PLANT SCIENCE TODAY
Vol x(x): xx-xx
https://doi.org/10.14719/pst.7486

eISSN 2348-1900

RESEARCH ARTICLE

Morphological and quality variability of white wine grape (*Vitis vinifera* L.) varieties under Pune conditions

Praveen Kumar Ausari[1], R G Somkuwar[2*], P S Gharate[3], Nilima Gobade[2], P B Kakade[4] & P S Karande[2]

[1]Department of Horticulture, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior 474 001, Madhya Pradesh, India
[2]Indian Council of Agricultural Research, National Research Centre for Grapes, Pune 412 307, Maharashtra, India
[3]Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani 431 402, Maharashtra, India
[4]Mahatma Phule Krishi Vidyapeeth, Rahuri 413 722, Maharashtra, India

*Correspondence email - rgsgrapes@gmail.com

Received: 29 January 2025; Accepted: 18 August 2025; Available online: Version 1.0: 17 December 2025

Cite this article: Praveen KA, Somkuwar RG, Gharate PS, Nilima G, Kakade PB, Karande PS. Morphological and quality variability of white wine grape (*Vitis vinifera* L.) varieties under Pune conditions. Plant Science Today (Early Access). https://doi.org/10.14719/pst.7486

Abstract

This study evaluated the ampelographical and bunch characteristics of 19 white wine grape varieties (*Vitis vinifera* L.) grafted on Dogridge rootstock at the National Active Germplasm Site, National Research Centre for Grapes, Pune, during 2023-24. The experiment was conducted on completely randomized block design comprising five vines per replication and three replications per cultivar. The results of the study revealed significant variability in the morphological characteristics of white wine grape varieties. The young shoot tip's opening with a high CV of 37.86 %, indicating substantial variation. The highest variability was observed for berry shape (CV 58.66 %) and berry color (CV 62.09 %), highlighted the diverse phenotypic traits among cultivars. Parameters such as bunch compactness and formation of seed showed lower variability, suggesting more consistency in these traits. Most cultivars had fully open young shoot tips. Tendril distribution was predominantly found sub-continuous, with unified tendrils. Young leaves were found mainly green colored with bronze spots (7). All cultivars exhibited bark peeling. The shoot attitude was primarily erect. Most mature leaves had large blades and pentagonal shapes. Berry density in bunches was generally compact, with round berries being the most common shape. Berry skin color was often green-yellow and all berries lacked anthocyanin coloration in the mesocarp. Time to bud burst ranged from 8.7 to 12.7 days after fruit pruning. Full bloom stage occurred between 34 and 44 days after fruit pruning. Flowering lasted 3.3 to 6.7 days. Veraison occurred from 95 to 114.67 days after fruit pruning and physiological berry maturity ranged from 122 to 147 days after fruit pruning. The results showed a range of correlations among various traits. Pruning biomass had a moderate positive correlation with 50 berry weight and berry skin thickness. Bunch weight showed strong correlations with bunch length and bunch width. TSS was negatively correlated with bunch weight and berry skin thickness. Total acids had a high positive correlation with malic acid. Ethanol content was positively correlated with TSS.

Keywords: correlation; evaluation; Oenofoss; phenological traits; quality wine

Introduction

Grape (*Vitis vinifera* L.) is assumed as one of the most valuable and popular fruit crops all over the world (1). The world vineyard surface area is estimated to be 7.2 Mha, with the production of 27.9 million metric tonnes (2). Major grape producing countries are China, Italy, France, Spain, USA, Turkey and India while, major wine producing countries are France, Italy, Spain and USA (2). In 2023, global wine production, excluding juices and musts, was estimated at 237 mL (2). According to II advance estimates of 2023, an area of 175 thousand ha was covered under grapevines and production was 3896 thousand tons in India (3). The grapes are mainly grown in tropical regions of country. Maximum area and production were recorded in Maharashtra state followed by Karnataka and Tamil Nadu. India is known as table grape producing country and only about 2 % of the total production is being utilized for juice or wine purpose (4).

Identifying and describing varieties is a crucial phase in the certification program, ensuring the accuracy of breeding materials by type, improving and preserving germplasm and monitoring genetic quality. Morphological and pomological traits remain the primary methods for describing and classifying any germplasm and serve as valuable tools for screening accessions in any population (5). Ampelographic characterization based on morphological features is valuable for identifying well-known grape cultivars and clarifying ambiguous denominations or establishing phenological relationships. Ampelography is a recognized scientific method for characterizing grapevine genotypes, involving the description of various morphological, phenological and pomological traits (5). This method has been refined and expanded by numerous scientists to enable a more precise and accurate identification of Vitis materials (6 - 8).

The variability of the grapevine can be observed in terms of both morphology and quality (9, 10). Ampelography studies are beneficial for identifying grape cultivars (10-13). In recent years, there has been a significant increase in genomic resources available to the grapevine research community, driven by a

renewed focus on grapevine (*Vitis vinifera* L.) germplasm resources and the analysis of genetic diversity in grapes.

A certain amount of everyday wine consumption may prevent various chronic diseases. This is due to the presence of certain number of important antioxidants in red wine like resveratrol, anthocyanins and catechins. Resveratrol is active in the prevention of cardiovascular diseases by neutralizing free oxygen radicals and reactive nitrogenous radicals; it penetrates the blood-brain barrier and, thus, protects the brain and nerve cells. It also reduces platelet aggregation and so counteracts the formation of blood clots or thrombi (14). Considering the importance of health benefits of wine consumption, wine grape cultivation is gaining importance in the country. Genetic variation, either natural or induced, is valuable for crop improvement. In the present study, genetic diversity in grape genotypes was investigated using morphological markers for germplasm that can be used for wine making.

Materials and Methods

Experimental site

In the current study, ampelographical, bunch and quality characterizations of 19 grape wine varieties (*V. vinifera* L.) grafted on Dogridge rootstock planted in National Active Germplasm Site (NAGS) at National Research Centre for Grapes, Pune were undertaken during 2023-24. The age of the vineyard was seven years old with good health and regular crops. The vines were trained to a Y trellis system with single cordons trained in the horizontal direction while shoots were placed in a vertical position. The soil of this region is black having pH 7.75 and EC 0.46 dS m^{-1}. However, water used for irrigation had EC of 1.8 and pH was 8.3 (15-17).

Experimental design

The design followed a completely randomized setup, with three replications and five vines per replication for each cultivar (285 vines). All vines within the row were planted at a spacing of 3 m between the rows and 1.5 m between the vines.

Ampelographic study

Morphological characters were analyzed including the leaf, berries, bunches and yield. The observations were recorded and described using the International Organization of Vine and Wine (OIV) descriptors. Each trait was assigned to an OIV code and a numerical value indicating its measurement. Morphological evaluations of berries and bunches were conducted at full veraison, when the berries changed their color. For bunch characterization, randomly ten bunches per cultivar were selected. For berry characterization, fifty berries per bunch are randomly selected from the selected ten bunches. At the time of harvest, the average weight was recorded for 10 largest bunches per cultivar with the help of a weighing balance and used to estimate the yield (kg) ha^{-1} (18).

Fruit quality analysis

Fresh berry samples collected were hand-pressed for extraction of juice and filtered through muslin cloth. Samples were then kept at -20 °C until analysis could be performed. The TSS and acidity was determined as described by OECD (19). The °Brix was determined using handheld refractometer.

For acidity, the solution was titrated against 0.1N NaOH until a permanent pink colour was achieved.

TA (g/L) =

(mL NaOH x N (NaOH) x acid meq. factor x 100)/ mL juice titrated

The pH of grape juice was measured using a pH meter at room temperature (23 ± 2 °C). The procedure for the above-mentioned parameters was replicated three times and data recorded.

Wine quality parameters

Wine quality parameters (volatile acid, mallic acid, total acids, pH and ethanol) were estimated with using OenoFoss.

Statistical analysis

The variation among cultivars was assessed using a standardized dataset. Analysis of variance (ANOVA) was conducted for all morphological traits using SAS software (20). The mean and standard deviation (SD) for each dataset were calculated and the coefficients of variation (CV %) were determined as indicators of variability. The Pearson correlation coefficient was employed to analyze the correlation between yield and fruit characters using WASP software.

Results and Discussion

This study concentrates on the use of both indigenous and foreign white wine grapevine collections to assess, conserve and utilize them for future grape improvement programs. Of the 26 ampelographic parameters examined, quality parameters like berry shape (CV 58.66 %) and berry colour (CV 62.09 %) showed the highest variability. Conversely, the lowest CV was observed for bark peeling (15.85 %), bunch compactness (16.95 %) and seed formation (19.16 %), indicating substantial variation among the different characteristics of the studied accessions. Somkuwar et al. The growth habit of grapevines had the highest CV (79.16%), followed by erect hairs on the dorsal side of mature leaves (78.37 %) (20). Previous works reported variations among 55 and 31 grape cultivars, respectively (21, 22). In this study, 20 out of the 26 characters had CV values exceeding 30 % (Table 1).

Most cultivars fell into the bark peeling category (19), with peeling flecks varying from short to long strips. Among the accessions, long strips were most common (9), followed by short strips (6) and the fewest were in the checks category (4). The cultivars displayed a range of under-bark colors, from creamish (3) to light brown (16). Opening of shoot tip ranged from fully opened to closed, in which most accession showed fully open (13) followed by half open (4) and closed (2). Tendril distribution, continuous (4), sub-continuous (12) and discontinuous (1). There are two types of tendrils shown among selected accessions- unifid (9) and bifid (8). For color of upper side of blade were seen variations- green (2), green with bronze spot (7), yellow (7), yellow with bronze spot (3). Erect growth habit was seen in 16 accessions while 3 accessions had semi-erect growth habit. Large width of blade was recorded in 12 accessions while very large (5) and medium length of blade recorded in 2 accessions. The shape of blade was pentagonal and wedge shaped in most of accessions. Anthocyanin coloration on the main vein on the lower of the leaf blade was absent in 11 accessions, while in the remaining cultivar, it was present at point (5) and 1st bifergation (1) (Fig. 1). The wedge-shaped teeth of mature leaf shown in most of the cultivars (14). Most of the cultivars had

Table 1. Morphological description of grape cultivars studied

Characters	Unit	Min.	Max.	Mean	SD	CV (%)
Young shoot: Opening of shoot tip	code	1	9	7.32	2.77	37.86
Young leaf: Colour upper side of blade	code	1	4	2.47	0.84	34.01
Bark peeling	code	0	3	2.89	0.45	15.85
Peeling flakes	code	1	7	5	2.65	53.13
Under bark colour	code	1	3	2.68	0.74	27.91
Inflorescence: average number of inflorescences	code	1	5	3.73	1.19	31.96
Width of blade (cm)	code	5	9	7.31	1.2	16.46
Shoot attitude (growth habit)	code	1	3	1.31	0.74	56.94
Shape of blade	code	1	4	2.52	0.96	38.16
Overlapping of petiole sinus	code	1	9	3.55	2.03	57.25
Prostrate hairs	code	1	9	5.73	2.23	38.9
Erect hairs	code	1	3	1.21	0.63	52.09
Bunch shape	code	2	7	3.36	1.67	49.68
Bunch compactness	code	5	7	6.05	1.02	16.95
Bunch uniformity	code	3	7	6.36	1.49	23.53
Berry shape	code	2	7	3.31	1.94	58.66
Berry colour	code	1	7	4.79	2.97	62.09
Mature leaf: anthocyanin coloration of main vein on lower side of blade	code	1	3	1.36	0.59	43.64
Berry attachment with peduncle	code	3	7	5.94	1.8	30.42
Berry anthocyanin coloration of mesocarp	code	0	1	0.82	0.3	36.57
Formation of seed	code	1	5	4.78	0.91	19.16
Berry flavour	code	1	3	1.21	0.63	52.09
Tendril distribution on shoot	code	1	5	3.52	1.12	31.87
Tendril type	code	3	6	4.42	1.53	34.8
Mature leaf: shape of teeth	code	2	5	2.31	0.74	32.35
Berry: length of pedicel	Code	1	7	2.89	1.24	42.92

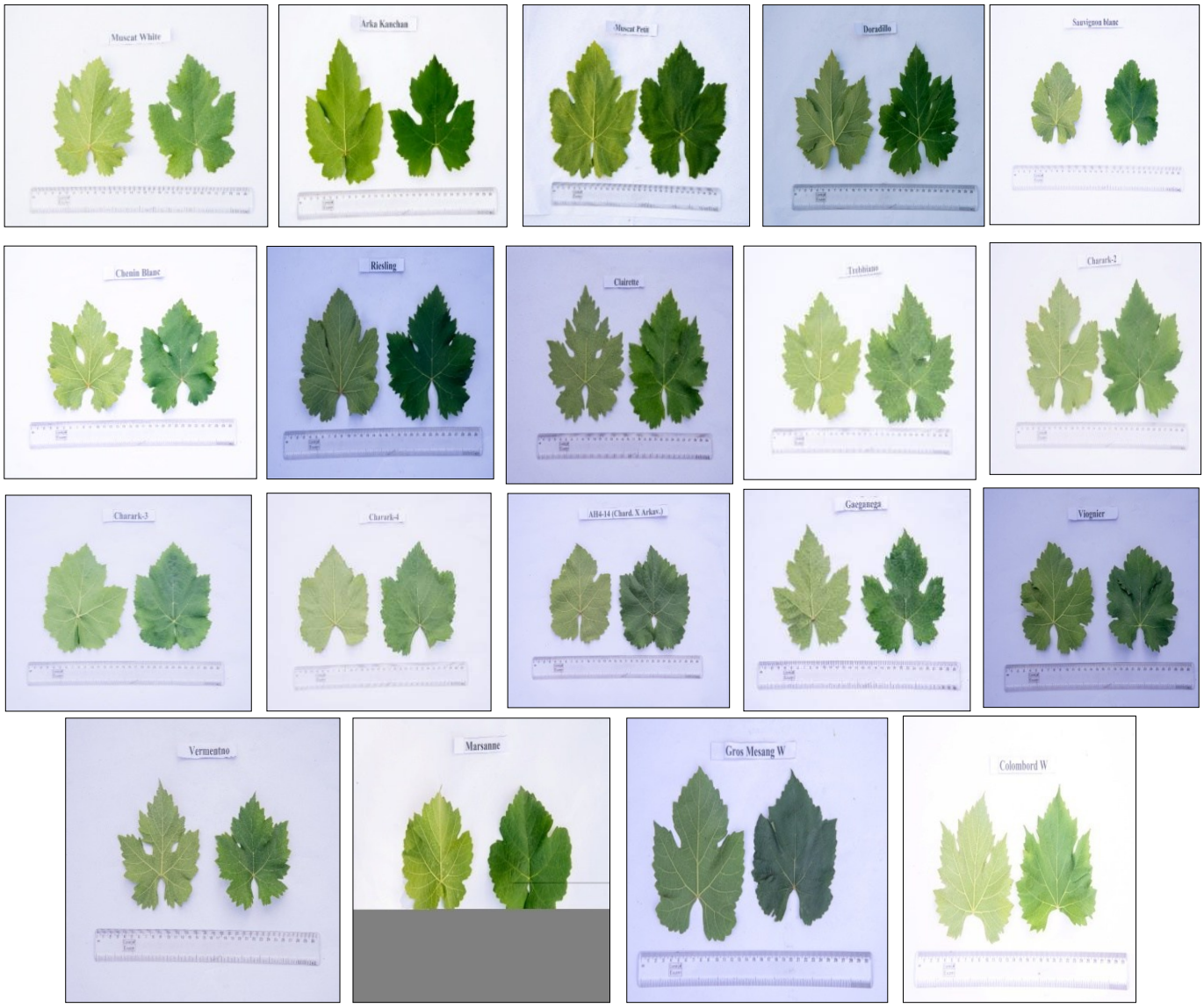

Fig. 1. The leaf pictures of the studied grape cultivars.

open petiole sinus (10) followed by very wide open (3) and closed (2). Prostrate hairs between veins on lower side of blade were medium (6) to high (6) and erect hairs between veins on lower side of blade were absent in most of cultivars (16). The ratio of length of petiole compared to mid vein was reported short for most of the cultivars (15) studied. Average number of inflorescences per shoot were 1 to < 3 in most of the cultivars. Berry density in bunch was shown medium to compact, while cylindrical shape was reported in most of the cultivars (7) (Fig. 2). Berry size in bunch was uniform for most of the cultivars (13). Most of the cultivars had round berry shape and green to green, yellow berry color (Fig. 3). The anthocyanin coloration of mesocarp were absent in all the cultivars studied with neutral flavour followed by muscat and foxy flavor. The length of pedicel was short for most of the cultivars (14). Berry attachment with pedicle was firm for most of the accessions and among 19 accessions, most were seeded (16) (Table 2).

The data revealed significant variation among grape cultivars for various ampelographic parameters under tropical Indian conditions. These findings align with the research of (21-24). Early works studied 55 grape accessions, reporting substantial variability and recommending the integration of the present data into future studies and the investigation of genetic diversity in grapes from other regions (25).

Phenological calendar of 19 white wine grape cultivars

For the evaluation of early, middle and late cultivar, five phonological stages of each cultivar were recorded at specific (time of budburst, time to full bloom, duration of flowering, time of veraison, physiological maturity of the berry, etc.). The data of each stage was recorded when more than 50 % of plants showed stage symptoms. The time of bud burst indicated great variation in observed genotypes as mentioned in Table 3. The time of budburst started in observed cultivars from 8 days after fruit pruning to 13 days after fruit pruning depending upon the specific genotype. Time of full bloom ranged from 34 to 44 days after fruit pruning, duration of flowering from 3.3 to 6.6 days, while time of veraison from 95 to 115 days and time required for physiological maturity of the berry ranges from 122 to 147 days after fruit pruning in selected cultivars. Early results observed great variations in phonological calendar among 30 grape genotypes (20, 25).

Correlation between the yield and quality traits

To examine the relationship between yield and quality traits among cultivars, a correlation analysis was conducted (Table 4). The study revealed that pruned biomass has a strong positive correlation with 50-berry weight (r = 0.4081), berry skin thickness (r = 0.3688), berry firmness (r = 0.3512) and bunch width (r = 0.3037), but a weak correlation with acidity (r = 0.069) and bunch length (r = 0.042). Bunch weight was positively correlated with bunch length (r = 0.7469), bunch width (r = 0.6773), 50-berry weight (r = 0.5827), berry firmness (r = 0.5458), berry skin thickness (r = 0.3639) and the number of berries (r = 0.1688). Additionally, bunch length showed a positive correlation with bunch width (r = 0.7683), 50-berry weight (r = 0.5851), berry firmness (r = 0.5736), number of berries per bunch (r = 0.3561) and berry skin thickness (r = 0.3003). Bunch width was strongly correlated with 50-berry weight (r = 0.6953) and berry firmness (r = 0.6848). The results of this investigation align with the findings of (21, 24). Total soluble solids (TSS) showed a positive correlation with acidity (r = 0.0696) and a negative correlation with bunch width (r = -0.0319). However, a negative correlation reported between TSS and acidity (21, 27). Skin thickness exhibited a negative correlation with TSS (r = -0.4262). As berry diameter and bunch weight (bunch width) increase, TSS decreases. Additionally, an increase in the number of bunches per vine reduces the TSS in grape berries (28). Volatile acids and pH in wine was negatively correlated with TSS (r = -0.0285) while ethanol percentage showed strongly positive correlation with TSS (r = 0.7033). This might be due to conversion of sugar into ethanol after fermentation.

Fig. 2. The bunch pictures of the studied grape cultivars.

Fig. 3. The berry pictures of the studied grape cultivars.

Table 2. Frequency distribution of the morphological characters utilized for the studies

Characteristics	Frequency and code (No. of cultivars)				
Young shoot: opening of shoot tip	Fully open (13)	Half open (04)	Closed (02)		
Tendril distribution on shoot	Continuous (06)	Sub continuous (12)	Discontinuous (01)		
Tendril type	Unifid (09)	Bifid (08)			
Young leaf: color of upper side of blade	Green (02)	Green with bronze spot (07)	Yellow (07)	Yellow with bronze spot (03)	
Bark peeling	Peeling (19)	Non-peeling (0)			
Peeling flakes	Short strip (06)	Long strip (09)	Checks (04)		
Under bark colour	Creamish (03)	Light brown (16)			
Shoot Attitude: (Growth habit)	Erect (16)	Semi Erect (03)			
Mature leaf: Width of blade	Short (0)	Medium (02)	Large (12)	Very large (05)	
Mature leaf: shape of blade	Circular (03)	Cordate (03)	Pentagonal (07)	Wedge shaped (06)	
Mature leaf: anthocyanin coloration of main vein on lower side of blade	Point (05)	1st Bifurgation (01)	Absent (13)		
Mature leaf: Shape of teeth	Wedge (15)	Convex (03)	Irregular (01)		
Mature leaf: degree of opening/ overlapping of petiole sinus	Open (12)	Close (02)	Overlapped (01)	Very wide Open (03)	Strongly overlapped (01)
Mature leaf: Prostrate hairs between veins on lower side of blade	Very low (01)	Low (02)	Medium (06)	High (06)	Very high (03)	Absent (01)
Mature leaf: erect hairs between veins on lower side of blade	Low (02)	Very low (01)	Absent (16)		
Mature leaf: ratio of length of petiole compared to mid vein	Equal (03)	Short (16)			
Inflorescence: average number of inflorescences per shoot	<1 (01)	1 (01)	1 to <2 (09)	2 to <3 (08)	
Bunch: berry density	Medium (06)	Compact (13)			
Bunch: Shape/type	Cylindrical (08)	Conical (05)	Poly winged (03)	Double cluster (02)	Winged cylindrical (01)
Bunch: uniformity of berry size	Uniform (16)	Non uniform (03)			
Berry shape	Round (11)	Short elliptical (03)	Ovate (03)	Obovate (02)	
Berry: colour of skin (without bloom)	Green (06)	Greenish (03)	Greenish Yellow (02)	Green yellow (07)	
Berry: anthocyanin coloration of mesocarp	Present (0)	Absent (19)			
Berry: flavour	Neutral (15)	Muscat (02)	Foxy (02)		
Berry: length of pedicel	Short (13)	Very short (04)	Long (02)		
Berry attachment with pedicle	Firm (13)	Loose (06)			
Berry: formation of seed	Seeded (17)	Seedless (02)			

Table 3. Descriptive statistics for physiological growth characters utilized for the studied grape cultivars

Traits	Unit	Min.	Max.	Mean	SD	CV (%)
Time to bud burst	Days	8.7	12.7	10.42	1.383	13.268
Time to full bloom	Days	34	44	38.09	2.336	6.132
Duration of flowering	Days	3.3	6.7	5.61	0.833	14.845
Time of veraison	Days	95	114.67	104.19	5.134	4.928
Physiological maturity of the berry	Days	122	147	131.7	6.705	5.091

Table 4. Simple correlation among yield and quality variable utilized for the studied grape cultivars

	Prunning biomass (kg)	Bunch weight (g)	Bunch length (cm)	Bunch width (cm)	No. of berries	Berry skin thickness (mm)	50 berry weight (g)	Firmness (%)	TSS (°B)	Acidity (%)	Mallic acid (g/l)	Volatile acids (g/l)	Total acids (g/l)	pH	Ethanol (%)
Prunning biomass (kg)	1														
Bunch weight (g)	-0.0553	1													
Bunch length (cm)	0.2842	0.7469	1												
Bunch width (cm)	0.3037	0.6773	0.7683	1											
No. of berries	-0.0637	0.1688	0.3561	-0.0577	1										
Berry skin thickness (mm)	0.3688	0.3639	0.3003	0.2369	-0.3036	1									
50 berry weight (g)	0.4081	0.5827	0.5851	0.6953	-0.3703	0.7634	1								
Firmness (%)	0.3512	0.5458	0.5736	0.6848	0.0537	0.1380	0.5026	1							
TSS (^{0}B)	0.0638	-0.4033	-0.2131	-0.0319	-0.0343	-0.4262	-0.3177	0.0494	1						
Acidity (%)	-0.1584	-0.0458	-0.2526	-0.0355	0.1477	-0.3137	-0.2951	0.2459	0.0696	1					
Mallic acid (g/l)	-0.1866	-0.2860	-0.3024	-0.2184	0.0771	-0.5077	-0.3942	-0.2707	0.1731	-0.0722	1				
Volatile acids (g/l)	-0.1771	-0.0328	-0.1240	-0.0562	-0.3277	-0.1088	-0.0991	-0.2252	-0.0285	0.0678	0.2117	1			
Total acids (g/l)	-0.1655	-0.2810	-0.3173	-0.2196	-0.0948	-0.5458	-0.3419	-0.2491	0.1860	-0.1656	0.9034	0.2188	1		
pH	0.1075	-0.1092	0.0213	0.3152	-0.3700	0.0674	0.1170	-0.1153	-0.1119	-0.1133	0.1444	0.1102	0.1266	1	
Ethanol (%)	0.1377	-0.2505	-0.0315	0.0904	0.0317	-0.2220	-0.0442	0.1212	0.7034	0.2581	-0.0827	-0.1788	-0.0596	-0.2233	1

Conclusion

This study focused on the morphological characterization and evaluation of genetic diversity among 19 white wine grape varieties. In the present study, significant differences were observed between different grapes germplasms. The morphological characterization results highlighted the distinct qualitative characteristics that differentiate grape germplasms. These findings offer a comprehensive understanding of the morphological diversity within the studied grape germplasms, facilitating better identification and classification. The study emphasizes the importance of preserving and maintaining valuable germplasm for future research and breeding programs. The insights gained can guide viticulturists and winemakers in making informed decisions about grape variety selection. It is suggested that conduct multi-season and multi-location trials to understand how environment affects morphological and quality traits.

Acknowledgements

The authors are thankful to the Director, ICAR- National Research Centre for Grapes, Pune for providing facilities to conduct research.

Authors' contributions

RGS done the conceptualization, experimental design and editing of the manuscript. PKA conducted research, data acquisition, data analysis, statistical analysis and final drafting of the manuscript. PSG assisting data analysis and drafting of the manuscript. PBK helped in editing manuscripts. NG performed the data acquisition and helped in statistical analysis. PSK helped in conducting the experiment and data collection. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: The authors declare that they have no sort of competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Ethical issues: None

References

1. Mohsen FS. Effect of some rootstocks on the performance of Flame Seedless grapevines. Egyptian J Hortic. 2021;48:1-8. https://doi.org/10.21608/ejoh.2020.47060.1145
2. OIV. State of the world vine and wine sector in 2023. 2024.
3. Anonymous. Area and production of horticulture crops for 2023-24 (2nd advance estimates). 2024.

4. Ausari PK, Gurjar PKS, Somkuwar RG, Naruka IS, Sharma AK, Gharate PS. Effect of rootstocks on yield and wine quality of Sauvignon Blanc variety. Plant Arch. 2024;24(1):1477-82. https://doi.org/10.51470/PLANTARCHIVES.2024.v24.no.1.207
5. El-Morsy FM, Gaser ASA, Mohamed MN. Morphological description and evaluation of six newly introduced grape cultivars under Egyptian conditions. J Plant Prod. 2017;8:1059-70. https://doi.org/10.21608/jpp.2017.41111
6. Soylemezoglu G, Agaoglu YS, Uzun HI. Ampelographic characteristics and isozymic analysis of *Vitis vinifera* spp. sylvestris Gmel. in southwestern Turkey. Biotechnol Biotechnol Equip. 2001;15:106-13. https://doi.org/10.1080/13102818.2001.10819140
7. Santiago JL, Boso S, Gago P, Alonso-Villaverde V, Martinez MC. Molecular and ampelographic characterization of *Vitis vinifera* L. 'Albariño', 'Savagnin Blanc' and 'Caíño Blanco' shows that they are different cultivars. Span J Agric Res. 2007;5:333-40. https://doi.org/10.5424/sjar/2007053-253
8. Mahmoud RA, Dahab AA, Mahmoud GA, El-Aziz Abd El-Wahab MA, El -Bassel EH, Mahdy EMB. Ampelographic and genetic diversity assessment of some local grape genotypes under Egyptian conditions. Am J Mol Biol. 2023;13:183-96. https://doi.org/10.4236/ajmb.2023.133013
9. Alleweldt G, Possingham JV. Progress in grapevine breeding. Theor Appl Genet. 1988;75:669-73. https://doi.org/10.1007/BF00265585
10. Singh A, Gill MIS, Arora NK, Bedi S, Bakshi P, Kumar K. Variability in grapes (*Vitis vinifera*) genotypes using morphological traits. J Pharmacogn Phytochem. 2019;8(SP1):439-46.
11. Fatahi R, Ebadi A, Vezvaei A, Zamani Z, Ghanadha MR. Relationship among quantitative and qualitative characters in 90 grapevine (*Vitis vinifera*) cultivars. Acta Hortic. 2004;640:275-82.
12. Rubio JA, Yuste J. Ampelographic differentiation of 'Tempranillo' clones from different area of origin, according to their synonym. Acta Hortic. 2004;652:73-9. https://doi.org/10.17660/ActaHortic.2004.652.7
13. Pavek DS, Lamboy WF, Garvey EJ. Selecting in situ conservation sites for grape genetic resources in the USA. Genet Resour Crop Evol. 2004;50(2):165-73. https://doi.org/10.1023/A:1022947605916
14. Snopek L, Mlcek J, Baron L, Sochorova M, Hlavacova I, Jurikova T, et al. Contribution of red wine consumption to human health protection. Molecules. 2018;23(7):1684. https://doi.org/10.3390/molecules23071684
15. Sharma J, Upadhyay AK. Effect of moisture stress on performance of own rooted and grafted vines of Tas-A Ganesh (*Vitis vinifera* L.). Acta Hortic. 2005;662:253-7.
16. Somkuwar RG, Ramteke SD, Sawant SD, Takawale P. Canopy modification influences growth, yield, quality and powdery mildew incidence in Tas-A-Ganesh grapevine. Int J Fruit Sci. 2019;19:437-51. https://doi.org/10.1080/15538362.2018.1555509
17. Somkuwar RG, Ausari PK, Sharma AK, Gobade N, Gharate PS. Evaluation of training systems for growth, yield, photosynthetic activities and wine quality in Cabernet Sauvignon. J Eco-friendly Agric. 2025;20(1):122-9. https://doi.org/10.48165/jefa.2024.20.1.19
18. Office International de la Vigne et du Vin (OIV). List of descriptors for grapevine cultivars and species (*Vitis* L.). 2012. http://www.oiv.int/oiv/info/enizmiroivreport
19. Organization for Economic Co-operation and Development (OECD). Guidance on objective tests to determine quality of fruits and vegetables and dry and dried produce. 2018; p.11-6.
20. SAS Institute. SAS procedures, version 6. 3rd ed. Cary, NC: SAS Institute; 1990.
21. Somkuwar RG, Nale RD, Karande PB, Sharma AK, Nikumbhe NH, Naik S, et al. Morphological and fruit variability in grape (*Vitis vinifera* L.) germplasm under Indian condition. Res Square. 2024. https://www.researchsquare.com/article/rs-4100305/v1
22. Abiri K, Rezaei M, Tahanian H, Heidari P, Khadivi A. Morphological and pomological variability of a grape (*Vitis vinifera* L.) germplasm collection. Sci Hortic. 2020;266:109285. https://doi.org/10.1016/j.scienta.2020.109285
23. Vafaee Y, Ghaderi N, Khadivi A. Morphological variation and marker-fruit trait associations in a collection of grapes (*Vitis vinifera* L.). Sci Hortic. 2017;225:771-82. https://doi.org/10.1016/j.scienta.2017.08.007
24. Khadivi-Khub A, Salimpour A, Rasouli M. Analysis of grape germplasm from Iran based on fruit characteristics. Braz J Bot. 2014;37:105-13. https://doi.org/10.1007/s40415-014-0054-5
25. Boz Y, Bakir M, Cerlikkol BP, Kazan K, Yilmaz F, Cakir B, et al. Genetic characterization of grape (*Vitis vinifera* L.) germplasm from southeast Anatolia by SSR markers. Vitis. 2011;50:99-106. https://doi.org/10.5073/vitis.2011.50.99-106
26. Akram MT, Qadri R, Khan MA, Hafiz IA, Nisar N, Khan MM, et al. Morpho -phenological characterization of grape (*Vitis vinifera* L.) germplasm grown in northern zones of Punjab, Pakistan. Pak J Agric Sci. 2021;58 (4):1223-36. https://doi.org/10.21162/PAKJAS/21.91
27. Leao PCS, Cruz CD, Motoike SY. Genetic diversity of table grape based on morphoagronomic traits. Sci Agric (Piracicaba, Braz). 2011;68:42-9. https://doi.org/10.1590/S0103-90162011000100007
28. Somkuwar RG, Satisha J, Ramteke SD. Effect of bunch load on berry growth in Tas-A-Ganesh grafted on different rootstocks. Indian J Hortic. 2010;64(4b):578-80.

Additional information

Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

Reprints & permissions information is available at https://horizonepublishing.com/journals/index.php/PST/open_access_policy

Publisher's Note: Horizon e-Publishing Group remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Indexing: Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS, UGC Care, etc
See https://horizonepublishing.com/journals/index.php/PST/indexing_abstracting

Publisher information: Plant Science Today is published by HORIZON e-Publishing Group with support from Empirion Publishers Private Limited, Thiruvananthapuram, India.