were calculated as described by Singh and Choudhary (1977) and as per Johnson *et al.* (1955).

RESULTS AND DISCUSSION

The extent of variability present in the grape genotypes was measured in terms of mean, range, phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability (broad sense), genetic advance and correlation. All the genotypes differed significantly with respect to different attributes studied. The comparison of coloured and white grape varieties for different agro-morphological traits is presented in Table 1 and 2. The white seedless grape varieties recorded higher pruning weight (1.62 kg) in comparison to coloured seedless (1.59 kg). The amount of pruning weight depends upon the vigour of the vine, as highly vigorous varieties produce more pruning weight than less and medium vigorous varieties. This corroborated with the findings of Benz *et al.* (2006). The mean number of canes per vine was higher for coloured varieties (42.3) than white varieties (40.8). The mean number of fruitful canes was higher for white varieties (10.16) in comparison to coloured (10.12). Varieties producing more number of canes per vine may be considered as vigorous. Therefore, regulation of canes in grape cultivar affects the growth, yield and quality of grapes. Highly vigorous varieties which strengthen our present finding that high pruning weight may result in more number of canes giving rise to more vigorous vines. This with the findings of Joshi *et al.* (2015). The mean girth of main trunk was highest for white (3.97 cm) in comparison to coloured (3.96 cm). It also indicated the vigourness of the vine. Similar findings were reported by Pina and Bautists (2006) in grape, Islam *et al*. (2013) in sapota for girth of stem.

The coloured varieties took 10.54 days while white varieties took 10.75 days for 50% bud break. Days taken for bud burst vary from variety to variety and climatic conditions. The time taken for bud burst is taken as an index to classify the grape varieties as early, mid and late varieties.This was in accordance with the findings of Mandelli *et al.* (2003). White seedless took higher mean days (28.49) in comparison to coloured (27.51) for 50% panicle appearance. The coloured varieties took more mean number of days (44.48) to 50% flowering than white varieties (43.38). Flowering is a special trait, polygenic in expression and environment plays critical role. Bright warm weather induces early flowering than rainy and cool weather. Coloured varieties took higher mean number days (49.66) to 50% fruit set than white varieties (48.77). The weather plays a vital role in fertilization of a crop. Similar findings were reported by Huang and Lu (2000) in Muscadine grape, Uddin *et al*. (2011), Gupta *et al*. (2015) for bud burst, panicle initiation, flowering and fruit set in grape.

The mean number of bunch were recorded highest for red varieties (11.97) than white varieties (11.69). The increased number of bunches per vine increases the grape yield per vine with an increment in carbohydrate content in

Table 1 Mean and range values of coloured seedless varieties of grape for different traits

Treatment	PW (kg/ vine)	NMC	NFC	GMT (cm)	DBB	DPA	DF	DFS	NB	WB (g)	NBB	100 BW (g)	BL (cm)	BD (mm)	BW (g)	DTR	HUR (0 Days)	YPV (kg/ vine)	TSS (0 Brix)	ACDT (%)	TS (%)
T1 (Sharad Seedless)	1.99	37.33	11.67	4.46	11.00	27.33	43.33	49.67	10.67	62.33	59.37	145.67	20.07	14.49	1.43	142.67	1805.8	1.73	24.33	0.41	17.33
T2 (Krishna Seedless)	1.47	36.00	7.00	4.04	8.00	26.00	45.67	50.33	7.00	127.83	190.00	170.67	17.25	12.87	1.71	153.67	1965.1	1.95	23.33	0.46	17.67
T3 (Flame Seedless)	1.99	28.67	10.00	3.66	12.67	26.00	43.67	50.00	17.33	74.33	236.06	189.33	17.36	15.33	1.88	127.33	1640.7	1.93	25.67	0.43	20.67
T4 (A18-3)	2.16	30.67	13.33	4.07	12.33	26.67	43.33	47.67	19.67	74.15	43.50	156.00	18.41	14.24	1.47	142.67	1805.8	2.31	20.00	0.51	18.33
T5 (Fantasy Seedless)	1.63	21.67	5.67	4.15	14.00	28.67	43.00	48.33	5.33	111.94	74.67	184.33	22.67	16.56	1.89	142.33	1801.5	1.83	21.00	0.51	17.33
T6 (Kishmish Moldowsky)	1.39	19.00	4.67	2.23	11.67	29.00	46.00	51.00	6.00	116.76	163.33	197.67	16.67	14.82	1.96	148.00	1873.5	1.95	22.67	0.57	15.67
T7 (Black Seedless)	1.66	26.67	21.33	4.03	7.00	26.00	41.67	45.00	26.00	56.45	66.33	208.67	18.89	15.41	2.09	146.00	1848.1	1.53	22.00	0.53	16.67
T8 (Kishmish Red)	1.29	31.67	10.67	3.51	10.33	28.00	44.33	51.00	8.00	149.92	191.67	114.33	17.24	13.05	1.15	158.00	2038.3	1.44	22.33	0.54	18.33
T9 (Crimson Seedless)	1.19	45.00	11.00	4.61	11.33	28.00	45.00	51.33	10.67	73.90	104.83	147.67	18.65	13.21	1.48	158.67	2015.8	1.77	19.00	0.48	19.33
T10 (Ruby Seedless)	1.90	25.33	7.67	4.36	8.00	29.67	48.33	50.67	6.33	75.89	146.93	141.67	17.13	14.73	1.42	156.67	2032.7	1.57	21.33	0.47	19.00
T11 (Kishmish Charnyi)	0.92	26.33	9.00	4.45	9.67	29.00	45.00	50.33	14.67	63.27	185.87	131.33	15.05	12.85	1.35	127.67	1615.3	1.81	19.33	0.45	18.33
Mean	1.59	29.84	10.12	3.96	10.54	27.51	44.48	49.66	11.97	89.70	132.96	156.30	18.12	14.32	1.61	145.78	1858.4	1.80	21.90	0.48	18.06
Range	1.24	26.00	16.66	2.38	7.00	3.67	6.66	6.33	20.67	93.47	192.56	94.34	7.62	3.71	0.94	31.34	423.0	0.87	6.67	0.16	5.00

Table 2 Mean and range values of white seedless varieties of grape for different traits

Treatment	PW(kg/vine)	NMC	NFC	GMT (cm)	DBB	DPA	DF	DFS	NB	WB (g)	NBB	100 BW(g)	BL (cm)	BD (mm)	BW (g)	DTR	HUR (0 Days)	YPV (kg/vine)	TSS (°Brix)	ACDT (%)	TS (%)
T12 (Thompson Seedless)	1.65	31.67	9.67	3.88	9.67	27.33	44.33	50.67	9.00	72.47	192.14	122.67	15.21	12.65	1.25	149.67	1897.5	1.64	22.67	0.55	18.33
T13 (2A-clone)	1.37	34.33	8.33	3.61	9.33	28.00	43.67	48.33	6.00	106.97	185.34	124.00	14.06	10.97	1.30	149.33	1891.8	1.41	17.67	0.46	17.67
T14 (Superior Seedless)	1.21	33.00	4.67	4.50	10.00	29.00	41.67	47.00	5.33	89.66	81.60	273.33	22.03	17.34	2.51	124.67	1564.5	1.46	21.00	0.54	19.67
T15 (Manjri Naveen)	1.98	26.33	5.00	4.13	14.67	29.00	41.00	46.33	5.00	112.61	179.60	211.00	23.79	15.52	2.14	136.67	1729.6	1.73	20.00	0.49	17.33
T16 (Merbein Seedless)	3.34	27.33	6.00	5.05	12.67	27.33	43.33	49.67	4.67	87.14	150.72	116.00	15.07	13.15	1.26	143.67	1780.4	1.55	20.67	0.56	16.00
T17 (H-5)	2.20	39.67	8.00	3.83	10.00	29.00	44.33	51.00	8.33	102.58	161.33	122.00	14.58	9.97	1.28	145.33	1839.6	1.89	22.67	0.49	16.67
T18 (Sonaka)	1.72	23.00	6.00	3.73	11.00	28.67	42.00	49.67	4.67	124.00	175.20	109.33	20.33	11.41	1.09	147.33	1865.0	1.43	23.00	0.51	17.33
T19 (New Perlette)	1.59	41.00	16.67	3.77	11.67	28.00	43.00	48.00	9.00	149.56	191.10	143.33	17.18	15.68	1.35	128.67	1628.0	2.16	21.00	0.49	18.00
T20 (Sultanin-2)	1.53	30.67	22.00	3.64	11.00	28.00	41.67	45.67	30.67	85.33	173.27	146.67	14.05	13.41	1.60	122.67	1547.5	3.94	23.33	0.54	18.67
T21 (Pusa Seedless)	1.64	41.67	9.67	4.00	11.00	28.67	48.00	51.33	8.00	79.58	165.53	116.67	17.25	12.41	1.17	143.33	1814.2	1.56	20.00	0.59	17.33
T22 (Pusa Urvashi)	0.62	26.33	18.67	3.72	9.00	29.00	40.00	46.00	43.00	82.91	153.93	140.00	15.20	13.43	1.33	123.33	1560.2	4.53	21.00	0.55	16.67
T23 (Kishmish Rozavis White)	0.68	36.67	7.33	3.63	9.00	29.00	44.67	51.00	14.00	149.78	140.57	279.00	19.47	15.44	2.41	168.00	2190.4	2.08	21.67	0.53	16.67
Mean	1.62	32.63	10.16	3.97	1.75	28.49	43.38	48.77	11.69	103.54	162.52	158.77	17.35	13.44	1.55	140.22	1775.7	2.11	21.22	0.52	17.52
Range	2.72	18.67	17.33	1.44	5.67	1.67	8.00	5.66	38.33	77.31	110.54	169.67	9.74	7.37	1.42	45.33	642.9	3.12	5.66	0.13	3.67
Grand mean	1.61	31.30	10.17	3.95	10.65	28.05	43.78	49.13	12.14	96.92	148.38	160.49	17.72	13.88	1.58	143.00	1817.0	1.95	21.56	0.50	17.79

the berries to the maximum extent. This was in accordance with the findings of Kadu *et al.* (2007), Karibasappa and Adsule (2008), Ratnacharyulu (2010), Walker *et al.* (2000). White varieties recorded higher mean (103.54 g) in comparison to coloured (89.70 g) for weight of bunch. The heavier the bunch, more will be the grape yield. The differences in the bunch weight in different varieties may be attributed to inherent genetic character of the variety. White seedless varieties recorded higher mean (158.77 g) in comparison to coloured seedless (156.30 g) for 100 berry weight. Coloured seedless varieties took more mean (18.12 mm) than white seedless (17.35 mm) for berry length. The mean diameter of berry were recorded highest for coloured (14.32 mm) than white varieties (13.49 mm). The high berry diameter may be due to presence of less number of berries in a bunch, if more berries are present in the bunch may lead to less diameter of the grape berries. Coloured varieties took higher mean (1.61 g) than white varieties (1.55 g) for berry weight. The variation in the berry weight might be due to variation in the diameter of the berries and also due to number of berries per bunch. White varieties recorded higher mean (162.52) than coloured varieties (132.96) for number of berries per bunch. The difference in the number of berries per bunch may be attributed to the difference in the size and diameter of the berry.This was in accordance with the findings of Ratnacharyulu (2010).

Coloured varieties took higher mean days (145.78) than white varieties (140.22) to ripening. The variation in DFFB can be due to the genotypic effects. This variation may be due to the reason that the early maturing varieties took lesser number of days from pruning to ripening as compared to others varieties resulting in early ripening and vice versa. The heat unit requirement was high for coloured varieties (1858.5) than white seedless (1775.6). Each variety has a specific heat summation requirement which however, varies under the influence of climatic condition and time. The requirements of heat units also differed with earliness or lateness of the variety. This was in accordance with the findings of Shinde *et al.* (2001), Rai *et al.* (2002) and Thakur *et al.* (2008).

The mean fruit yield was recorded highest for white seedless varieties (2.42 kg) than coloured seedless (2.21 kg). 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, nutrition, and cultural practices adopted. Wide range of yield among different varieties of grape screened at different location was reported by Kadu (2007), Shellie (2007), Karibasappa and Adsule (2008), Havinal *et al.* (2008) and Ratnacharyulu (2010) which support the results of the present study. Coloured varieties took higher mean (21.90) than white varieties (21.22) for TSS. The white seedless varieties recorded highest mean (0.52) than coloured seedless varieties (0.48) for acidity. The mean total sugar was recorded highest for coloured seedless varieties (18.06) than white seedless varieties (17.52). The biochemical (SSC, TA, sugars, amino acids, organic acids, phenolic compounds and total antioxidants) attributes of table grapes varieties can be vary with change in the site, locality, topography and environment. Similar observations were also noted by Mattheou *et al*. (1995), Thakur *et al*. (2008) and Khan *et al*. (2011).

Perusal of the data in Table 3 shows differences between phenotypic coefficient of variation and genotypic coefficient of variation for all the agro-morphological traits under study. This indicated presence of greater environmental influence on expression of all these traits and selection may not be effective in the improvement of grape. The grape varieties under study have higher phenotypic coefficient of variation than corresponding genotypic coefficient of variation indicating the dominance of environment over genotype in expression of traits under study. However, there was narrow difference between PCV and GCV for acidity, days to ripening, heat unit requirement, total sugars, number of berries per bunch and TSS. This indicated less influence of environment and more contribution from genotype on expression of these traits. The high degree of

Table 3 Genetic parameters for coloured seedless and white seedless varieties

Trait	PCV	GCV	Heritability (%)	GA	GA (as % mean)
PW(kg/vine)	36.319	34.356	89.480	1.082	66.947
NMC	27.513	18.321	44.342	7.867	25.131
NFC	58.676	45.007	58.834	7.235	71.115
GMT (cm)	16.389	12.056	54.113	0.723	18.27
DBB	21.060	15.860	56.714	2.621	24.605
DPA	5.205	3.015	33.570	1.01	3.599
DF	5.375	4.280	63.415	3.074	7.022
DFS	4.500	3.868	73.908	3.366	6.851
NB	90.223	73.363	66.118	14.924	122.888
WB (g)	36.885	25.601	48.176	35.481	36.605
100 BW(g)	30.286	29.382	94.123	94.246	58.723
BL (cm)	16.219	14.992	85.443	5.059	28.548
BD (mm)	13.605	12.717	87.370	3.395	24.487
BW (g)	26.328	25.385	92.968	0.800	50.422
NBB	34.832	34.642	98.910	105.314	70.973
DFR	8.736	8.686	98.858	25.421	17.791
HUR (0 Days)	9.390	9.339	98.930	347.382	19.136
YPV (kg/vine)	127.835	76.406	35.723	0.834	94.075
TSS (°Brix)	112.257	112.065	99.658	22.398	230.459
ACDT (%)	112.251	112.227	99.958	0.528	231.140
TS (%)	111.957	111.828	99.769	18.453	230.101

PW: pruning weight (kg/vine); NMC: number of mature canes per vine; NFC: number of fruitful canes; GMT: girth of main trunk (cm); DBB: Days taken for 50% bud break; DPA: Days taken for 50% panicle appearance; DF: days taken to 50% flowering; DFS: days taken for 50% fruit set; NB: number of bunches per vine; WB: bunch weight (g); 100BW: Hundred berry weight (g); BL: berry length (cm); BD: berry diameter (mm); BW: berry weight (g); NBB: number of berries per bunch; DFR: days to fruit ripening; HUR: heat unit requirement (0 Days); YPV: fruit yield (kg/vine); TSS: total soluble solids (°Brix); ACDT: acidity (%); TS: total sugars (%)

Table 4 Genotypic correlation coefficient of yield and its contributing traits of grape

Trait	PW (kg/vine)	NMC	NFC	GMT (cm)	DBB	DPA	DF	DFS	NB	WB (g)	NBB	100BW (g)	BL (cm)	BD (mm)	BW (g)	DFR	YPV (kg/vine)
PW(kg/ vine)	1.000	-0.103^{NS}	-0.190^{NS}	0.402*	0.458*	-0.409*	0.036^{NS}	0.036^{NS}	-0.366^{NS}	-0.241^{NS}	-0.077^{NS}	-0.304^{NS}	-0.019^{NS}	-0.109^{NS}	-0.235^{NS}	-0.004^{NS}	-0.358^{NS}
NMC		1.000	0.200^{NS}	0.330^{NS}	-0.196^{NS}	-0.201^{NS}	0.294^{NS}	0.336^{NS}	-0.118^{NS}	0.089^{NS}	-0.017^{NS}	-0.119^{NS}	-0.161^{NS}	-0.286^{NS}	-0.201^{NS}	0.212^{NS}	-0.106^{NS}
NFC			1.000	-0.070^{NS}	-0.342^{NS}	-0.470*	-0.429*	-0.630**	0.938**	-0.358^{NS}	-0.136^{NS}	-0.177^{NS}	-0.373^{NS}	0.011^{NS}	-0.172^{NS}	-0.381^{NS}	0.743**
GMT (cm)				1.000	0.050^{NS}	-0.151^{NS}	-0.073^{NS}	-0.081^{NS}	-0.139^{NS}	-0.550**	-0.393^{NS}	-0.108^{NS}	0.223^{NS}	0.076^{NS}	-0.102^{NS}	-0.076^{NS}	-0.262^{NS}
DBB					1.000	0.095^{NS}	-0.257^{NS}	-0.048^{NS}	-0.319^{NS}	0.146^{NS}	-0.003^{NS}	-0.012^{NS}	0.431*	0.266^{NS}	0.043^{NS}	-0.293^{NS}	-0.055ND
DPA						1.000	0.175^{NS}	0.188^{NS}	-0.233^{NS}	0.334^{NS}	0.079^{NS}	0.053^{NS}	0.131^{NS}	-0.021^{NS}	0.008^{NS}	-0.008^{NS}	0.111^{NS}
DF							1.000	0.883**	-0.519**	-0.004^{NS}	0.190^{NS}	-0.217^{NS}	-0.269^{NS}	-0.232^{NS}	-0.245^{NS}	0.567**	-0.498*
DFS								1.000	-0.609**	0.213^{NS}	0.307^{NS}	-0.276^{NS}	-0.205^{NS}	-0.385^{NS}	-0.334^{NS}	0.602**	-0.532**
NB									1.000	-0.427*	-0.109^{NS}	0.026^{NS}	-0.331^{NS}	0.041^{NS}	0.017^{NS}	-0.454*	0.981**
WB (g)										1.000	0.394^{NS}	0.170^{NS}	0.182^{NS}	0.025^{NS}	0.110^{NS}	0.348^{NS}	-0.101^{NS}
NBB											1.000	-0.300^{NS}	-0.459*	-0.383^{NS}	-0.285^{NS}	-0.091^{NS}	0.057^{NS}
100BW (g)												1.000	0.572**	0.744**	0.962**	-0.005^{NS}	-0.035^{NS}
BL (cm)													1.000	0.644**	0.569**	0.073^{NS}	-0.364^{NS}
BD (mm)														1.000	0.746**	-0.222^{NS}	0.004^{NS}
BW (g)															1.000	-0.050^{NS}	-0.040^{NS}
DFR																1.000	-0.535**
YPV (kg/ vine)																	1.000

*Significant; **Highly Significant

Table 5 Phenotypic correlation coefficient of yield and its contributing traits of grape

Trait	PW (kg/vine)	NMC	NFC	GMT (cm)	DBB	DPA	DF	DFS	NB	WB (g)	NBB	100BW (g)	BL (cm)	BD (mm)	BW (g)	DFR	YPV (kg/vine)
PW(kg/vine)	1.000	-0.065^{NS}	-0.138^{NS}	0.280^{NS}	0.326^{NS}	-0.224^{NS}	0.027^{NS}	0.029^{NS}	-0.281^{NS}	-0.158^{NS}	-0.072^{NS}	-0.279^{NS}	-0.016^{NS}	-0.096^{NS}	-0.214^{NS}	-0.004^{NS}	-0.202^{NS}
NMC		1.000	0.102^{NS}	0.162^{NS}	-0.099^{NS}	-0.077^{NS}	0.156^{NS}	0.192^{NS}	-0.064^{NS}	0.041^{NS}	-0.011^{NS}	-0.077^{NS}	-0.099^{NS}	-0.178^{NS}	-0.129^{NS}	0.140^{NS}	-0.042^{NS}
NFC			1.000	-0.039^{NS}	-0.197^{NS}	-0.209^{NS}	-0.262^{NS}	-0.415*	0.585**	-0.190^{NS}	-0.103^{NS}	-0.131^{NS}	-0.264^{NS}	0.008^{NS}	-0.127^{NS}	-0.291^{NS}	0.341^{NS}
GMT (cm)				1.000	0.028^{NS}	-0.064^{NS}	-0.043^{NS}	-0.051^{NS}	-0.083^{NS}	-0.281^{NS}	-0.287^{NS}	-0.077^{NS}	0.152^{NS}	0.052^{NS}	-0.073^{NS}	-0.056^{NS}	-0.115^{NS}
DBB					1.000	0.042^{NS}	-0.154^{NS}	-0.031^{NS}	-0.196^{NS}	0.076^{NS}	-0.002^{NS}	-0.009^{NS}	0.300^{NS}	0.187^{NS}	0.031^{NS}	-0.219^{NS}	-0.025^{NS}
DPA						1.000	0.081^{NS}	0.093^{NS}	-0.110^{NS}	0.134^{NS}	0.046^{NS}	0.030^{NS}	0.070^{NS}	-0.012^{NS}	0.004^{NS}	-0.005^{NS}	0.038^{NS}
DF							1.000	0.604**	-0.336^{NS}	-0.002^{NS}	0.150^{NS}	-0.168^{NS}	-0.198^{NS}	-0.172^{NS}	-0.188^{NS}	0.449*	-0.237^{NS}
DFS								1.000	-0.426*	0.127^{NS}	0.262^{NS}	-0.230^{NS}	-0.163^{NS}	-0.310^{NS}	-0.277^{NS}	0.515**	-0.273^{NS}
NB									1.000	-0.241^{NS}	-0.088^{NS}	0.020^{NS}	-0.249^{NS}	0.031^{NS}	0.013^{NS}	-0.367^{NS}	0.477^{NS}
WB (g)										1.000	0.272^{NS}	0.115^{NS}	0.117^{NS}	0.016^{NS}	0.074^{NS}	0.240^{NS}	-0.042^{NS}
NBB											1.000	-0.289^{NS}	-0.422*	-0.356^{NS}	-0.273^{NS}	-0.090^{NS}	0.034^{NS}
100BW (g)												1.000	0.513**	0.675**	0.899**	-0.004^{NS}	-0.020^{NS}
BL (cm)													1.000	0.556**	0.507**	0.067^{NS}	-0.201^{NS}
BD (mm)														1.000	0.672**	-0.206^{NS}	0.002^{NS}
BW (g)															1.000	-0.048^{NS}	-0.023^{NS}
DFR																1.000	-0.318^{NS}
YPV (kg/vine)																	1.000

*Significant; **Highly Significant

difference between GCV and PCV was observed for yield per vine, number of bunch, number of fruitful canes and weight of bunch indicating dominance of environment on the expression of these traits. The genetic variability is heritable from generation to generation. Hence, heritability and genetic advance is a useful tool for breeders in determining the direction and magnitude of selection. The yield and yield attributes are polygenic in nature and are subjected to different degree of non-heritable variation (Sivcev *et al.* 2000). Heritability estimates gives a measure of transmission of characters from one generation to the next and the consistency in the performance of progeny in succeeding generations and depends mainly on the magnitude of heritable portion of variation.

Acidity (99.95%), total sugar (99.76%), TSS (99.65%), heat unit requirement (98.93%), number of berries per bunch (98.91%), days to fruit ripening (98.85%) and 100 berry weight (94.12%) are the important traits in grape which have expressed high heritability signifying high potential for improvement of grape through selection. The heritability will be more effective and meaningful when accompanied by genetic advance and genetic advance as per cent of mean (Johnson 1955). The genetic advance as per cent of mean was high for 100 berry weight (94.12%), number of berries per bunch (105.31%) followed by heat unit requirement (347.38%).

The correlation coefficients between different characters are presented in Table 4 and 5. Pearson correlation indicated fruit yield per vine showed significant correlation between number of bunch (r=0.981) and number of fruitful canes (r=0.743). Pruning weight was significantly correlated with girth of main trunk (r=0.402) and days taken to 50% bud break (r=0.458). Number of fruitful canes were significantly associated with number of bunch (r= 0.938) and yield per vine (r=0.743). Days taken to 50% bud break was significantly correlated with berry length (r=0.431). Days taken to 50% flowering was significantly correlated with days to 50% fruit set (r= 0.833) and days to ripening (r= 0.567). Days taken to 50% fruit set was significantly correlated with days to ripening (r= 0.602). Number of bunch was significantly correlated with yield per vine (r=0.981). 100 berry weight was significantly correlated with berry length (r= 0.572), berry diameter (r=0.744) and berry weight (r=0.962). Berry length was significantly correlated with berry diameter (r= 0.644) and berry weight (r=0.569). Berry diameter was significantly correlated with berry weight (r=0.746). Similar findings were reported by Joshi *et al.* (2015), Singh *et al*. (2016) and Thakur *et al.* (2008).

Based on agro morphological traits, it was found that among red varieties, A 18-3 and Merbein Seedless among white may be considered as vigorous varieties based on their respective pruning weights. Based on 50% flowering, the varieties can be classified into early (Black Seedless among coloured varieties and Pusa Urvashi among white varieties), mid (Fantasy Seedless among coloured and New Perlette among white varieties) and late (Ruby seedless among coloured and Pusa Seedless among white seedless varieties) bursting varieties. However, A 18-3, Krishna Seedless, Kishmish Moldowsky and Flame Seedless among coloured seedless and Pusa Urvashi, Sultanin-2, New Perlette and Kishmish Rozavis White among white seedless varieties considered to high yielders.

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