

Genetic variability and divergence studies to identify superior germplasm for wine grape (*Vitis* sp.) under semi-arid condition

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ABSTRACT

The study was carried out to assess genetic variability of wine grape germplasm at ICAR- National Research Centre for Grapes, Pune during 2020–21, 2021–2022 and 2022– 2023. A total of 75 germplasm were evaluated for various yield-contributing traits. The combined data from three years revealed significant difference among all genotypes. The germplasm, Arka Hans, Arka Shyam, Clairette, Sauvignon Blanc, Muscat White, and Petit Syrah, performed well during all year. The pruning biomass demonstrated the highest phenotypic and genotypic of variability (68.39% and 68.28%, respectively). The bunch weight, berry weight, number of berries/bunch, seed weight, bunch width, berry length, compactness and peduncle length exhibited high heritability. Based on Mahalanobis D2 statistics, three cluster were identified with a majority of germplasm falling into cluster I group while cluster II showed highest intra-cluster similarity (3.86 %) that demonstrated maximum genetic diversity.

Key words: Wine grape, Genotypic, Heritability, Phenotypic, Genetic diversity.

The grapevine is the most important fruit crop in the world. Grape belongs to Vitaceae family which includes around 60 inter-fertile wild species of *Vitis* found across Asia, North America, and Europe under subtropical, mediterranean, and continental temperate climates. Among them, the most commonly cultivated and widely distributed species is the European grapevine (*Vitis vinifera* L.). Grape possesses diverse medicinal properties encompassing antioxidant, antidiabetic, cardioprotective, neuroprotective, anticarcinogenic, immunomodulatory, antiatherogenic, anti-obesity, antiaging, anti-infection, and antipyretic effect (Somkuwar *et al.*, 2023).

This extensive variation is largely a result of long history of grapevine cultivation and vegetative propagation which has allowed for the preservation of cultivars over the centuries (Lauco *et al.*, 2011). In the characterization of fruit trees, fruit traits have been primarily utilized as key morphological characteristics (Cunha *et al.*, 2007). India is most suitable region for diversity and cultivation of grape in the world. Keeping in view, studies were planned to assess the genetic diversity in wine genotypes for fruit yield and quality traits under semi-arid conditions.

MATERIALS AND METHODS

The study was carried out during 2020–21, 2021–2022 and 2022– 2023 at ICAR- National Research Centre for

Grapes, Pune (18°32'N and 73°51'E). Pune has sub tropical and semi-arid climatic conditions with a temperature range of 7.2°C minimum and 37.90°C maximum during trial period. The annual average rainfall was between 600–700mm, with the majority of rains occurring during south-east monsoon period from June to August. The soil is heavy black with pH 7.75 and EC 0.46 dS m⁻¹. The seventy-five wine grape genotypes (*Vitis vinifera* L.) grafted on Dogridge rootstock planted in National Active Germplasm Site (NAGS) were selected. In this region, double pruning and single cropping pattern are being practiced.

The crop is harvested during March - April and foundation pruning is done leaving single bud on a last season matured cane after harvesting while second pruning is done during October. The level of forward pruning was normally kept to short canes or spurs leaving behind 4–7 buds depending upon the cane thickness in all varieties. All recommended cultural practices were followed. The observation were recorded on including pruning biomass (g), time of veraison (DAP), time of full bloom, time of verasion, bunch weight (g), berry weight (g), berry diameter and length (mm), bunch length and width (cm), number of berries/bunch, total soluble solid (°Brix), acidity (%), peduncle length (mm), bunch compactness, berry firmness (%), seed number/berry and seed weight. Qualitative traits of berry and bunch were recorded based on grape DUS guideline.

Five vines per replication were selected in each genotype and fifty samples were used for traits measurements. Quantitative characters were measured using suitable equipment such as digital caliper and precision weighing balance, while qualitative traits were measured based on rating, scoring, and coding according

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to the grape descriptor. Data on various growth, quality and yield parameters were recorded. The INDOSTAT software was utilized to conduct statistical analyses, including ANOVA, genotypic and phenotypic correlation, to explore the connections between yield and its contributing factors.

RESULTS AND DISCUSSION

All the genotypes differed significantly with in different attributes. The pooled average performance of wine genotypes for growth and yield related traits is given Table 1. The variety Champion recorded higher pruning biomass (2.64 kg) compared to Cayuga White (0.05kg). The difference in pruning weight among varieties may be attributed to difference in vigour of vine resulting from assimilation of carbohydrates due to more number of canes, number of leaves produced and other growth parameters results in more dry matter production. As highly vigorous varieties produce more pruning weight than less and medium vigorous varieties. The results aligns with these of Benz *et al.* (2006) and Jayalakshmi *et al.* (2019). Bud burst is a varietal character as it marks the beginning of seasonal growth and it is strongly influenced by temperature.

The variety Rosaria Bianca took 8.00 days, while Marquise took 14.33 days for 50% bud break. Days required for bud burst differ among grape varieties and depends on climatic conditions prevailing in that area. The time taken for bud burst is used as a criterion to classify grape varieties into early, mid, and late categories. This was in accordance with the findings of Gris *et al.* (2010). The variety Ribier and E29/3 (BC X TS) took more days (40.67) to 50 % flowering than Candaigua (30.67). Flowering is a unique characteristic that is influenced by multiple genes and environmental conditions play a crucial role. Warm, sunny weather encourages earlier flowering compared to rainy and cool conditions. Similar findings were reported by Anjanawe *et al.* (2020) for bud burst and flowering in wine grapes under Malwa Plateau conditions.

The maximum bunch weight was observed in Symphony (558.93 g), while minimum in Rose of Peru (35.66 g). The heavier the bunch, more will be the grape yield. Variations in bunch weight among different varieties can be attributed to inherent genetic traits of each variety. Greaca variety recorded highest 50 berry weight (254.25 g), while lowest was noted in VP × Beauty Seedless (41.28 g). Higher number of berries per bunch was observed in Clairette (186.80), while lower in Champion (26.27) followed by Amber Sweet (26.97). The maximum berry diameter and length were recorded in Aledo (21.33mm and 23.67 mm respectively). The maximum bunch length was observed in Muscat Petit (19.70 cm), while Leon

Mellot (6.20) had minimum bunch length. The genotype, E29/3 (BC X TS), had maximum bunch width (13.40 cm), whereas Goethe had minimum (2.53 cm). Similar results were also reported by Anupama *et al.*, (2016) for different wine varieties.

Differences between phenotypic (PCV) and genotypic coefficients (GCV) of variation for all morphological traits under study are given in Table 2. Data revealed that magnitude of PCV was higher than GCV for all the characters studied. The estimate of PCV and GCV were high for pruning biomass (68.39 and 68.28), bunch weight (51.10 and 51.03), 50 berry weight (42.99 and 42.91), number of berries/bunch (42.18 and 41.97), compactness (39.54 and 39.34) and seed weight (42.68 and 42.38) indicating the presence of adequate genetic variation among the germplasm and suitability of these attributes for further improvement. Gupta *et al.*, (2015) also found that the phenotypic and genotypic coefficients of variance were high for bunch weight, berry weight and yield.

Low PCV and GCV were recorded for time of veraison (5.39 and 5.09), time of full bloom (8.12 and 7.64), total soluble solid (11.34 and 10.72) and physiological maturity (5.78 and 5.69). The estimates of PCV and GCV for time of veraison, time of full bloom, total soluble solid and physiological maturity were small in magnitude, but their values were similar suggesting that environmental factors had influence on the inheritance of these traits. A higher percentage of additive variability can result in large genetic gain, high heritability and significant genetic advancement. The genetic variability is heritable from one generation to the next. Therefore, heritability and genetic gain serve as valuable tools for breeders in assessing the direction and magnitude of selection. Yield and yield attributes are polygenic in nature and are subjected to different degree of non-heritable variation (Sivcev *et al.*, 2000).

Heritability estimate gives a measure of transmission of characters from one generation to next and the consistency in the performance of progeny in succeeding generations that depends mainly on the magnitude of heritable portion of variation. Average bunch weight (99.72), berry weight (99.64), number of berries per bunch (99.01), compactness (98.98) and bunch length (94.69) are key traits in grapes that show high heritability, indicating significant potential for improving grapes through selection. Heritability is more valuable and informative when evaluated together with genetic gain and genetic gain as a percentage of the mean (Saniya *et al.*, 2018). The genetic advance was reported as high for average bunch weight (276.15), berry weight (104.73) and number of berries per bunch (62.19).

Table 1: Pooled mean performance of wine grape germplasm for fruit traits

Genotype	PB	TOB	ToFB	ToV	ABW	BW	NOB	BD	BL	TSS	AD	CP	SF	BuL	BuW	PL	PM	SW	NOS
Aledo	0.91	10.67	39.67	109.00	124.34	176.87	57.94	21.33	23.67	18.09	0.67	5.56	51.20	15.78	12.66	22.07	141.67	5.39	2.33
Amber Sweet	0.53	10.00	36.33	99.33	85.63	137.36	26.91	15.17	17.60	18.01	0.55	3.82	38.23	9.27	5.70	10.95	121.33	4.03	1.33
Arka Hans	0.47	9.33	33.33	114.00	398.04	122.17	62.60	15.10	16.87	21.25	0.44	4.36	48.33	13.70	3.70	20.77	143.67	5.22	2.33
Armas	0.22	11.67	35.00	114.67	177.30	104.13	62.20	13.77	15.17	17.31	0.67	5.45	47.27	12.60	6.40	17.23	148.67	4.20	1.67
Bangalore Purple	0.45	8.67	38.00	109.33	383.97	180.57	86.23	18.47	19.57	18.32	0.61	5.36	66.43	13.83	2.00	24.00	139.33	6.24	2.67
E-8-25	0.52	12.33	34.67	116.67	57.09	62.43	36.37	12.03	12.30	18.68	0.58	2.49	43.30	15.50	8.47	20.33	143.33	3.30	1.67
Goethe	0.95	10.00	30.00	109.33	201.48	115.48	50.51	15.57	17.27	19.67	0.53	4.41	54.47	9.27	2.53	13.33	138.00	6.60	2.33
Gulabi	0.34	9.67	34.00	101.00	226.27	125.44	103.56	15.50	17.00	16.36	0.50	3.43	46.63	15.13	7.44	14.67	140.00	4.52	1.33
Gold	2.09	11.00	35.33	104.33	362.26	149.30	85.46	16.00	19.66	18.19	0.65	2.65	67.70	19.62	11.99	30.50	144.33	5.25	1.67
H-27	0.56	9.33	34.33	110.33	268.79	92.78	122.83	12.61	12.67	17.52	0.75	5.43	56.70	16.40	8.33	31.07	138.33	6.46	1.33
Khalili	2.51	12.67	31.00	101.33	248.57	206.54	61.02	15.50	17.90	17.57	0.76	2.69	48.17	8.40	3.63	16.13	132.00	5.44	2.33
Muscat of Alexandria	0.42	9.67	34.33	104.00	264.95	207.30	46.79	16.83	17.47	17.54	0.77	3.65	61.87	17.60	9.16	30.87	133.00	5.39	1.67
Muscat White	0.82	8.67	37.00	103.00	122.13	68.07	64.79	13.56	15.04	23.12	0.72	8.45	59.33	15.37	11.53	25.20	125.67	4.49	2.00
Pearl of Csaba	0.84	10.00	36.67	99.00	269.34	102.03	77.71	14.90	18.00	24.15	0.61	5.39	55.50	17.50	6.70	31.47	127.33	0.00	0.00
Petit Syrah	0.51	9.00	38.00	103.00	510.94	62.79	115.10	12.60	13.77	20.13	0.65	8.48	42.47	12.17	8.47	21.90	132.33	5.23	1.67
Ribier	0.70	12.33	40.67	109.33	330.45	66.92	72.43	18.40	19.50	16.62	0.72	2.65	50.47	15.73	8.40	13.47	134.67	3.84	1.67
Riesling	0.44	10.67	37.00	110.67	274.20	176.90	41.80	16.93	18.73	18.47	0.81	2.52	45.40	18.07	9.20	17.80	137.33	5.14	1.00
Rubi red	0.76	11.67	35.00	105.33	389.39	72.39	41.93	13.67	14.67	18.87	0.66	2.49	47.40	12.70	6.43	21.80	137.67	7.58	1.67
Sauvignon Blanc	1.01	9.67	34.00	100.33	322.48	71.97	71.07	12.40	12.67	22.63	0.57	5.49	52.53	9.40	5.33	12.00	141.33	4.89	1.33
Seibel 9308	0.72	9.67	34.00	104.00	255.03	84.25	70.47	13.83	16.20	18.75	0.60	3.50	31.77	11.40	5.20	13.27	136.00	6.79	2.67
Semillon	0.70	9.33	38.00	109.00	194.30	77.59	113.19	13.17	14.17	18.57	0.71	4.33	43.40	14.43	4.33	15.70	138.33	6.43	1.67
SV-12309	0.25	12.00	36.00	103.00	367.86	54.16	90.29	12.73	13.40	18.20	0.71	6.80	59.73	13.17	3.63	12.77	140.67	7.43	1.67
SV-23501	0.79	9.00	31.33	108.00	477.77	88.76	111.02	12.27	13.27	17.10	0.67	8.45	52.00	12.67	3.57	8.00	134.67	6.99	1.67
Symphony	0.68	8.67	40.00	103.67	558.93	106.53	70.43	15.70	16.77	20.70	0.64	2.53	50.50	13.77	7.30	20.43	131.00	4.35	1.67
Tannat(B2-6-1)	0.77	12.00	34.33	103.33	112.01	104.43	63.30	16.07	16.93	19.23	0.82	5.31	54.57	10.40	5.53	17.20	136.00	7.54	1.67
Tigrosa	0.45	11.00	34.00	97.00	410.04	67.03	77.37	12.40	13.83	18.33	0.73	7.38	56.03	9.27	6.83	15.27	123.67	5.37	1.67
Tslimlyanski Chernyi	0.62	12.00	35.33	100.33	297.49	113.88	65.30	18.40	19.07	17.99	0.99	2.36	41.40	19.33	8.20	16.37	126.67	3.43	1.67
VP X Beauty Seedless	1.07	10.00	31.33	105.33	55.57	41.28	55.22	13.77	17.93	20.48	0.61	4.48	46.50	9.33	3.60	11.70	137.00	3.58	1.00
VP X Centennial Seedless	0.30	11.67	35.00	97.67	164.44	87.12	28.22	15.43	18.37	16.67	0.64	4.53	51.13	12.53	6.63	21.13	130.00	5.53	1.67
Golden Queen	0.74	11.00	37.00	97.67	224.86	175.97	46.63	16.43	17.60	23.68	0.59	4.46	71.67	14.27	9.52	20.30	121.67	5.06	1.33
Alden	2.14	10.00	35.33	102.67	262.87	182.78	54.77	15.52	17.67	18.66	0.72	8.45	40.70	14.16	9.59	25.23	116.67	11.84	2.00
Barbarossa	0.82	9.00	37.00	102.67	146.70	58.77	43.03	12.27	14.03	22.92	0.51	4.50	58.00	9.27	5.43	17.63	128.00	4.59	1.67
Black Champa	0.72	9.67	31.00	113.00	165.87	196.52	30.66	18.10	18.43	17.30	0.66	4.50	51.93	7.33	11.50	16.73	131.00	6.30	1.67
Labrusca (FV)	1.07	9.33	31.33	99.33	323.40	92.84	57.50	16.77	18.43	18.28	0.65	8.52	40.40	13.47	7.47	21.30	124.00	7.50	1.67
Bianca	0.94	10.33	34.00	94.00	159.64	124.40	38.77	13.27	13.87	17.97	0.56	6.43	41.10	15.84	9.91	18.83	118.00	7.29	2.00
Champion	2.64	13.33	35.67	105.67	54.39	105.49	26.27	16.37	18.20	18.62	0.76	4.38	45.70	9.30	5.53	11.77	128.67	6.00	1.67
Doradillo	1.12	10.33	38.00	102.67	235.01	176.93	86.50	17.94	18.97	18.06	0.71	4.47	61.61	18.50	10.41	13.03	121.00	5.11	1.33
(Gulabi X Bangalore Purple)	0.33	9.00	38.33	105.00	558.68	104.80	76.95	16.90	18.23	18.53	0.57	5.55	60.97	10.43	6.83	32.93	127.00	4.20	2.00
Arka Kanchan	0.62	10.00	36.33	107.33	247.67	189.76	72.39	15.56	16.63	15.89	0.56	2.30	59.39	17.16	10.22	20.97	121.33	9.34	1.67
Vermantino	0.09	10.33	36.00	99.00	136.83	100.17	65.99	14.60	15.53	21.82	0.65	5.30	51.73	14.37	8.20	19.57	116.33	5.27	1.33
Viognier	0.65	9.33	32.00	94.00	137.20	103.27	90.80	14.23	12.57	17.67	0.74	9.55	48.77	12.17	5.73	12.63	117.33	6.48	2.00
Arka Chitra	1.08	10.00	35.00	102.67	317.27	237.71	91.45	18.77	21.27	16.94	0.75	2.79	52.64	17.63	9.27	26.37	127.33	3.46	1.67
Peru white	0.95	9.33	35.33	104.67	338.27	179.38	74.97	17.50	19.33	24.80	0.55	4.22	48.33	17.60	4.53	24.90	128.67	5.38	1.67
Waltham Cross	1.82	11.00	37.67	99.33	273.93	200.76	66.28	16.17	20.16	18.44	0.94	5.29	59.46	15.66	9.58	28.97	123.67	5.38	2.00
E12/2	1.47	10.67	30.00	110.00	69.71	157.74	51.27	13.50	14.50	21.69	0.65	2.62	40.48	11.03	5.47	22.23	130.67	6.47	1.33
Red prince	1.95	13.00	35.00	106.00	132.59	113.21	62.02	14.10	17.57	21.03	0.67	3.43	62.17	12.83	6.57	29.10	126.67	5.88	1.67
Maroo Seedless	0.13	10.00	38.33	106.00	257.96	148.04	123.92	13.33	14.63	19.37	0.71	6.43	45.30	12.53	6.33	10.23	127.33	0.00	1.67
E29/3 (BC XTS)	0.89	8.33	40.67	100.00	355.70	110.90	140.80	12.97	14.53	21.68	0.61	6.63	57.11	17.40	13.40	27.13	116.33	0.00	1.33
E4/15 IIHR Hybrid	1.34	9.00	33.33	106.00	358.30	170.50	74.22	21.07	20.13	17.53	0.75	4.49	66.03	7.90	12.20	26.57	121.33	4.55	2.00
Medica	0.54	11.00	29.00	104.67	356.03	112.84	110.90	15.20	16.53	18.93	0.51	6.61	61.97	16.53	11.23	21.93	120.00	0.00	1.33
Beauty Seedless	0.50	8.33	37.33	91.00	399.80	49.67	79.00	12.27	14.37	20.35	0.55	7.47	67.41	15.90	8.53	28.73	119.67	0.00	1.33

Genotype	PB	TOB	ToFB	ToV	ABW	BW	NOB	BD	BL	TSS	AD	CP	SF	BuL	BuW	PL	PM	SW	NOS
Arka Soma	0.42	8.67	35.00	105.33	526.66	173.23	60.60	17.93	19.27	20.01	0.61	3.44	53.97	13.97	4.40	25.27	131.33	5.27	2.00
Arka Shyam	1.04	10.00	29.33	100.67	226.63	86.38	73.83	14.03	15.03	20.93	0.55	4.68	67.78	17.03	6.40	26.30	123.33	6.29	1.67
Athens	0.74	12.33	36.00	103.00	356.00	134.89	54.53	15.57	20.57	21.07	0.63	5.54	36.33	11.50	8.20	23.30	122.00	5.61	1.67
Trebbiano	0.41	13.33	38.67	97.67	386.33	71.03	162.27	12.73	14.17	18.38	0.52	3.58	46.67	15.73	7.50	16.10	124.67	6.55	1.67
Gaeganega	0.51	13.33	35.00	103.00	461.97	79.37	91.76	14.50	15.50	17.28	0.67	7.30	54.20	14.50	5.23	21.73	128.00	4.78	2.00
Catawba	0.94	10.33	35.67	104.00	81.90	105.57	57.84	13.67	14.60	22.83	0.71	5.38	53.17	9.51	5.79	19.23	125.00	6.35	2.33
Charark-2	0.78	8.33	34.33	101.33	243.13	83.78	96.03	13.83	15.10	22.23	0.77	4.80	37.60	16.40	8.33	17.03	126.67	6.68	2.67
Charark-3	0.20	10.00	33.33	100.67	289.00	77.42	111.27	13.93	14.51	20.42	0.48	5.49	51.07	13.60	8.40	21.23	127.00	6.32	2.00
Rose of Penn	0.82	12.33	34.67	103.00	189.78	97.94	30.67	13.67	16.33	21.13	0.51	8.42	50.53	8.23	5.57	12.57	125.67	5.15	2.33
Rose Ciotat	0.85	12.67	34.67	101.33	121.00	100.82	57.33	17.43	18.63	18.03	0.57	3.44	46.47	10.77	6.43	3.77	127.33	8.22	3.00
Cabernet Franc	0.27	9.33	37.33	110.00	133.86	63.25	75.28	14.10	12.20	18.57	0.55	4.40	42.57	11.07	6.63	15.83	135.67	6.40	2.33
Marquise	0.52	14.33	31.67	100.67	159.23	115.48	68.17	13.33	15.27	18.62	0.59	5.59	49.00	17.57	9.47	29.40	125.67	0.00	0.00
Cayuga White	0.05	11.67	32.33	102.33	66.20	128.25	46.50	15.93	16.30	17.19	0.85	4.44	36.83	9.10	4.43	13.13	125.33	4.02	1.33
Rosaria Bianca	0.44	8.00	37.33	105.67	245.69	123.02	70.82	18.00	21.93	16.52	0.70	3.49	54.90	14.66	10.28	29.77	125.00	5.41	2.33
Clairette	0.32	12.33	40.33	110.33	374.97	81.18	186.80	14.00	14.43	19.00	0.63	8.43	43.77	18.43	7.63	14.10	129.67	7.77	3.00
SV-12364	0.51	13.33	32.67	103.33	380.90	61.41	52.86	12.17	12.60	22.48	0.59	2.59	54.43	14.73	5.83	16.20	136.33	6.85	2.00
Candaigua	0.22	9.33	28.67	104.33	117.48	241.89	33.63	18.17	19.80	16.51	0.65	3.67	55.63	8.63	7.50	11.43	125.00	6.01	2.33
SV-18402	0.67	11.00	31.00	105.67	533.66	93.67	65.87	12.77	14.93	18.53	0.62	3.56	58.57	11.63	4.63	6.67	126.33	5.85	2.00
Leon Mellot	0.60	13.00	32.33	105.67	43.83	41.42	55.18	10.80	12.03	17.98	0.75	9.31	54.50	6.20	3.57	4.90	124.67	2.91	1.67
Muscat Petit	1.03	11.67	34.67	106.33	225.01	66.62	116.38	12.00	13.06	17.79	0.78	8.45	63.43	19.70	10.36	26.20	126.33	0.00	0.00
Rose of Peru	0.52	12.00	35.33	101.33	35.66	75.34	93.91	13.57	15.40	18.32	0.79	3.56	55.03	11.97	3.83	12.20	125.67	7.16	2.33
Greaca	0.26	10.00	34.67	96.67	291.71	254.25	63.23	18.60	21.90	15.92	0.66	6.23	47.83	16.87	9.23	14.43	121.67	5.22	2.33
Concord	0.72	12.00	31.33	105.00	391.64	157.12	43.63	13.60	18.80	18.17	0.62	3.72	52.66	10.93	6.80	18.27	133.00	7.35	2.00
Choltu White	0.24	13.00	30.67	104.00	421.39	167.96	56.09	16.67	18.07	25.40	0.61	4.60	37.87	10.70	6.40	15.23	124.33	2.83	1.67
Mean	0.76	10.63	34.86	104.11	263.03	118.67	72.29	15.04	16.57	19.23	0.65	5.09	51.57	13.45	7.24	19.18	129.23	5.20	1.76
C.V.	6.55	11.89	4.76	3.08	4.65	4.47	7.28	9.56	8.65	6.43	14.75	6.90	8.67	9.90	9.97	7.55	1.74	8.64	27.90
S.E.	0.03	0.73	0.96	1.85	7.07	3.06	3.04	0.83	0.83	0.71	0.06	0.20	2.58	0.77	0.42	0.84	1.30	0.26	0.28
C.D. 5%	0.08	2.04	2.68	5.17	19.75	8.55	8.49	2.32	2.31	1.99	0.16	0.57	7.22	2.15	1.17	2.34	3.62	0.72	0.79

Table 2: Coefficient of variability, heritability, and genetic advance for different parameters of wine grape during 2020–21, 2021–22 and 2022-23

Character	Range	Mean	SD	PCV (%)	GCV (%)	Heritability (%)	Genetic advance
Pruning biomass (kg)	0.05- 2.64	0.7606	0.52	68.39	68.28	99.69	1.06
Time of budburst (DAP)	8.00-14.33	10.62	1.53	14.36	12.61	77.15	2.42
Time of full bloom (DAP)	28.67-40.67	34.85	2.83	8.12	7.64	88.56	5.16
Time of veraison (DAP)	91.00-116.6	104.1	5.62	5.397	5.096	89.16	10.32
Average bunch weight (g)	35.66-558.93	263.03	134.42	51.1	51.035	99.72	276.15
50 berry weight (g)	41.28-254.25	118.66	51.02	42.99	42.91	99.64	104.73
No. of berries/bunch	26.27-186.80	72.28	30.49	42.18	41.97	99.01	62.19
Berry diameter (mm)	10.80-21.33	15.03	2.24	14.9	13.84	86.3	3.98
Berry length (mm)	12.03-23.67	16.57	2.66	16.04	15.25	90.32	4.94
Total Soluable Solid (°B)	15.89-25.40	19.22	2.18	11.34	10.72	89.3	4.01
Acidity (%)	0.44-0.99	0.65	0.10	15.62	13.1	70.3	0.14
Compactness	2.30-9.55	5.09	2.01	39.54	39.34	98.98	4.1
Skin firmness (%)	31.77-71.67	51.57	8.58	16.63	15.85	90.94	16.06
Bunch length (cm)	6.20-19.70	13.45	3.34	24.8	24.13	94.69	6.5
Bunch width (cm)	2.00-13.40	7.24	2.55	35.23	34.76	97.33	5.11
Peduncle length (mm)	3.77-32.93	19.18	6.78	35.31	35.04	98.47	13.74
Physiological maturity(DAP)	116.33-148.67	129.23	7.48	5.78	5.69	97	14.93
Seed weight (g)	0.00-11.84	5.19	2.22	42.68	42.38	98.63	4.5
Number of seed/berry	0.00-3.00	1.76	0.55	31.53	27.1	73.91	0.84

The data on genotypic and phenotypic correlation coefficient among different characters is presented in Table 3. The correlation analysis indicated that average bunch weight was significantly correlated between pruning biomass ($r=0.334$), berry weight ($r=0.412$), berry diameter ($r=0.786$) and berry length ($r=0.348$). Days taken to physiological maturity was positively correlated with time of veraison ($r=0.489$). Peduncle length was significantly correlated with pruning biomass ($r=0.169$), time of full bloom ($r=0.178$), berry weight ($r=0.184$), berry diameter ($r=0.157$), berry length ($r=0.212$) and bunch length ($r=0.451$).

Table 3: Phenotypic and genotypic correlation coefficient of yield parameters of wine grape

Traits		PB	TBB	TFB	TOV	BW	BD	BL	TSS	AD	CP	SF	BuL	PL	PM	ABW
PB	P	1 **														
	G	1 **														
TBB	P	0.109 ^{NS}	1 **													
	G	0.152 ^{NS}	1 **													
TFB	P	-0.076 ^{NS}	-0.123 ^{NS}	1 **												
	G	-0.089 ^{NS}	-0.157 ^{NS}	1 **												
TOV	P	-0.015 ^{NS}	0.005 ^{NS}	-0.042 ^{NS}	1 **											
	G	-0.027 ^{NS}	-0.011 ^{NS}	0.082 ^{NS}	1 **											
BW	P	0.193 ^{NS}	-0.117 ^{NS}	-0.090 ^{NS}	0.088 ^{NS}	1 **										
	G	0.195 ^{NS}	-0.166 ^{NS}	-0.109 ^{NS}	0.103 ^{NS}	1 **										
BD	P	0.094 ^{NS}	-0.140*	0.073 ^{NS}	0.091 ^{NS}	0.611 **	1 **									
	G	0.115 ^{NS}	-0.166 ^{NS}	0.123 ^{NS}	0.161 ^{NS}	0.749 **	1 **									
BL	P	0.204*	-0.050 ^{NS}	0.092 ^{NS}	0.016 ^{NS}	0.625**	0.811 **	1 **								
	G	0.229*	-0.085 ^{NS}	0.094 ^{NS}	0.055 ^{NS}	0.725**	0.936 **	1 **								
TSS	P	0.056 ^{NS}	-0.045 ^{NS}	0.035 ^{NS}	-0.123 ^{NS}	-0.182**	-0.221**	-0.180**	1 **							
	G	0.061 ^{NS}	-0.114 ^{NS}	0.041 ^{NS}	-0.147 ^{NS}	-0.213 ^{NS}	-0.265*	-0.196 ^{NS}	1 **							
AD	P	0.175**	0.104 ^{NS}	0.089 ^{NS}	0.046 ^{NS}	0.133*	0.137*	0.112 ^{NS}	-0.232**	1 **						
	G	0.274 *	0.176 ^{NS}	0.099 ^{NS}	-0.060 ^{NS}	0.204 ^{NS}	0.264*	0.191 ^{NS}	-0.356**	1 **						
CP	P	-0.081 ^{NS}	-0.054 ^{NS}	0.002 ^{NS}	-0.195**	-0.278**	-0.264**	-0.292**	0.050 ^{NS}	0.063 ^{NS}	1 **					
	G	-0.082 ^{NS}	-0.081 ^{NS}	0.013 ^{NS}	0.2311 *	-0.283*	-0.319**	-0.336**	0.047 ^{NS}	0.081 ^{NS}	1 **					
SF	P	0.096 ^{NS}	-0.110 ^{NS}	0.045 ^{NS}	-0.047 ^{NS}	0.063 ^{NS}	0.075 ^{NS}	0.061 ^{NS}	0.002 ^{NS}	-0.009 ^{NS}	0.054 ^{NS}	1 **				
	G	0.112 ^{NS}	-0.160 ^{NS}	0.054 ^{NS}	-0.084 ^{NS}	0.078 ^{NS}	0.060 ^{NS}	0.052 ^{NS}	0.019 ^{NS}	-0.055 ^{NS}	0.062 ^{NS}	1 **				
BuL	P	-0.043 ^{NS}	-0.051 ^{NS}	0.292**	-0.132*	0.104 ^{NS}	0.084 ^{NS}	0.094 ^{NS}	-0.022 ^{NS}	0.037 ^{NS}	-0.079 ^{NS}	0.168*	1 **			
	G	-0.051 ^{NS}	-0.085 ^{NS}	0.393**	-0.152 ^{NS}	0.120 ^{NS}	0.104 ^{NS}	0.102 ^{NS}	-0.034 ^{NS}	0.114 ^{NS}	-0.094 ^{NS}	0.192 ^{NS}	1 **			
PL	P	0.169*	-0.224**	0.178**	-0.043 ^{NS}	0.184**	0.157*	0.212**	0.134*	0.017 ^{NS}	-0.040 ^{NS}	0.354**	0.451**	1 **		
	G	0.174 ^{NS}	-0.284 *	0.220 ^{NS}	-0.047 ^{NS}	0.192 ^{NS}	0.173 ^{NS}	0.231*	0.162 ^{NS}	-0.001 ^{NS}	-0.039 ^{NS}	0.411**	0.498**	1 **		
PM	P	-0.048 ^{NS}	0.045 ^{NS}	0.020 ^{NS}	0.489**	-0.151*	-0.042 ^{NS}	-0.060 ^{NS}	-0.092 ^{NS}	-0.071 ^{NS}	-0.262**	-0.073 ^{NS}	-0.025 ^{NS}	-0.076 ^{NS}	1 **	
	G	-0.054 ^{NS}	0.060 ^{NS}	0.007 ^{NS}	0.580**	-0.159 ^{NS}	-0.051 ^{NS}	-0.052 ^{NS}	-0.100 ^{NS}	-0.086 ^{NS}	-0.276*	-0.080 ^{NS}	-0.029 ^{NS}	-0.079 ^{NS}	1 **	
ABW	P	0.334*	-0.189 ^{NS}	-0.256 ^{NS}	0.292 ^{NS}	0.412**	0.786**	0.348*	-0.289 ^{NS}	0.246 ^{NS}	-0.196*	0.061 ^{NS}	0.138 ^{NS}	0.008 ^{NS}	-0.156 ^{NS}	1 **
	G	0.367*	-0.238 ^{NS}	-0.291 ^{NS}	0.314 ^{NS}	0.445**	0.834**	0.378*	-0.305 ^{NS}	0.271 ^{NS}	-0.234*	0.086 ^{NS}	0.189 ^{NS}	0.021 ^{NS}	-0.178 ^{NS}	1 **

*Significant; **Highly Significant ($P=0.05$); ^{NS} Non- significant

(PB, pruning biomass (kg); TOB, Time of bud burst (DAP); ToFB, Time of full bloom (DAP); ToV, time of veraison (DAP); ABW, Average bunch weight (g); BW, 50 berry weight; NOB, number of berries per bunch; BD, Berry diameter (mm); BL, Berry length (mm); TSS, total soluble solid (°B); AD, Acidity(%); CP, Compactness; SF, Skin firmness (%); BuL, Bunch length (cm); BuW, Bunch Width (cm); PL, Peduncle length (mm); PM, Physiological Maturity (DAP); SW, Seed weight (g); NOS, Number of seed per berry).

The genetic diversity was assessed using Mahalanobis D^2 analysis resulting that all the 75 genotypes were grouped into three clusters. Out of three clusters, cluster I showed maximum number of genotypes (45), followed by cluster III (23) and cluster II (7). The cluster I consisted of cultivars Symphony, Petit Syrah, Gulabi × Bangalore Blue having highest fruit weight, highest TSS (24.56), highest number of berries/bunch (186.0).

The intra-cluster distance is used to measure genetic dissimilarity among genotypes within the same cluster, while, inter-cluster distance represents genetic distance between genotypes in any two clusters. The intra-cluster distances were recorded from 3.53 (cluster I) to 3.86 (cluster II) whereas, the inter cluster was highest (4.30) between cluster I and cluster II, followed by cluster I and cluster III (3.59) and cluster II and cluster III (3.40). Clusters with higher inter-cluster distances indicated that grape genotypes within those clusters showed significant genetic differentiation. Anjanawe *et al.*, (2020) noted variability with respect to various fruit traits in wine varieties under Malwa plateau.

CONCLUSION

The present study identified significant genetic variability in wine grape germplasm for fruit yield and quality traits. Traits like pruning biomass, bunch weight,

number of berries/ bunch, berry diameter, bunch length, and berry weight strongly correlated with fruit yield. The comprehensive understanding of genetic diversity and yield-contributing traits provides a foundation for targeted breeding strategies aiming to improve wine grape for better productivity and resilience.

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