Ampelographic Diversity Assessment of Local Grape Genotype Grown in India

R. G. Somkuwar [a], R. D. Nale [b*], S. A. Ranpise [b] and P.H. Nikumbhe [a]

[a] ICAR- National Research Centre for Grapes, Pune-412307, (MS), India.
[b] Department of Horticulture, MPKV, Rahuri, Ahmednagar-413722, (MS), India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Original Research Article

ABSTRACT

Grapevine is well adapted to the agro climatic conditions of India, which makes it one of the major element of the Indian horticulture. However, there has been limited focus on assessing grapevine germplasm, and genetic resources have previously remained underutilized despite their potential for adapting to environmental changes. This study aims to evaluate the diversity of local (developed in India) grapevine accessions growing in different regions in India. A total of 20 local varieties were evaluated using 14 fruit traits previously developed by DUS. An important variability was revealed among the local varieties studied based on fruit characteristics. The most discriminant traits were bunch weight, berry diameter, bunch length, berry weight, berry shape, seed number per berry. Hierarchical clustering analysis showed three main clusters, each regrouping accessions of

---

Corresponding author: E-mail: rutujanale2502@gmail.com;

different named varieties. Mean values of cluster for various yield parameters revealed that cluster I possessed maximum value for yield related attributes. Maximum bunch weight was observed in Manjari Medika (270.0g) followed by Pusa Seedless (243.1 g), Arka Shyam (213.5 g) while higher 50 berry weight (201.0 g) and berry diameter (20.30 mm) in Arka Majestic genotype. Arka Majestic and Manjari Medika showed better quality traits. Our results indicate a potential of morphological diversity within the local genotypes that should be further investigated in order to understand their performance and to evaluate them in selection programs.

1. INTRODUCTION

"Grape (*Vitis vinifera* L.) is a significant horticultural crop, valued globally for their economic importance in various regions and their historical association with the development of human culture since ancient times" [1]. "Our country has a history of viticulture of about 6000 years and there is rich grape biodiversity as a wild vine (*Vitis vinifera* L. *subsp. sylvestris*) and cultivated vine (*Vitis vinifera* L. *subsp. sativa*)" [2]. In India, grape is grown on an area of about 1.62 lakh hectare with annual production of 3489.40 tons [3]. "Grape is a significant fruit crop known for its bioactive compounds and is considered a nutraceuticals food. Its nutrient content plays a vital role in human metabolism. Grapes are valued for their ability to protect the body from infections, support the immune and nervous systems against diseases like cancer, obesity, diabetes, and various joint disorders, while also helping to slow the aging process. Local grape cultivars vary in their morphological traits, cluster and berry sizes, phenology, harvest times, productivity, and quality measures" [4,5]. "Evaluating grape diversity is crucial for characterizing and conserving germplasm, which is essential for maintaining and enhancing crop productivity. Identifying local varieties accurately and conserving them can prevent their extinction and safeguard them for future requirements, enabling genetic, ecological, and agronomic diversity that can handle different diseases, enhance adaptation to local soil and climate conditions, and facilitate adjustments to future market shifts" [6]. "Traditionally, grape variety identification has relied on observing the morphological characteristics of both plant growth and reproductive parts. Morphological characteristics of fruits have traditionally served as a valuable tool for characterizing fruit trees due to their economic significance and ability to differentiate varieties" [7]. "Local grape cultivars play a crucial role in maintaining agricultural diversity and are vital for ensuring food security, nutrition, and economic stability, especially for small-scale farmers and rural communities in marginal areas. The variation in local grapes helps mitigate risks of crop failure, provides unique ingredients for traditional local dishes, and meets specific dietary needs. Additionally, these diverse grape cultivars offer valuable locally adapted genetic resources for enhancing new grape varieties" [8,9]. The main objective of this research work is focused on morphological identification of a 20 local varieties released from different research institute. In India different grapes are grown, a multitude of local varieties contribute to the global diversity of grapevines. These varieties exhibit significant variation within each type, highlighting the importance of accurately defining and identifying them in both scientific research and practical applications in modern viticulture.

2. MATERIALS AND METHODS

2.1 Plant Materials

Present investigation was carried at National Active Germplasm Site of ICAR-National Research Centre for Grapes, (latitude 18°32′N and longitude 73°51′E), Pune during 2023. Eight-year-old local varieties grafted on Dogridge rootstocks were specifically selected for this research (Table 1 and Fig. 1). The vines were planted with a distance of 3.0 m between the rows and 1.83 m between the vines, thus accommodating 1800 vines per hectare. Due to the tropical conditions of the region, single cropping and double pruning approach is being adopted. As a result, the vines were pruned two times in a year - once after the crop harvest (known as back pruning) and a second time for fruit production (known as forward pruning).

2.2 Ampelographic Character

Fourteen fruit character were evaluated to study pomological variability of the local cultivars on the basis of DUS (Distinctness, Uniformity and Stability) testing guideline. The fruit bunches

were harvested when they reached full ripeness, which was determined by measuring total soluble solids, titratable acidity, as well as assessing taste and color. Bunch and berry parameter (length and width) were measured with digital caliper. Weight of cluster, berry and seed were measured by weighing balance. The grape juice was extracted and the total soluble solid was recorded using a refractometer (Erma, Japan) while the acidity was measured using 0.1 N NaOH by titration. The pH values were measured by pH meter ((HANNA pH212; Woonsocket, RI, USA).

2.3 Statistical Analysis

The following parameters were assessed for phenotypic variables: mean, minimum value, maximum value, standard deviation (SD), and coefficient of variation (CV%). Analysis of variance (ANOVA) was performed for all ampelographic traits by SAS software SAS Institute [10] using one-way ANOVA. Mean and standard deviation (SD) were calculated for each parameter. Also, coefficients of variation (CV %) were determined as indicators of variability. Relationships between cultivars were investigated by using principal component analysis (PCA) using SPSS statistics software. The distance matrix created from ampelographic data was utilized in cluster analysis to examine variations among cultivars, employing the unweighted pair-group method of arithmetic average (UPGMA).

3. RESULTS AND DISCUSSION

The fruit characteristics among the studied local varieties showed significant variability. Table 2 provides some descriptive statistics namely; the mean, standard deviation (SD), coefficient of variation (CV), minimum and, maximum values for these fruit traits. Average bunch weight ranged from 129.90 g (Arkavati) to 270.50 g (Manjari Medika), with a coefficient of variance (CV) of 38.97 %. Cluster length ranged from 10.40 cm (Manjari Naveen) to 28.30 cm (Pusa Aditi). The CV for the cluster length was calculated as 25.47 %. Berry length varied from 13.0 mm (Pusa Navrang) to 21.0mm for (Arka Soma). Grape breeding has emphasized creating table grape varieties with preferred characteristics, such as large berry and bunch sizes [11]. Additionally, some varieties like Pusa Seedless, Arkavati, Arka Neelmani, Manjari Naveen, Manjari Kishmish were seedless, while other contained one to four seeds per berry.

Somkuwar et al. [12] similarly observed one to four seeds per berry in Indian grape while Vafaee et al. [13] noted that seed number per berry ranged from zero to three. In the studied cultivars, berry shape included four types (Round, conical, oval, globular), while very diverse berry skin colors were observed, with different color categories identified (Such as white, green, yellow, purple and black). The dominant berry colour was yellowish green. Berry skin color serves as a key indicator of fruit ripeness and harvest timing for certain fruits. Additionally, cultivars featuring diverse berry skin colors can cater to a range of consumer preferences [13]. The CV or the juice characteristics in the berries of the studied vines were 5.35% for pH, 7.77% for TSS and 15.78% for TA (Titratable Acidity). TSS levels ranged from 16.50% to 22.60%, with a mean of 20.07%. The pH values ranged between 3.08 and 3.67, averaging 3.36. Titratable Acidity varied from 0.41% to 0.78%, with a mean of 0.57%.

Correlation analysis was conducted to examine the relationships among the traits (Fig. 1). Bunch weight showed positive correlation with cluster length (r = 0.32) and seed number in berry (r= 0.45). Bunch length exhibited positive correlations with bunch width (r = 0.85). Additionally, larger berries generally occur on larger bunches. Berry length was positively correlated with berry width (r = 0.76), consistent with previous research [14,15,13,16] suggesting that berries larger in one dimension tend to be larger in the other. Berry diameter showed negative bunch length and width. These insights could be valuable for future plant breeding program, such as conducting crosses between cultivars with large berry size and low seed count to achieve high yield and superior quality cultivars. Seed number per berry was negatively correlated with berry length and berry width, while Khadvi-Khub et al., [15] reported positive correlation between seed number per berry was positively with berry length and berry width. A negative correlation was found between TSS and TA (r = -0.33). Our results are in accordance with the result of Leao et al. [14] who noted a negative correlation between TSS and TA in grape. The correlation coefficient can offer information on the traits that are most significant in evaluating genotypes [17]. This information could be very useful for future plant breeding programs. For example, to achieve high yields and superior quality cultivars, breeders might cross cultivars with large berry sizes, high total soluble solids (TSS), and low seed numbers.

Table 1. Information about the local grape varieties developed by different research institute

Varieties	Parentage	Released by	Year	End use
Arka Chitra	Angur Kalan x Anab-e-Shahi	IIHR, Bengaluru	1994	Table Grape
Arka soma	Anab-e-Shahi x Queen of Vineyards	IIHR, Bengaluru	1994	White wine
Arkavati	Black Champa x Thompson seedless	IIHR, Bengaluru	1980	Raisin purpose
Arka Krishna	Black Champa x Thompson Seedless	IIHR, Bengaluru	1994	Wine making
Arka Neelmani	Black Champa x Thompson seedless	IIHR, Bengaluru	1992	Table and wine
Arka Hans	Bangalore Blue x Anab-e-Shahi	IIHR, Bengaluru	1980	White wine
Arka Kanchan	Anab-e-Shahi x Queen of Vineyards	IIHR, Bengaluru	1980	Port wine
Arka Shweta	Anab-e-Shahi x Thompson Seedless	IIHR, Bengaluru	1994	Table and wine
Arka Majestic	Angur Kalan x Black Champa	IIHR, Bengaluru	1994	Table grape
Arka Trishna	Bangalore Blue x Convent Large Black	IIHR, Bengaluru	1994	Wine grape
Arka Shyam	Bangalore Blue x Black Champa	IIHR, Bengaluru	1980	Juice purpose
Pusa Seedless	Clonal selection from Thompson Seedless	IARI, New Delhi	1970	Table
Pusa Swarnika	Hur x Cardinal	IARI, New Delhi	2014	Table and Munnaka
Pusa Aditi	Banqui Abyad x Perlette	IARI, New Delhi	2014	Table grape
Pusa Navrang	Madeleine Angevine x Rubi Red	IARI, New Delhi	1997	Juice and wine
Manjari Medika	Pusa Navrang X Flame Seedless	NRCG, Pune	2018	Juice
Manjari Naveen	Clonal selection from Centennial Seedless	NRCG, Pune	2008	Table
Manjari Kishmish	Mutant derived from Kishmish Rozavis	NRCG, Pune	2019	Raisin
Manjari Shyama	Black Champa x Thompson Seedless	NRCG, Pune	2019	Table grape
H-516	Catawba x Beauty Seedless	ARI, Pune	2008	Juice grape

Table 2. Descriptive statistics for measured fruit characteristics between the local grape varieties

| Characteristics	Minimum	Maximum	Mean	SD	CV (%)
Average bunch weight (g)	129.90	270.50	138.39	61.04	44.10
50 berry weight (g)	61.00	201.00	138.08	59.39	43.01
No of berries per bunches	40.00	125.30	76.56	24.47	31.96
Cluster length (cm)	10.40	28.30	15.27	3.89	25.47
Cluster width (cm)	3.50	13.50	8.88	2.55	28.71
Berry length (mm)	13.00	21.00	16.11	2.19	13.59
Berry diameter (mm)	13.20	20.30	15.97	1.89	11.83
Seed number in berry	0.00	4.00	1.60	1.46	91.25
Seed weight (g)	0.00	9.78	4.11	3.36	81.75
Berry shape	1.00	4.00	2.45	0.82	33.46
Berry skin colour	1.00	6.00	3.30	2.51	76.06
TSS (°Brix)	16.50	22.60	20.07	1.56	7.77
TA (%)	0.41	0.78	0.57	0.09	15.78
pH	3.08	3.67	3.36	0.18	5.35
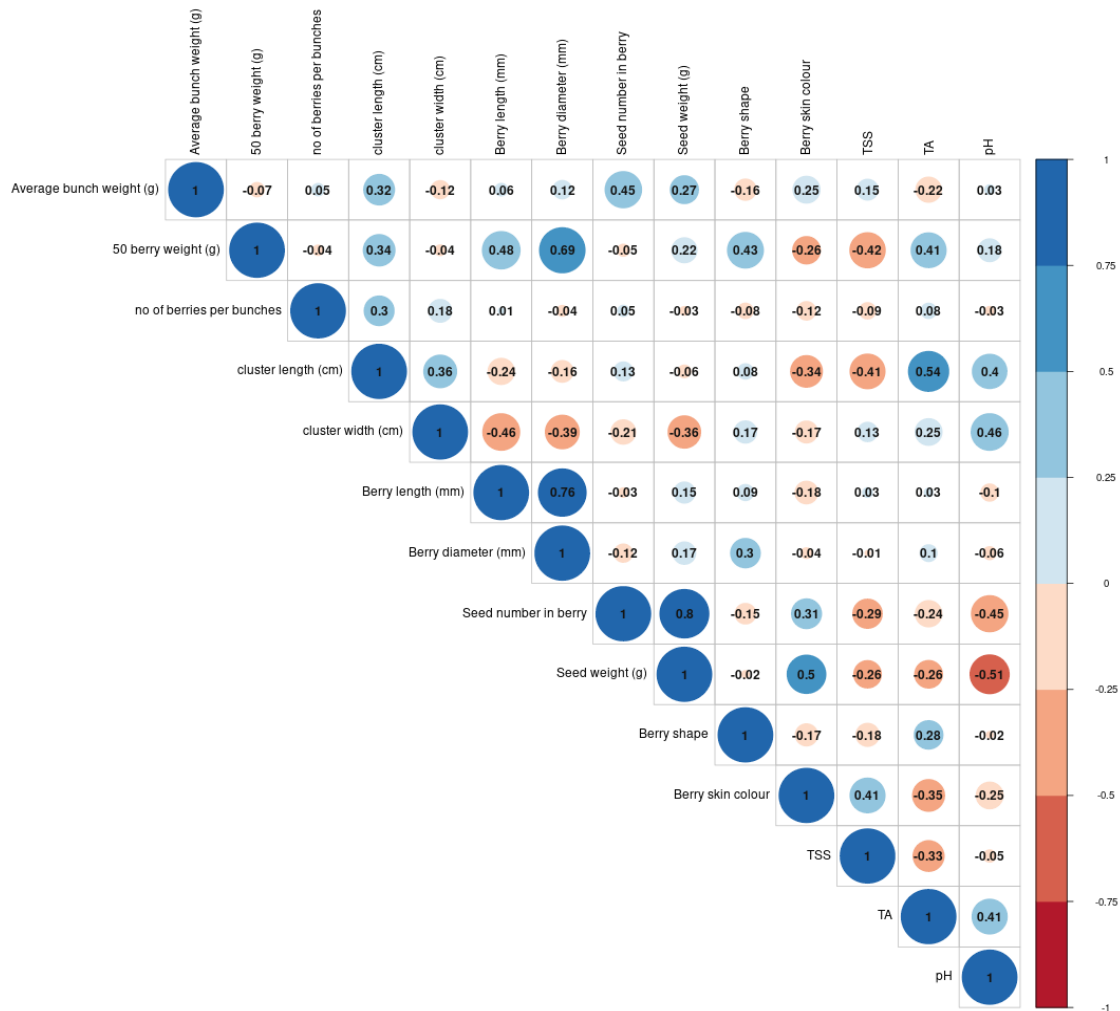
Fig. 1. Correlation between different bunch and berry parameters in studied local varieties

PCA using the correlation matrix was conducted to assess fruit differentiation among cultivars and to determine if the data reduction achieved through the new set of variables (principal components) uncovered a variation pattern that aligns with grouping, especially when the major components of overall variance are due to differences between groups. For each factor, a PC loading of more than 0.52 was considered as being significant, indicating five components and explaining 77.18% of the total variance (Table 3). The first three PCs explained 59.62% of the variance (23.84, 20.31 and 15.47%, respectively), showing that these attributes exhibit the greatest variation among the cultivars and have the most significant effect on differentiating them. The highest loading on the PC1 [15]. The highest loadings on the PC1 axis were associated with attributes such as cluster length and cluster width. The variables with the highest loadings on the second principal component (PC2) axis included berry diameter and berry weight. Meanwhile, the highest loadings on the third component (PC3) were cluster length and seed number per berry. The remaining components accounted for less variability. Variables that had a strong correlation with PC1 can be regarded as respective of berry size. While berry traits are crucial for distinguishing and analyzing breeding materials in the morphological characterization of grapes [14]. Correlations between traits identified through PCA might indicate either a genetic linkage between the loci controlling these traits or a pleiotropic effect.

A multivariate statistical analysis of the data was performed using PCA. Fig. 2 was plotted according to the correlation between Local cultivars and morphological parameters. PC1 accounted for 23.8% of the total variance (44.16%), and PC2 accounted for 20.31%. The

position of each variable in the loading plot describes its relationship with the other variables. Variables that are close to each other have high correlations. Variables on the same side of the origin (0.0) are positively correlated and those on the opposite side of the origin are negatively correlated. Local grape varieties could be discriminated on the PCA plane. PC1 was positively related to berry weight, berry shape, cluster length and titratable acidity. PC2 was related to average bunch weight, seed weight, berry diameter and berry length. Arka majestic, Arka Chitra, Arka Kanchan, Manjari Naveen, Pusa Aditi, Pusa Seedless, Arkavati and Arka Shweta were located on positive side of PC1. On the other hand, Arka Soma, Arka Hans, Arka Krishna, Manjari Medika, Pusa Navrang, Arka Neelmani were located on negative side of PC2.

Table 3. Eigenvalues and proportion of total variability and eigenvectors of five principal components (PCs) for studied local grape cultivars

| Traits	PC1	PC2	PC3	PC4	PC5
Average bunch weight	-0.322	0.071	0.424	0.731**	-0.074
Berry weight (g)	0.37	0.831**	0.055	0.043	-0.194
No of berries	0.149	-0.034	0.319	0.177	0.581**
Cluster length	0.559**	0.083	0.719**	0.246	0.015
Cluster width	0.557**	-0.46	0.205	0.091	-0.31
Berry length	-0.104	0.739	-0.4	0.261	0.273
Berry diameter	-0.027	0.832**	-0.368	0.296	-0.038
Seed number per berry	-0.593	0.19	0.698**	-0.073	-0.025
Seed weight	-0.667	0.437	0.467	-0.128	-0.183
Berry shape	0.334	0.402	-0.08	-0.266	-0.511
Berry skin	-0.67	-0.176	0.034	0.189	-0.46
TSS	-0.275	-0.434	-0.534	0.491	-0.186
TA	0.724	0.242	0.173	-0.036	-0.095
*p*H	0.696	-0.163	0.004	0.414	-0.149
Eigenvalue	3.339	2.844	2.167	1.33	1.125
Percent of variance	23.849	20.312	15.476	9.522	8.039
Cumulative %	23.849	44.161	59.476	69.159	77.198

**Eigentvalues significant ≥0.52
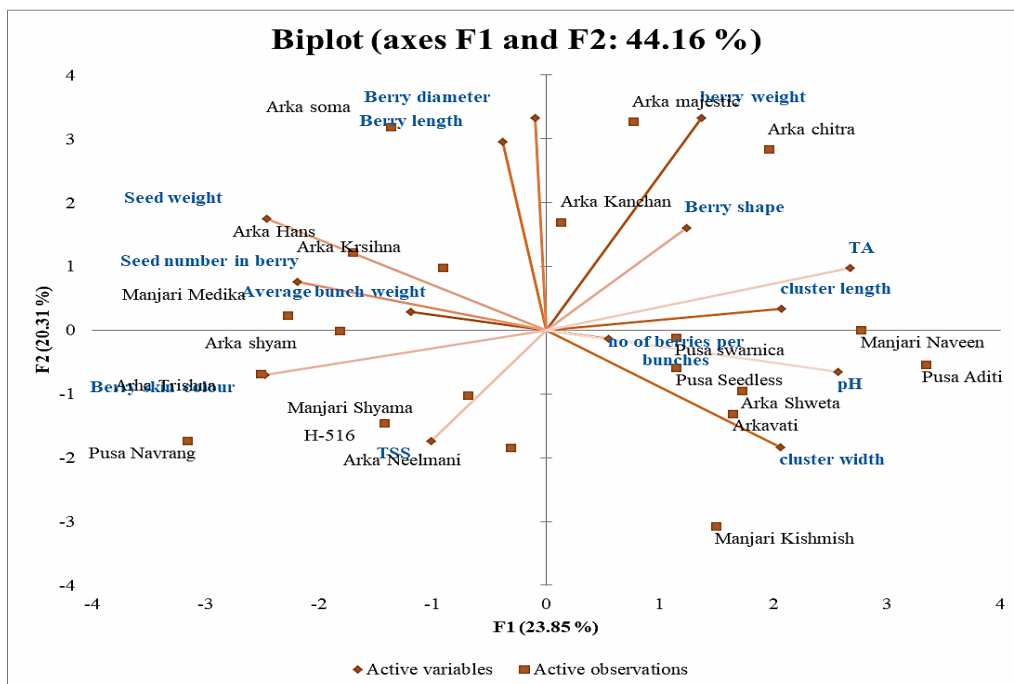
Fig. 2. Biplot of the first two principal components (44.16 % of the total variability) based on fruit parameters in local grape varieties
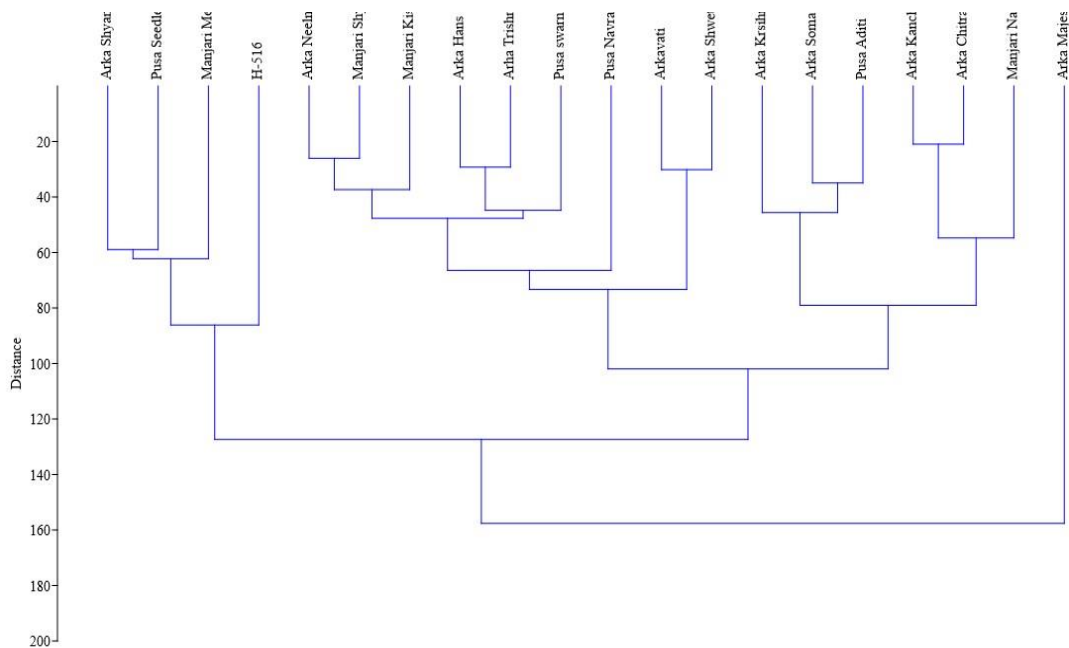
Fig. 3. UPGMA cluster analysis of the studied local grape cultivars based on morphological traits using Euclidean distance

3.1 Cluster Analysis

Based on their phenotypic data, Euclidean distances applied through the UPGMA method, served as the metric for cluster analysis to assess the dissimilarity and similarity among the studied local cultivars (Fig. 3). The dendrogram revealed three clusters. The first cluster (I) contained 4 cultivars, second cluster (II) contained 15 cultivars, while the third cluster (I) included only on cultivar. The obtained data revealed the morphological diversity within the studied local cultivars. High dissimilarity level among the studied cultivars showed high fruit variability in the germplasm. Natural hybridization and human selection may have contributed to this variation [18].

4. CONCLUSION

Our findings show a significant morphological variability within the local grape variety. In future research on the morpho-agronomic assessment of grapes, the traits of fruits, particularly those related to berry characteristics, could be taken into account. The high morphological variability of Indian local grape cultivars might be considered as characterizing the large gene pool that contributed to the domestication process of grape. This morphological characterization should be further completed with molecular analysis through DNA markers. Genetic analysis

of these resources will help establish the genetic distances between accessions, enabling the selection of diversity to preserve, distinguishing local cultivars from international germplasm, and informing their application in future breeding programs.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Somkuwar RG, Kakade PB, Sharma AK, Shabeer TA. Optimization of bunch load in relation to juice quality in Manjari Medika grape. Plant Archives. 2024;24(1):549-555.
2. Samarth R, Bhosale P, Anupa T, Deore P, Gaikwad S. Morphological and molecular characterization of different grape varieties. Research on Crops. 2016; 17(3): 517-523.

3. Anonymous (2023). Area and Production of Horticulture Crops: All India (APEDA); 2023. Available:https://agriexchange.apeda.gov.in/India%20Production/ India_Productions.aspx?cat=fruit&hscode= 1045.

4. Eyduran SP, Akin M, Ercisli S, Eyduran E, Magharadze D. Sugars, organic acids, and phenolic compounds of ancient grape cultivars (*Vitis vinifera* L.) from Igdir province of Eastern Turkey. Biol. Res. 2015;48:2.

5. Salimov V, Musayev M, Asadullayev R. Ampelographic characteristics of Azerbaijani local grape varieties. VITIS-Journal of Grapevine Research. 2015;54: 121-123.

6. Sancho-Galán P, Amores-Arrochan A, Palacios V, Jiménez-Cantizano A. Identification and characterization of white grape varieties autochthonous of a warm climate region (Andalusia, Spain). Agronomy. 2020;10:205.

7. Chessa I, Nieddu G. Analysis of diversity in the fruit tree genetic resources from a Mediterranean island. Genet. Resour. Crop Evol. 2005;52:267–276.

8. Pallas EI. Sustainable wine and grape production, the example of Hungary. Visegrad J. Bioeconomy Sustain. Develop. 2016;5:53–57.

9. Sargolzaei M, Rustioni L, Cola G, Ricciardi V, Bianco PA, Maghradze D, Failla O, Quaglino F, Toffolatti SL, de Lorenzis G. Georgian Grapevine Cultivars: Ancient Biodiversity for Future Viticulture. Front. Plant Sci. 2021;12:630122.

10. SAS® Procedures. Version 6, 3rd ed. SAS Institute, Cary, NC; 1990.

11. Bouquet A. Grapevines and viticulture. In: Adam-Blondon AF, Martínez Zapater JM, Kole C. (Eds.), Genetics, Genomics and Breeding of Grapes. CRC Press, Boca Raton, FL. 2011;1–29.

12. Somkuwar RG, Bhor VA, Samarth RR. Genetic Variability and Multivariate Analysis of Physio-Biochemical Traits in Coloured Grape Genotypes. Grape Insight. 2023;116-123.

13. Vafaee Y, Ghaderi N, Khadivi A. Morphological variation and marker-fruit trait associations in a collection of grape (*Vitis vinifera* L.). Scientia horticulturae. 2017;225:771-782

14. Leao PCS, Cruz CD, Motoike SY. Genetic diversity of table grape based on morphoagronomic traits. Sci Agric (*Piracicaba, Braz*.). 2011;68:42–49.

15. Khadivi-Khub A, Salimpour A, Rasouli M. Analysis of grape germplasm from Iran based on fruit characteristics. Braz. J. Bot. 2014;37:105–113.

16. Migicovsky Z, Sawler J, Gardner KM, Aradhya MK, Prins BH, Schwaninger HR, Bustamante CD, Buckler ES, Zhong GY, Brown PJ, Myles S. Patterns of genomic and phenomic diversity in wine and table grapes. Hortic. Res. 2017;4: 17035.

17. Norman PE, Tongoona P, Shanahan PE. Determination of interrelationships among agr-morphological traits of yams (Discorea spp.) using correlation and factor analyses. J Appl Biosci. 2011;45:3059–3070

18. Sefc KM, Steinkellner H, Lefort F. Evaluation of the genetic contribution of local wild vines to European grapevine cultivars. Am. J. Enol. Vitic. 2003;54:15–2.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/124266