International Journal of Bio-resource and Stress Management https://ojs.pphouse.org/index.php/IJBSM

Crossref

IJBSM March 2025, 16(3): 01-11 **Article** AR5889

Research Article *Natural Resource Management*

DOI: HTTPS://DOI.ORG/10.23910/1.2025.5889

Morphological Characterization of White Colored Grape Accession (*Vitis vinifera* L.) through Multivariate Approach under Indian Condition

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0009-0001-8746-1031

ABSTRACT

The present study was conducted during October, 2022 to March, 2023 at ICAR-National Research Centre for Grapes, Pune, Maharashtra, India to characterize white colored grape genotype based on morphological qualitative traits and their relations. The morphological and fruit traits of 83 white coloured grape accession were evaluated. The grapevines were grown under standard recommended practices of irrigation, fertilization, and pest and disease control. The morphological quantitative traits such as bunch weight, bunch length, bunch width, berry length, berry diameter, berry thickness of skin, berry firmness of mesocarp, berry weight were in the following range 41.6–1456.5 g, 7.0–22.0 cm, 4.0–15.5 cm, 9.5–25.0 mm, 8.0–24.0 mm, 0.140–0.420, 25.0–88.0%, 55.0–316.0 g respectively, which indicated a wide level of diversity in the selected genotypes. Significant genotypic and phenotypic variation were observed among the studied accession for the measured characters. In addition, 4 types of berry flavor, 5 types of bunch shape and 6 types of different berry shape were observed. Multivariate analysis such as principal component analysis, cluster analysis was used for assessing the diversity of accession. The clustering dendrogram based on the obtained data showed two main cluster with several sub-clusters. The obtained data revealed high morphological variability within the studied collection of grapevine cultivars, which could be considered to characterize the large gene pool that contributes to the breeding process of grapes.

KEYWORDS: Grape germplasm, morphological traits, genetic variation, cluster analysis

***Citation* (VANCOUVER):** Nale et al., Morphological Characterization of White Colored Grape Accession (*Vitis vinifera* L.) through Multivariate Approach under Indian Condition. *International Journal of Bio-resource and Stress Management,* 2025; 16(3), 01-11. HTTPS://DOI.ORG/10.23910/1.2025.5889.

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Conflict of interests: The authors have declared that no conflict of interest exists.

RECEIVED on 24th October 2024 RECEIVED in revised form on 19th February 2025 ACCEPTED in final form on 01st March 2025 PUBLISHED on 07th March 2025

1. INTRODUCTION

The grapevine (*Vitis vinifera* L.), is one of the most extensively cultivated fruit in the world, (Myles et al., 2015; Laucou et al., 2018) and it is believed to include between 6000 and 10000 cultivars worldwide. Due to wide diversification in the climatic condition, grapes are acclimatized in temperate to the tropical zones of the world. Cultivated grapes are believed to have been introduced into India in 1300 AD by Muslim invaders from Iran and Afghanistan (Thapar, 1960). Introduction of grapes to South India by a French priest in 1832 was another success and then Bellary in Karnataka state in 1842. From the primary domestication in these states, the grapevine was spread to other states and became the successive in grape cultivation. The grapes were then introduced to South India in 14th century. From the primary domestication areas, the grapevine spread to neighboring regions and followed different pathways. Grape (*V. vinifera*) 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 (Abiri et al., 2020). It is extremely important resource, not only because of its fruit, but also because of the presence of secondary metabolites in its cellular structure. Resveratrol is a secondary metabolite that acts as an antioxidant that protects the body from high risks (Arslan et al., 2023). These compounds have anti-inflammatory, anti-aging and antimicrobial properties which protect from cardiovascular diseases.

The field of viticulture has always attracted a great deal of interest. At present, in India, Maharashtra, Karnataka and Tamil Nadu are the major grape growing states. Due to wider adaptability, grape growing is adopted under the tropical conditions of India It is one of the major fruit crops and most widely cultivated in three distinct agro-climatic conditions (sub-tropical, tropical, and temperate climatic conditions) in India. It is important to mention that it has an economic importance, with a total area of 7.726 mha and global production up to 27.9 million mt over the world. India has rich grapevine biodiversity with second largest producer of grape. It occupies an area about 1,71,000 ha with production of 37.81 lakh mt and productivity in 21.06 mt ha^{-1} (Anonymous, 2023). The climate of a particular location greatly affects the diversity and production of the crop. Researchers and scientists around the world are far more interested in grape genetic resources now that they are aware of them because germplasm is essential for studying gene functions, developing new and improved lines, and conserving species (Ates et al., 2011; Khadivi et al., 2019). Therefore, assessment of grape diversity is an essential component of the characterization and conservation of germplasm, which are necessary to maintain and improve crop production. The morphological characteristics of fruit trees are often used to characterize fruit trees because of their obvious economic importance and discriminatory power (Chessa and Nieddu, 2005). Morphological variations in plant species have been reported for traits controlled by a single or multiple gene systems. Variation in morphological traits is the result of both genetic and environmental factors. Fruit traits have been used as main morphological traits in characterization of fruit trees (Cunha et al., 2007). Morphological traits, combined with multivariate statistical methods such as principal component analysis (PCA) and cluster analysis, have long been used to evaluate genetic variation and relationships among genotypes and cultivars (Leao et al., 2011; Ates et al., 2011; Khadvi-Khub et al., 2014, Vafaee et al., 2017; Kupe et al., 2021). In India, grapes are mainly grown for table purpose followed by raisin, juice and wine making. Among the different grape varieties, Thompson Seedless, a white seedless and its clones are the major varieties grown. The aim of present investigation was to characterize white colored grape genotype based on morphological qualitative traits to check the morphological variation and their relationship among the exotic.

2. MATERIALS AND METHODS

2.1. Plant materials

The experiment was conducted during October, 2022 to March, 2023 at ICAR-National Research Centre for Grapes, Pune. The genotypes included in the study are as follows.

Westfield, Coarna Alba, Frumoasa Alba, Muscat White, Arka Chitra, Arka Kanchan, Bianca, Ugni Bianca, Muscat of Alexandria, Rosaria Bianca, Gold, Aledo, Anab-E-Shahi, Pandhari Sahebi, Hussain Kadu, Golden Queen, Cheema Sahebi, Sahebi Ali, Julsky Muscat, Dilkhush, Italia, Palomino, Waltham cross, Muscat, Muscat Petit, Doradillo, Cardinal, Marquise, Sultana Seedless, TAS (White Seedless), TAS A Ganesh, Sonaka Original, 2A clone, Sonaka Mutant, Sonaka, H-5-clone, Manik Chaman, Maruti seedless, Manjari Naveen, Superior Seedless, Perlette, Early Perlette, Loose Perlette, Ambe, Vijay Chaman, Delight, Mint, Pusa Seedless, New Perlette, Kishmish Belyi, Merbein Seedless, KR White, Peru White, Jaos Belyi, Banqui Ahyad, Symphony, Semillon, Arka Soma, Pierce, Arka Hans, Motia, Queen of Vineyard, Large White, Haitha, Almeria, Leh1, Leh2, Leh3, Leh4, Leh5, Leh6, Leh7, Leh8, Leh9, Leh10, Leh 12, Leh 13, Leh14, Pusa Swarnica, Pusa Aditi, Super Sonaka, Arka Chitra, Pusa Urvashi.

All the genotypes were collected from different location and were planted at National Active Germplasm Site at NRCG Pune (latitude 18˚32N and longitude 73˚51E) for germplasm conservation. The vines were spaced at 8

Table 1: Descriptive statistics for morphological variables between the studied white grape germplasm

Sl. No.	Traits	Abbreviation	Unit	Min	Max	Mean	SD	CV (%)
1.	Time of bud burst (DAP)	TBB	Number	8	14	10.14	1.28	12.62
2.	Young shoot: opening of shoot tip	YS: OST	Code	1	9	6.73	2.66	39.52
3.	Young leaf: colour upper side of blade	YS: CUB	Code	1	9	3.14	1.30	41.40
4.	Time to full bloom (DAP)	TFB	Number	31	43	40.04	2.47	6.10
5.	Inflorescence: number of inflorescences	NL	Code	1	7	2.85	1.49	52.28
6.	Tendril type	TT	Code	1	3	1.89	0.45	23.80
7.	Tendril distribution on shoot	TDS	Code	1	3	2.01	0.89	44.27
8.	Shoot attitude: (Growth habit)	SA	Code	1	5	2.03	1.47	72.41
9.	Mature leaf: width of blade	ML:WB	Code	1	9	7.69	1.22	15.86
10.	Mature leaf: shape of blade	ML:SB	Code	1	5	3.04	1.03	33.88
11.	Mature leaf: number of lobes	ML:NL	Code	1	9	5.32	1.57	29.51
12.	Mature leaf: anthocyanin coloration on main vein	ACV	Code	1	5	1.81	0.95	52.48
13.	Mature leaf: shape of teeth	ST	Code	1	5	2.73	0.71	26.00
14.	Mature leaf: degree of opening	DOPS	Code	1	9	4.10	1.98	48.29
15.	Mature leaf: prostrate hairs between veins on lower side of blade	ML:DPHBV	Code	1	6	2.72	1.62	59.55
16.	Mature leaf: erect hairs between veins on lower side of blade	ML:EPHBV	Code	1	6	1.39	0.99	71.22
17.	Mature leaf: ratio of length of petiole compared to mid vein	RLPCMV	Code	1	7	1.50	1.49	99.33
18.	Time of verasion (DAP)	TOV	Number	90	110	101.7	4.55	4.47
19.	Sex of flower	FS	Code	3	3	3	0	0
20.	Duration of flower	ANI	Number	4	8	5.67	3.27	57.67
21.	Bunch: weight of grapes	BW	g	41.6	1456.5	330.4	248.93	75.34
22.	Bunch: shape	BS	Code	1	7	2.91	1.35	46.39
23.	Bunch length	BL	cm	7.0	22.0	14.59	3.43	23.50
24.	Bunch width	BW	cm	4.0	15.5	9.066	2.37	26.15
25.	Bunch: compactness in grapes	BC	Code	1	7	5.62	1.32	23.48
26.	Bunch: peduncle length	BPL	cm	7	50	27.63	9.35	33.84
27.	Bunch: uniformity of berry size	BU	Code	1	7	6.56	1.25	19.05
28.	Berry shape	BrS	Code	1	7	2.95	1.12	37.96
29.	Berry: thickness of skin	BTS	mm	0.14	0.42	0.23	0.05	21.73
30.	Berry length	BrL	mm	9.5	25.0	17.28	3.32	19.21
31.	Berry diameter	BD	mm	8.00	24.00	15.38	2.60	17.03
32.	Berry: attachment of pedicle	BAP	Code	3	7	5.69	1.88	33.04
33.	Berry: flavor	BF	Code	1	9	2.73	2.04	74.75
34.	Beery: firmness of mesocarp	BFM	%	25.0	88.0	62.04	14.6	23.53
35.	Berry: weight of 50 berry	BrW	g	55.0	316.0	174.77	80.24	45.91

Table 1: continue....

Sl. No.	Traits	Abbreviation	Unit	Min	Max	Mean	SD	CV (%)
36.	Berry: length of pedicle	BPL	Code	1	7	2.87	1.66	57.83
37.	Berry: formation of seed	BFS	Code	1	5	3.65	1.90	52.05
38.	Berry: 100 seed-weight	SW	g	0	10.3	4.15	3.33	81.21
39.	Total soluable solid (TSS)	TSS	°Brix	17.0	23.6	18.96	2.07	10.91
40.	Titratable acidity	TA	%	0.41	0.86	0.93	1.36	146.23
41.	Juice pH	pH		3.05	3.82	3.41	0.18	5.27

(Coefficient of Variance (CV%)=(SD/Mean)×100)

f×4 ft distance, trained to Y trellises with vertical shoot orientation. The grapevines were grown under standard recommended practices of irrigation, fertilization, and pest and disease control. The vines of these germplasm were high-yielding and well-adapted under tropical climatic conditions, and are going to be used as planting material to establish new commercial orchards throughout the country.

2.2. Ampelographic qualitative traits

The mean values from 5 plants of each germplasm was recorded during years 2022–2023 based on 40 ampelographic traits. Qualitative characteristics were considered based on rating and coding according to the descriptor list for Vitis species (Anonymous, 2007).

2.3. Quantitative traits

Fruit characters were studied to assess the range of variation among the germplasm. Parameters related to the fruit were measured, calculated, and visually estimated at harvest stage (full maturity). Quantitative traits were measured by laboratory equipment such as digital caliper, precision weighing balance, and digital measuring tape. Cluster and berry dimensions (length and width) were measured with digital caliper. Bunch weight was measured by electronic balance with 0.01 g precision, berries bunch^{-1} and number of seeds berry^{-1} were also recorded. The fruit juice was used for analysis of total soluble solids (TSS), titratable acidity (TA), and pH. TSS was determined by refractometer (pocket PAL-1 ATAGO Corporation, Tokyo, Japan) and was expressed in Brix. TA was measured by neutralization to pH 8.10 with 0.1 N NaOH, data are given as % of tartaric acid. The pH values were measured by a pH meter.

2.4. Statistical analysis

The data resulting from the study was grouped and the average values were used for statistical analysis. The standardized data set was then used to estimate the genetic diversity and relationships between cultivars. Mean and standard deviation (SD) were calculated for each data set. Also, co-efficient of variation (CV %) were determined as indicators of variability. Relationships between cultivars were investigated by multivariate ANOVA (PCA) using SPSS statistics. The phenotypic distance coefficients were calculated according to the Euclidean method and the dendrogram was constructed using the unweighted pair group method with arithmetic means (UPGMA) using XLSTAT statistics software.

3. RESULTS AND DISCUSSION

3.1. Morphological analysis

The studied grape accessions showed significant differences for most of the morphological traits. Mean, SD, minimum, maximum, and CV % values for morphological traits are given in Table 1. The highest coefficient of variation was established for Acidity (CV=146.23%), while the lowest CV was observed in sex of flowers (CV=0.00%) followed by juice pH (CV=5.27%). Among the different accessions studied, 31 out of 41 characters reached CV values higher than 20%.

In most of accessions, bud burst time was from early to moderate. Significant variation for flowering time was observed in the studied accessions varying from early, moderate, and late. In all the 82 accessions, hermaphrodite (male and female) flowers were well developed. Three different forms were found in young shoot tip, ranging from closed, half open and fully opened, however, full open was the most common. Different color such as green, green with bronze spots, yellow, yellow with bronze spots, copper yellow, reddish were observed on upper side of young leaf blade. Green with bronze spot and yellow color was observed in most of the accessions (60.78%). Average number of inflorescences shoot^{-1} was less than 1 or one in most of the accessions (71.23%). Most of the accessions had erect shoot attitude (41.90%) and followed by semi-erect habit (32.30%). Most of the genotypes that had been evaluated possessed pentagonal blade morphology. The cordate blade shape as predomiant was reported by Vafaee et al. (2017). In most of germplasm, five lobes in leaves were recorded. Anthocyanin coloration of main vein on lower side of blade was very weak in the studied accessions. Teeth shape of mature leaf was a predominantly mixture of both sides straight and both sides convex (71.00%). The overlapping of petiole sinus was moderately open followed by narrowly

open in most of the accessions. Density of prostrate and erect hairs between veins on lower side of blade was absent, very low, low, medium, high, and very high. Erect hairs were absent in most of the accessions (80.23%), while in prostrate hairs present in few accessions.

Time of berry verasion was late in most of the accessions. The largest average bunch weight was recorded in Jaos Belyi (1456.4 g) and the lowest (41.6 g) in for Early Perlette. The cluster length varied between 7.34 cm (Early Perlette) to 22.3 cm (Pusa Aditi). Furthermore, 50-berry-weight ranged from 55.0 g (Ambe), 56.7 g (Early Perlette) to 316.0 g (Aledo). Few accessions were seedless while in most of the accessions, 2–3 seed were present in berry. In the studied accessions, berry shape included (oblate, round, short elliptical, long elliptical, cylindrical) while very diverse berry flavors were recorded, with 4 categories (Neutral, foxy, muscat, others). The TSS ranged from 17.0 to 23.6°Brix while acidity varied from 0.41 to 0.86% and juice pH from 3.05 to 3.82.

3.2. Principal component analysis

PCA based on correlation matrix were performed to estimate morphological variation between different germplasm. Using the Kaiser's criterion (Kaiser, 1958) (Eigen-value >1), it was possible to reduce the dimension of the 41 phenotypic traits to only 14 components, which could explain 74.38% of the total variation. For each factor, a PC loading of more than 0.57 was considered as being significant, indicating fourteen components and explaining 74.38% of the total variance (Table 2). The first three PCs explained 64.63% of the variance (13.22, 21.94 and 29.47%, respectively), indicating that these attributes have the highest variation between the cultivars and had the greatest impact on the distinction between them (Khadivi-Khub et al., 2014). The first component of PC1 was strongly correlated with shoot

Table 2: Eigenvalues of principal component axes from the PCA of morphological characters utilized for the studied white colored grape accessions

Component	1	2	3	4	5	6
Time of bud burst (DAP)	-0.287	0.195	-0.069	0.375	-0.056	-0.226
Young shoot: opening of shoot tip	-0.32	-0.135	0.082	0.363	0.02	0.347
Young leaf: colour up-per side of blade	0.094	0.382	0.238	0.057	0.247	-0.264
Time to full bloom (DAP)	-0.335	-0.039	0.638**	0.201	-0.04	0.094
Inflorescence: average number of inflorescence	-0.11	0.111	-0.6	-0.161	0.023	0.07
Shoot attitude: (Growth habit)	0.588**	-0.265	0.204	0.332	-0.157	0.042
Mature leaf: width of blade	-0.058	0.084	0.134	0.216	-0.142	0.558
Mature leaf: shape of blade	-0.302	0.178	0.203	0.21	0.409	0.017
Mature leaf: number of lobes	-0.154	0.43	0.001	0.214	0.212	0.349
Mature leaf: antho-cyanin coloration on main vein	-0.249	0.575**	-0.115	0.18	-0.117	0.025
Mature leaf: shape of teeth	-0.053	-0.118	0.275	-0.197	-0.321	0.094
Mature leaf: degree of opening	-0.065	-0.165	0.503	-0.104	0.322	0.185
Mature leaf: prostrate hairs between veins on lower side of blade	0.205	0.137	-0.47	-0.322	0.028	0.02
Mature leaf: erect hairs between veins on lower side of blade	0.270	0.085	0.389	0.13	0.288	-0.119
Mature leaf: shape of teeth	-0.046	0.119	-0.151	0.226	0.08	0.454
Time of verasion (DAP)	0.054	0.099	-0.311	0.065	-0.008	0.164
Bunch: weight of grapes	0.249	-0.032	0.167	-0.527	0.307	-0.22
Bunch: shape	-0.35	-0.227	-0.148	0.161	0.01	0.017
Bunch length	-0.406	0.395	0.178	-0.524	-0.039	0.009
Bunch width	-0.231	0.503**	0.497	0.12	-0.257	-0.244
Bunch: compactness in table grapes	0.381	-0.301	0.186	-0.116	0.408	-0.03
Bunch: peduncle length	-0.418	0.338	0.114	-0.295	-0.212	0.162
Bunch: uniformity of berry size	-0.36	0.492	-0.212	-0.143	0.221	0.007
Berry diameter	0.643**	0.4	0.121	-0.044	-0.328	-0.031

Table 2: Continue...

Component	1	2	3	4	5	6
Berry: shape	0.197	-0.071	0.177	-0.165	-0.152	0.609**
Berry: thickness of skin	0.134	0.513**	-0.14	0.485	0.054	0.016
Berry length	0.711**	0.141	0.197	0.025	-0.235	0.22
Berry: attachment with pedicel	0.027	-0.197	0.188	0.032	-0.107	0.022
100 seed weight	0.798**	0.262	-0.121	0.086	-0.053	-0.014
Berry: formation of seed	0.758**	0.363	-0.185	-0.082	0.105	-0.004
Berry: flavour	-0.187	0.133	-0.323	0.368	0.041	-0.086
Berry: firmness of mes-ocarp	-0.413	0.21	0.413	0.012	-0.301	-0.331
Berry: 50 berry weight	0.631**	0.544**	0.283	-0.016	-0.006	0.031
Berry: length of pedicle	0.411	-0.015	0.156	0.155	0.477	0.037
Total soluable solid (TSS)	0.152	-0.493	-0.001	0.468	0.001	-0.213
Titratable acidity	-0.236	0.07	0.169	-0.301	0.367	0.369
Juice pH	0.18	-0.311	-0.007	-0.178	-0.431	0.09
Eigenvalue	4.89	3.22	2.78	2.34	1.91	1.84
Percent of variance	13.22	8.72	7.53	6.32	5.16	4.99
Cumulative %	13.22	21.94	29.47	35.80	40.97	45.96

Table 2: Continue...

Component	7	8	9	10	11	12	13	14
Time of bud burst (DAP)	0.245	0.177	-0.042	-0.03	-0.023	0.448	0.274	-0.06
Young shoot: opening of shoot tip	-0.107	0.065	-0.205	0.371	0.063	-0.109	-0.145	-0.237
Young leaf: colour up-per side of blade	-0.087	0.452	-0.092	0.081	-0.039	0.119	0.29	-0.208
Time to full bloom (DAP)	0.147	-0.083	-0.077	-0.101	-0.11	-0.062	0.136	0.093
Inflorescence: average number of inflorescence	-0.093	-0.105	0.06	0.519	-0.077	0.216	-0.046	-0.081
Shoot attitude: (Growth habit)	-0.134	0.085	0.191	-0.021	0.104	0.003	0.246	0.012
Mature leaf: width of blade	0.227	-0.075	0.098	-0.3	-0.09	0.079	-0.362	0.002
Mature leaf: shape of blade	-0.312	0.247	-0.165	0.164	0.044	-0.056	-0.099	0.305
Mature leaf: number of lobes	0.039	-0.291	-0.026	0.188	-0.143	-0.084	0.324	0.429
Mature leaf: antho-cyanin coloration on main vein	0.174	-0.332	-0.035	0.067	0.044	-0.072	-0.211	-0.016
Mature leaf: shape of teeth	-0.224	-0.082	0.198	0.112	0.392	0.284	0.105	0.072
Mature leaf: degree of opening	0.117	-0.066	-0.319	0.245	-0.017	0.268	-0.256	-0.033
Mature leaf: prostrate hairs between veins on lower side of blade	0.136	0.122	-0.32	-0.276	0.126	0.023	0.192	0.218
Mature leaf: erect hairs between veins on lower side of blade	0.124	-0.405	-0.291	-0.412	0.125	0.011	0.006	-0.044
Mature leaf: shape of Teeth	0.036	0.151	0.213	-0.22	-0.085	0.434	0.035	-0.043
Time of verasion (DAP)	0.276	0.025	-0.149	0.153	0.713	0.099	0.068	0.104
Bunch: weight of grapes	0.405	0.263	-0.108	0.029	0.003	-0.01	-0.236	0.089
Bunch: shape	0.333	-0.131	0.045	-0.132	0.231	-0.344	0.161	-0.433
Bunch length	0.158	-0.012	0.326	0.09	0.038	-0.039	-0.075	0.093
Bunch width	-0.165	-0.087	0.151	0.13	0.095	0.009	0.005	0.054
Bunch: compactness in table grapes	0.174	-0.209	0.25	-0.023	0.241	0.096	0.025	0.104
Bunch: peduncle length	0.107	0.461	0.055	-0.157	0.055	-0.293	0.107	0.097

Table 2: Continue...

Component	7	8	9	10	11	12	13	14
Bunch: uniformity of berry size	0.023	-0.153	-0.253	-0.172	-0.118	0.177	0.101	-0.051
Berry diameter	0.323	0.097	-0.085	0.149	-0.114	-0.077	-0.084	0.057
Berry: shape	-0.233	0.337	-0.316	-0.081	0.152	-0.061	0.106	-0.092
Berry: thickness of skin	0.006	0.06	0.234	-0.101	0.015	-0.191	0.046	0.106
Berry length	0.221	0.125	-0.04	0.202	-0.151	-0.059	-0.096	-0.024
Berry: attachment with pedicel	0.57**	-0.154	-0.156	0.418	-0.004	-0.086	0.358	0.019
100 seed weight	-0.218	-0.1	-0.015	0.047	0.012	0.048	-0.026	-0.152
Berry: formation of seed	-0.269	-0.19	-0.053	0.012	0.089	-0.053	-0.026	-0.001
Berry: flavour	0.4	0.299	0.236	-0.02	0.123	0.13	-0.308	-0.009
Berry: firmness of mes-ocarp	-0.098	-0.01	-0.132	-0.043	0.155	0.226	-0.093	-0.132
Berry: 50 berry weight	0.051	0	0.093	-0.048	0.204	0.081	-0.078	-0.113
Berry: length of pedicle	0.186	0.194	0.313	0.089	-0.193	0.023	0.135	-0.183
Total soluable solid (TSS)	-0.014	0.186	0.02	-0.01	0.146	-0.008	-0.186	0.433
Titratable acidity	-0.083	-0.035	0.513	-0.024	0.131	0.056	0.094	-0.064
Juice pH	0.176	-0.101	0.128	-0.106	-0.276	0.323	0.136	0.163
Eigenvalue	1.75	1.50	1.42	1.35	1.20	1.14	1.12	1.02
Percent of variance	4.73	4.05	3.81	3.65	3.26	3.08	3.05	2.76
Cumulative %	50.69	54.74	58.56	62.21	65.47	68.56	71.61	74.38

attitude (0.588), prostrate hairs (0.205), erect hairs (0.270), formation of seed (0.758), 100-seed weight (0.798), Bunch weight (0.249), bunch compactness (0.381), berry diameter (0.643), berry length (0.711) and 50 berry weight (0.631). The second component of PC2 was mainly correlated with anthocyanin coloration (0.575), bunch width (0.503) and skin thickness (0.513). The third component was associated with berry firmness (0.413), degree of opening of petiole sinus (0.503) and time of full bloom (0.638). The remaining components (4–14) accounted for 44.86% of the total variation (Table 2). Variables that showed high correlation with PC1 can be considered representative of berry size. This type of analysis essentially restructures data sets containing many correlated variables into smaller sets of components. These results in some cases are in agreement with the result reported by Ekhvaia and Akhalkatsi, 2010; Leao et al., 2011. Bunch and berry traits were important parameters in identifying and analyzing breeding materials dealing with the morphological characterization of grape (Leao et al., 2011). Correlations between different morphological characters revealed by PCA method may correspond to a genetic linkage between loci of controlling traits or a pleiotropic effect (Khadivi-Khub et al., 2014).

3.3. PCA plots for morphological and fruit traits of grape genotypes

The PCA plot developed based on morphological traits divided the variables into four quadrants (Figure 1 and Figure 2). This plot depicts that grape variables are closely related to each other, have similar characteristics, and contribute less to diversity. Variables away from the center of the axis and those present away from each other showed a high level of variation in grape genotypes. Variables which were present at the lower left quadrant of the plot had close relation between them but have negative relation with the variables at the upper side of the plan. While variables present in the upper left side and lower side of PCA plot had a strong positive relation between them and was closely associated with each other.

3.4. Cluster analysis based on morphological qualitative traits

UPGMA cluster analysis was performed based on the Euclidean distance coefficient allowed the assessment of similarity or dissimilarity and clarified some of the relationships between grape cultivars. In the present study, dissimilarity level (d) or distance ranged from 0 to 12. Among the different accessions, highest similarity was observed between Perlette and Maruti Seedless while lowest between Pierce and Loose Perlette germplasm. Based on 41 morphological qualitative traits, 82 grape genotypes were divided into two main groups i.e., Group-1 and Group-2 (Figure 3). These groups were further divided into classes. Group-1 contained only one class. While Group-2 further contained two classes in it with further subclasses.

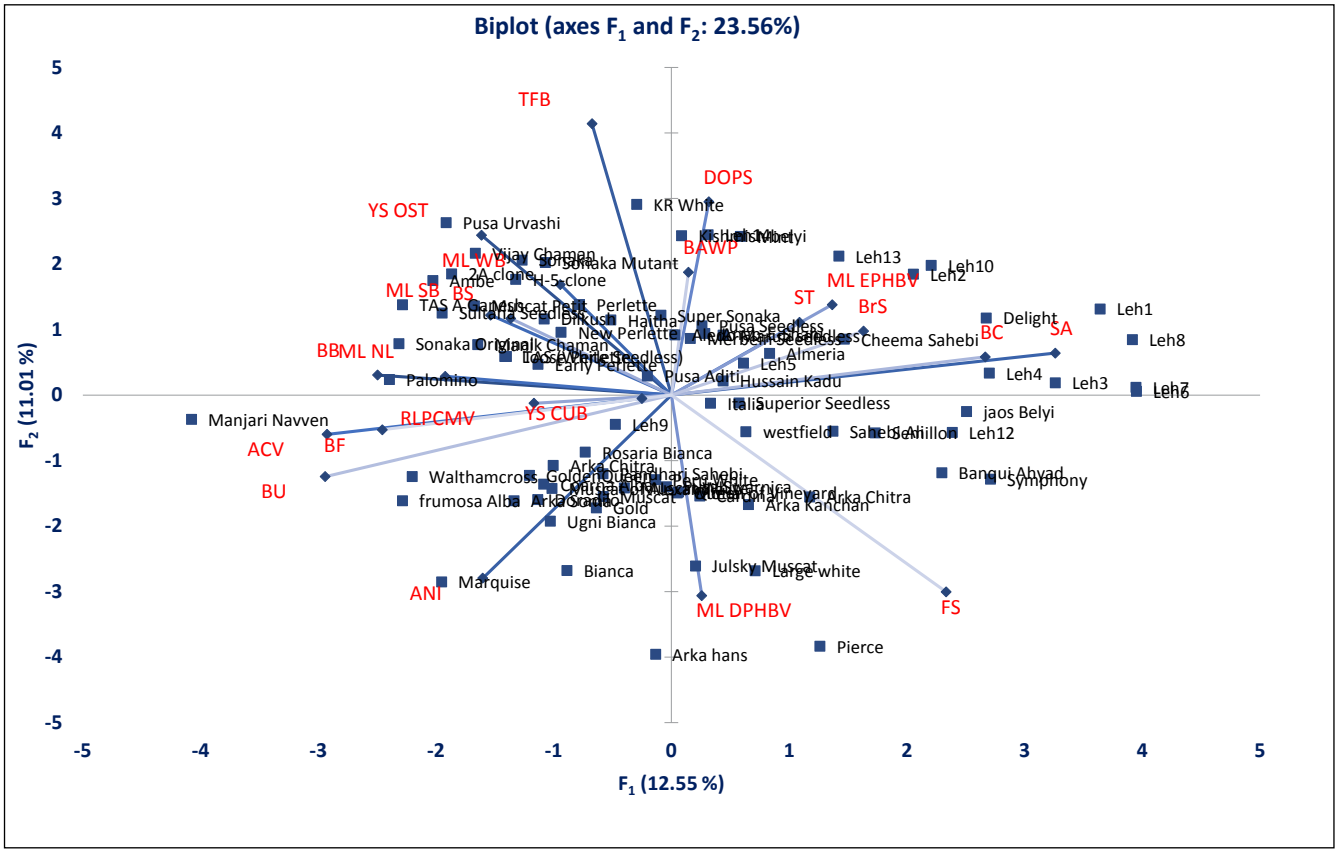

Figure 1: PCA biplot of 83 grape genotypes for qualitative morphological traits

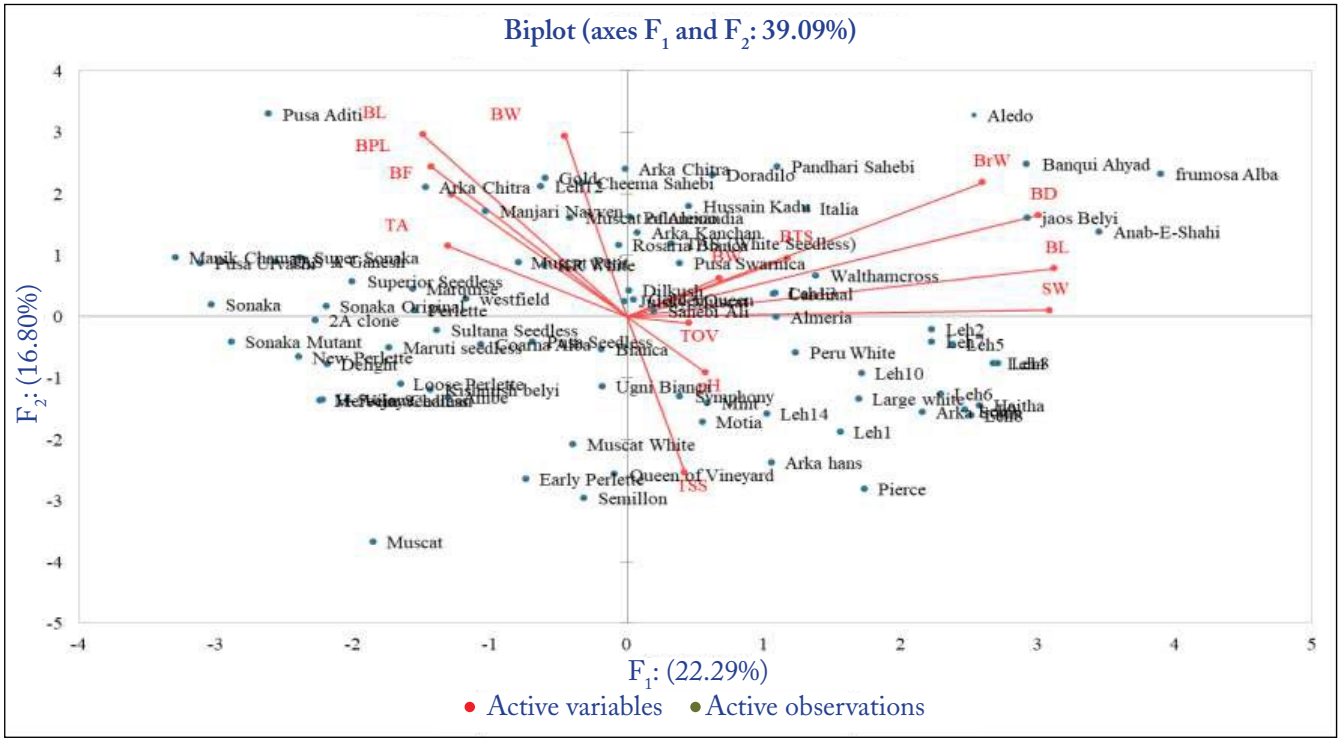

Figure 2: PCA biplot of 83 grape genotypes for quantitative fruits traits

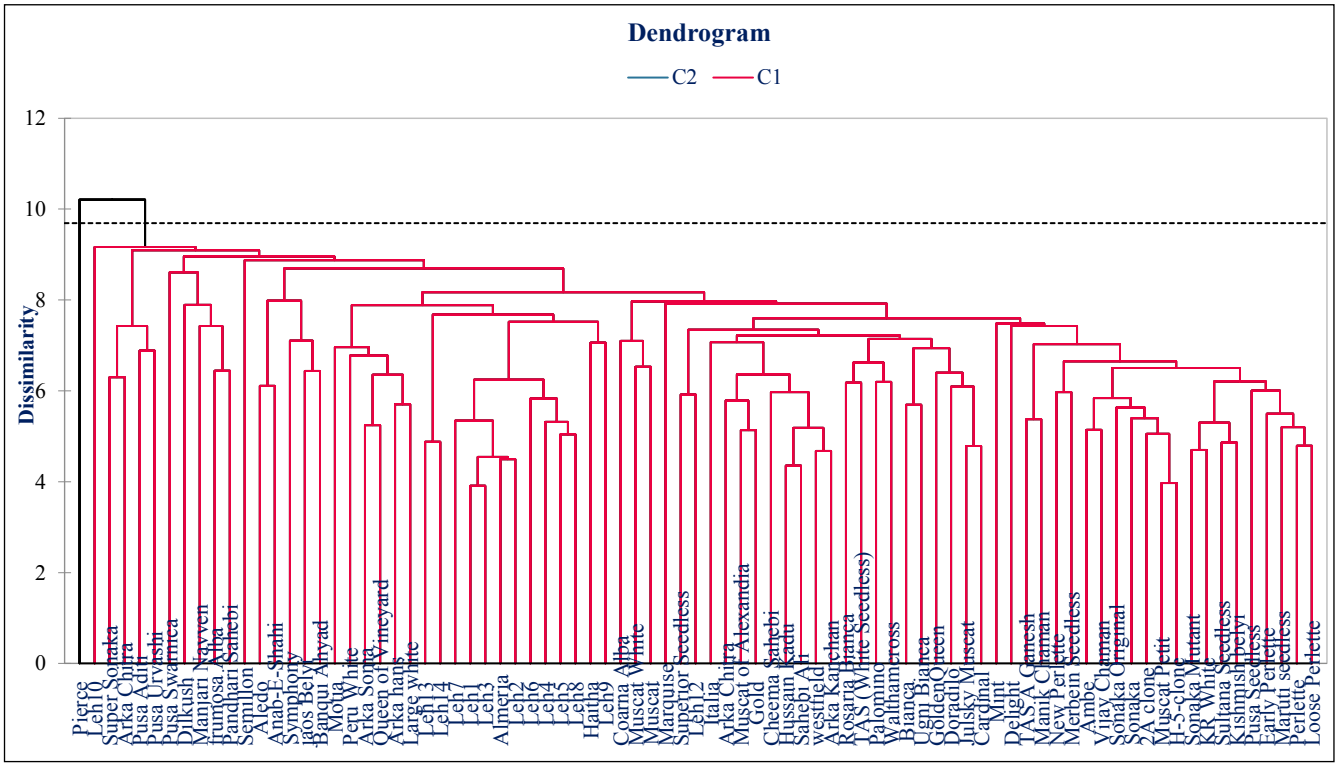

Figure 3: UPGMA cluster analysis of the studied grape genotypes based on morphological traits using Euclidean distances

Morphological characterization is one of the basic and simplest tools for differentiating genotypes based on visual observations. It has been used since Mendel's era and is still considered an important tool for the discrimination and identification of genotypes in this modern era. The basic information related to the traits are provided through morphological characterization. It is necessary to manage existing germplasm in vineyards for the development of new lines through breeding as breeding goals in fruits are to improve fruit weight, shape, color, and fruit quality (Atak et al., 2012). Morphological characterization provides superior results compared to other characterization methods because more characteristics can be determined. In the interpretation of the number of characteristics examined, it is necessary to consider the dominance of morphological characteristics (Guan et al., 2020). Morphological characterization found to be of great assistance in our investigation for genotype identification based on characteristics assessed according to with the IPGRI descriptor. These characteristics differed according to the grape genotypes grown in the tropical region of India. Maximum variation was observed in coefficient of variance (cv) among the studied germplasm for the measured characters. The result of present study was confirmed by Khadivi-Khub et al. (2014) who reported CV ranged from 5.53% (juice pH) to 133.33% (seed weight) in the studied grape cultivars measured for fruit variables. Vafaee et al. (2017) noted CV values higher than 20% in 29 out of 42 characters studied in different grapevine. Variation occurred in germplasm due to genetic diversity which refers that to the range of genetic difference within a species, and within population of the same species.

In present study, germplasm was divided into different subgroups based on the characteristics of young and mature leaves. Morphological characteristics of germplasm in each subgroup were very similar. In this comprehensive study of descriptors, certain characteristics played their anticipated role in identification of grape genotypes such as opening of shoot tip, colour on upper side of young leaf, anthocyanin coloration on main vein, degree of opening of petiole sinus, density of prostrate hairs between veins, and density of erect hairs between veins on lower side of blade. These characteristics also played a major role in the construction of a dendrogram to evaluate germplasm phylogenetic relationships. Similar finding was reported by Leao et al. (2011) who evaluated 136 table grape accessions to characterize and quantify the genetic variability among accessions using 18 morpho-agronomic traits and Atak et al. (2014) determined 55 morphological traits to check variability in nine grape cultivars. Likewise, Knezovic et al. (2017) who selected 16 characteristics from OIV descriptor to identify ten grapes. Vafaee et al. (2017) also assessed 42 characteristics to identify a phenotypic and genotypic diversity in 31 grape genotypes. Characteristics of mature leaves are also a powerful tool for the identification of grapevine (Ates et al., 2011). Several workers reported

that mature leaf characters provide discriminative data for identification and separation of germplasm (Santiago et al., 2007; Alba et al., 2011). However, in the present study, certain characters such as shoot attitude (growth habit), sex of flower, number of lobes, shape of teeth, shape of blade, width of blade was very similar in several germplasm and did not play a significant role in identification of the germplasm. One of the main distinctive morphological traits between the wild and cultivated grapevine forms is flower sex, which is mostly hermaphrodite for cultivars and male or female for wild grapevine (Lorenzis et al., 2015).

Fruit traits such as the average bunch weight, number of berries, bunch size, berry weight, berry length, berry width, berry flavor, TSS and titratable acidity were evaluated in present study. Grapes bunch and berry characters have their significant role in quality assessment especially in table grapes (Dilli et al., 2014). In addition, this information is important for breeders to improve genotypes. These traits also play a major role in breeding selection criteria for grape species (Vafaee et al., 2017) and assessing genotypes. These traits could be used to predict other traits and considered important for genotype characterization. In addition, a close relationship between traits could facilitate or hinder gene introgression because strong selection for a desirable trait could favor the presence of another desirable trait from germplasm (Khadivi Khub et al., 2014). Davies and Savolainen (2006) reported that morphological characters like berry length are highly correlated with changes in genetic characters. Variation in fruits parameters may be due to genotype and environmental factors which affect grapes quality (Ubalde et al., 2010). Furthermore, the evaluation of morphological and agronomical traits in grapes is helpful in adopting superior varieties and selecting the best-performing cultivars for a specific region based on fruit yield and quality attribute.

4. CONCLUSION

The gene pool of cultivated white colored grape had a significant amount of genetic variation. There was a wide variation in phenotypic and genotypic characters indicating their higher potential in breeding program. The genotypes were principally diverse for most of the traits, especially for berry traits.

5. ACKNOWLEDGEMENT

Authors are thankful to Director, ICAR-National Research Centre for Grapes, for interest, inspiring guidance and provided the facilities for this research. There is no funding or financial support for this research work.

6. REFERENCES

Abiri, K., Rezaei, M., Tahanian, H., Heidari, P., Khadivi, A., 2020. Morphological and pomological variability of a grape (*Vitis vinifera* L.) germplasm collection. Scientia Horticulturae 109, 266–285.

Alba, V., Anaclerio, A., Gasparro, M., Caputo, A.R., Montemurro, C., Blanco, A., Antonacci, D., 2011. Ampelographic and molecular characterization of Aglianico accessions (*Vitis vinifera* L.) collected in Southern Italy. South African Journal of Enology and Viticulture 32(2), 164–173.

Anonymous, 2007. OIV (Office International de la Vigne et du Vin.), 2007. OIV Descriptor List for Grape Varieties and Vitis Species. Available at www.oiv.int/oiv/info/enplubicationoiv.

Atak, A., Kahraman, K., Soylemezoglu, G., 2014. Ampelographic identification and comparison of some table grape (*Vitis vinifera* L.) clones. New Zealand Journal of Crop and Horticultural Science 42, 77–86.

Ates, F., Coban, H, Kara, Z., Sabir, A., 2011. Ampelographic characterization of some grape cultivars (*Vitis vinifera* L.) grown in south-western region of Turkey. Bulgarian Journal of Agricultural Science 17, 314–324.

Arslan, N., Yılmaz, F., Hazrati, N., Yüksel, C., Ergonul, O., Uysal, T., Yasasın, A.S., Ozer, C., Boz, Y., Kuleyin, Y.S., 2023. Genetic diversity and population structure analysis of anatolian kara grapevine (*Vitis vinifera* L.) germplasm using simple sequence repeats. Horticulturae 9, 743–751. https://doi.org/10.3390/horticulturae9070743.

Chessa, I., Nieddu, G., 2005. Analysis of diversity in the fruit tree genetic resources from a Mediterranean island. Genetic Resources and Crop Evolution 52, 267–276.

Cunha, J., Baleiras, G., Cunha, J., Banza, P., Soveral, A., Carneiro, L., Eiras, J., 2007. Characterization of portuguese pop-ulations of (*Vitis vinifera* L.) ssp. sylvestris (Gmelin) hegi. Genetic Resources and Crop Evolution 54, 981–988

Davies, T., Savolainen, G., 2006. Neutral theory, phylogenies, and the relationship between phenotypic change and evolutionary rates. Evolution 60, 476–483.

Dilli, Y., Akay, U., Kesgin, M., Inan, M., Soylemezoglu, G., 2014. Comparison of ampelographic characteristics of some important grape varieties are grown in the Aegean Region, rootstock and clones. Turkish Journal of Agricultural and Natural Sciences 7, 1546–1553.

Ekhvaia, J., Akhalkatsi, M., 2010. Morphological variation and relationships of Georgian populations of *Vitis vinifera* L. subsp. sylvestris (C.C. Gmel.). Flora 205, 608–617.

Guan, C., Zhang, P., Zhang, S., Chachar, R., Wang, X., Yang, Du., 2020. Germplasm conservation, molecular identity and morphological characterization of persimmon (*Diospyros kaki* Thunb.) in the NFGP of

China. Scientia Horticulturae 272, 109490.

Kaiser, H., 1958. The varimax criterion for analytic rotation in factor analysis. Psychometrika 23(3), 187–200.

Khadivi, A., Gismondi, A., Canini, A., 2019. Genetic characterization of Iranian grapes (*Vitis vinifera* L.) and their relationships with Italian ecotypes. Agroforestry System 93, 435–447.

Khadivi-Khub, A., Salimpour, A., Rasouli, M., 2014. Analysis of grape germplasm from Iran based on fruit characteristics. Brazilian Journal of Botany 37, 105–113.

Knezovic, Z., Mandic, P., Nikic, J., Beljo, J., Mihaljevic, M., 2017. Morphological and genetic characterization of vine grape cultivars of Herzegovina. CREBSS 3, 1–9.

Kupe, M., Sayinci, B., Demir, B., Ercisli, S., Aslan, K.A., Gundesli, M.A., Baron, M., Sochor, J., 2021. Multivariate analysis approaches for dimension and shape discrimination of *Vitis vinifera* varieties. Plants 10, 1528.

Leao, P., Cruz, D., Motoike, S., 2011. Genetic diversity of table grape based on morphoagronomic traits. The Journal of Agricultural Science (Piracicaba, Braz) 68, 42–49.

Laucou, V., Launay, A., Bacilieri, R., Lacombe, T., Adam-Blondon, A.F., Bérard, A., Boursiquot, J.M., 2018. Extended diversity analysis of cultivated grapevine Vitis vinifera with 10K genome-wide SNPs. PloS One 13(2), e-192540.

Lorenzis, G., Chipashvili, R., Failla, O., Maghradze, D., 2015. Study of genetic variability in *Vitis vinifera* L. germplasm by high-throughput Vitis18kSNP array: the case of Georgian genetic resources. BMC Plant Biology 15, 1–14.

Myles, S., Mahanil, S., Harriman, J., Gardner, K.M., Franklin, J.L., Reisch, B.I., Davidson, L., 2015. Genetic mapping in grapevine using SNP microarray intensity values. Molecular Breeding 35, 1–12.

Santiago, J., Boso, P., Gago, V., Villaverde, A., Martínez, M., 2007. Molecular and ampelographic characterization of *Vitis vinifera* L." Albariño"," Savagnin Blanc" and" Caíño Blanco" shows that they are different cultivars. Spanish Journal of Agricultural Research 5, 333–340.

Thapar, A.R., 1960. Horticulture in the hill regions of North India. Directorate of Extension, Ministry of Food and Agriculture, New Delhi.

Ubalde, J.M., Sort, A., Zayas, A., Poch, P., 2010. Effects of soil and climatic conditions on grape ripening and wine quality of cabernet sauvignon. Journal of Wine Research 21, 1–17.

Vafaee, Y., Ghaderi, N., Khadivi, A., 2017. Morphological variation and marker-fruit trait associations in a collection of grapes (*Vitis vinifera* L.). Scientia Horticulturae 225, 771–78.