JOURNAL OF HORTICULTURE AND POSTHARVEST RESEARCH
2024, VOL. 7(2), 115-140

Journal of Horticulture and Postharvest Research

Journal homepage: www.jhpr.birjand.ac.ir

University of Birjand

Phenotypic diversity of some Iranian grape cultivars and genotypes (*Vitis vinifera* L.) using morpho-phenological, bunch and berry traits

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ARTICLE INFO

Original Article

Article history:
Received 26 January 2024
Revised 2 April 2024
Accepted 3 April 2024

Keywords:
Berry
Cluster analysis
Correlation coefficient
Grapes
Morphological traits

DOI: 10.22077/jhpr.2024.7165.1355
P-ISSN: 2588-4883
E-ISSN: 2588-6169

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ABSTRACT

Purpose: Grape (*Vitis vinifera* L.) is one of the most important horticultural products that are grown in different parts of Iran and has high nutritional values. In this study, the genetic diversity of cultivars and genotypes of some vineyards of Markazi province were investigated for the preliminary selection of superior cultivars and genotypes in terms of morphological and fruit characteristics for use in grape breeding programs. **Research method:** For this purpose, grouping and comparing 84 grape cultivars and genotypes were carried out using 70 traits including phenological and vegetative traits, trichome and stomata, bunch and berry traits. **Findings:** Based on the results, the “Sahebi Hazaveh” cultivar with 1000.17 g had highest an average bunch weight to compare other cultivars and genotypes. Results showed that, some traits such as bunch weight, bunch shoulders, fresh weight, rachis weight, the ratio of bunch weight to peduncle weight, the ratio of rachis weight to bunch weight, dry weight of bunch shoulders, length of the tail of bunch, berry weight, pedicel weight, seed weight and length of seed had a high coefficient of variation. Factor analysis reduced the evaluated traits to 10 main factors showed that they justified 78.38% of the total variance. Cluster analysis divided cultivars and genotypes into 4 main groups at five Euclidean distances. **Limitations:** No limitations were encountered. **Originality/Value:** This study indicated that grapes germplasm resources in zone are of noticeable diversities and can be promising for the utilization in the breeding programs. Based on the results, cultivars and genotypes of “Khalili Khondab” region, “Yaghoti”, “Sahebi”, “Fakhri”, “Kharvand” and “Kondori” Hazaveh region and “Sahebi” Aghbolagh region in leafing time, late flowering, sugar percentage, bunch and berry characteristics, stomatal density, standing and lying trichome density in leaves were superior to other cultivars and genotypes.

INTRODUCTION

Grapes, scientifically known as *Vitis vinifera* L., belong to the Vitaceae family, also called the Sarmentaceae or Ampelidaceae family (Kellar & Tarara, 2010; Rasouli et al., 2014; Rasouli et al., 2015; Doulti Baneh.,2015; Jahnke et al., 2021; Kupe et al., 2021). This family belongs to the Rhamnales order and is part of the hidden flowering plant group in the Rosids branch. The mentioned family has over 15 genera and approximately 1000 species, with the most important genus, Vitis, having different subgenera with varying chromosome numbers (Rasouli et al., 2015). The Asian group includes 11 species, while the European group consists of only one species. The species found in Europe and the Middle East mainly include *V. vinifera*. American species are highly important due to their resistance to pests, cold weather, and tolerance to calcareous soils (Rasouli et al., 2015; Jalili Marandi et al.,2016; Rasouli & Kalvandi, 2022) Grapes is one of the most important fruits that have been used by humans since ancient times. Some experts believe that grapes were used even before the emergence of cereal. Based on botanical and archaeological studies, the Near East region is considered the primary center of grapes (Kellar & Tarara, 2010; Doulti Baneh., 2015; Jahnke et al., 2021; Kupe et al., 2021). Grapes have a high nutritional value, and according to research by the Food and Agriculture Organization (FAO, 2017) table grapes contain 67 kilocalories per 100 grams, while raisins contain 268 kilocalories per 100 grams (Doulit Baneh., 2015). *Vitis vinifera*, known as the wine grape, is one of the most widely used plant species in horticulture and is favored by farmers. It is the only species extensively used in the food industry and consumption worldwide. Alongside apples, citrus fruits, and bananas, it is one of the most important horticultural plants widely cultivated (Kupe et al., 2021). Climate greatly affects grape diversity and production in a specific location (Akram et al., 2021). Local grape cultivars are essential for preserving crop diversity and can be crucial for food, nutrition, and economic security for many individuals. For smallholder farmers and agricultural communities in rural and marginalized areas, the diversity of local grapes can provide insurance against damage due to reduced yield and supply special ingredients for traditional local dishes and specific dietary needs. In any country where grape cultivation is practiced, there are numerous local cultivars that contribute to global grape diversity (Gago et al., 2009; Antolin et al., 2020) According to experts, grape cultivation has been common in Iran for at least 2000 years before the Common Era. Grapes are an important horticultural product with increasing cultivation area in Iran. Due to its extensive history of grape cultivation and production, Iran is recognized as one of the important centers of grape genetic diversity. With over 255,000 hectares of vineyards (10.2% of the total orchards) and an approximate production of 2.8 million tons (about 12.4% of the total fruit production), Iran is among the most significant production centers.

Table 1. Geographical location of tested vineyards in Markazi province to investigate morphological diversity of grapes.

Number	Country	Province	Location	Above sea level (m)	Latitude	Longitude
1	Iran	Markazi	Marzijaran	1728	34.14346552	49.64018154
2	Iran	Markazi	Hazaveh	1921	34.18479862	49.53418064
3	Iran	Markazi	Khondab	1822	34.38872495	49.15541268
4	Iran	Markazi	Enaj	1765	34.23042971	49.31798172
5	Iran	Markazi	Derman	2012	34.24812195	49.47916174
6	Iran	Markazi	Aghbolagh	1965	34.10024373	49.50501716
7	Iran	Markazi	Anjudan	1972	33.97994426	50.03023696

Grapes have special importance in Iran, and this crop has the highest cultivation area in the horticultural sector after pistachios and the highest production after apples (Papademetriou & Dent, 2001; Rasouli et al., 2015; Elhami et al., 2019; Khan et al., 2020) Markazi province has approximately 57,000 hectares of horticultural products in Iran. The total area of fertile and infertile vineyards in Markazi province (Center of Iran) in 2021 was about 16,000 hectares, with a production of around 148,000 tons grapes in the country according to the latest available information of the statistics of the Ministry of Jihad Agriculture and the Statistics Center of Iran and the statistical yearbooks of different provinces (Organization of Agriculture, 2021; Salehnia & Rafati, 2023). Having precise selection power among plants is necessary for breeding and production of new varieties, which depends on the identification of existing varieties and their diversity. Studying the genetic diversity in plant populations and selecting the appropriate traits for production and introduction of superior genotypes will be helpful. Additionally, studying phenotypic and genotypic diversity is crucial for identifying similar genotypes, evaluating and utilizing genetic reserves, and preserving them. Identifying and differentiating genotypes from each other, as well as studying the diversity of wild, indigenous, or modified germplasm, before starting breeding programs and to respect the intellectual property rights of breeders, is of great importance (Zahedi et al., 2023). Based on the inter- and intraspecific morphological variability, several descriptor lists, manuals and ampelographic studies are available for identification (Bodor-Pesti et al., 2023). Among the organs, leaves have the most traits, while the young shoot, bunch and berry are also important in the characterization of the genotypes. *Vitis* species and cultivars are described by leaf morphological characterization developed in many ways for the identification of genotypes, to clarify synonymies and distinct clones or evaluate the diversity of wild *Vitis* taxa (Bodor-Pesti et al., 2023). The identification of grape genotypes is usually based on the characteristics of the mature plant, which are influenced by environmental conditions. Grape genotypes are typically identified and grouped based on 130 phenological traits, evaluated and identified using phenological methods (Razi et al., 2021). Regarding screening, various studies and experiments have been conducted in Iran and other countries with the aim of finding drought-tolerant or resistant genotypes as the goal of these experiments and studies. In some others, the identification of cultivars and genotypes with superior traits and high yield under these conditions is desired. Identifying resistant and tolerant cultivars and genotypes to abiotic and biotic stresses is one of the most important strategies for coping with these stresses (Razi et al., 2021). By determining appropriate morphological, physiological, and molecular traits for screening, it is possible to select cultivars and genotypes compatible with the climatic conditions of each region (Amiri & Eslamian, 2010). Among the different cultivars, there are some with desirable fruits that have gained the attention of farmers due to their high quality for table grape, raisin production, and processing. Their cultivation area is increasing recently. On the other hand, cultivars without desirable fruits lose their place and receive less attention. However, these cultivars may possess valuable genes such as resistance to pests, diseases, cold, salinity, drought, and the like, which have not been utilized and gradually become extinct due to lack of identification and accurate understanding of their nature (Khadivi-Khub et al., 2014) In a study conducted by Haddadinejad et al. (2013), screening of drought-tolerant genotypes was carried out among 698 genotypes in three stages. Initially, based on the characteristics of trichomes on the vegetative organs, 150 genotypes were selected. In the second stage, screening was done based on trunk diameter, and 44 genotypes with a diameter greater than 4 centimeters, indicating vigorous growth, were identified. In the third stage, several genotypes such as "Kaj Angor Bajnurd", "Sorkh Ghoochan", "Siah Zarqhan", and "Ghalati Shiraz" were introduced as options with traits related to drought tolerance based on 17 morphological markers related to drought stress and Pearson correlation coefficients (quantitative traits) and Spearman (qualitative traits) between traits related to drought tolerance (Haddadinejad et al., 2013).These studies can help identify genotypes with higher tolerance and use them as the basis for commercial cultivars to achieve better water efficiency in crop production (Zahedi et al., 2023). In another study conducted by Rasouli et al. (2014), phenotypic diversity of 32 grape cultivars and genotypes was examined over a period of 3 years for morphological and pomological traits, including phenolic content and the level of the anti-cancer compound resveratrol. The results indicated high diversity among the studied cultivars and genotypes in terms of the measured traits, including bunch, berry, seed and resveratrol content (Rasouli et al., 2014). In an experiment on morphological diversity, 36 grape cultivars and genotypes were evaluated using the international grape descriptor to select superior genotypes. The traits such as bunch weight, dried bunch weight, berry weight, rachis weight, berry weight, seed weight, and skin color showed high diversity among the cultivars and genotypes and had high coefficients of variation (Rasouli et al., 2014; Razi et al., 2021). Significant positive and negative correlations were observed between some traits (Rasouli et al., 2014). Factor analysis revealed that the first and second factors had the highest contributions to the variance. Traits such as bunch weight, dried bunch weight, bunch width, berry length, berry pedicel length, and skin color were included in the first factor (PC1), which accounted for 44.16% of the total variance. Additionally, traits such as diameter, weight, length, and size of the berry were included in the second factor (PC2), which accounted for 15% of the total variance. Based on cluster analysis using the Euclidean distance, the cultivars and genotypes were divided into four groups, with important factors for distinguishing the cultivars including bunch weight, dried bunch weight, fruit sugar content, leaf width, leaf length, and leaf surface area (Rasouli et al., 2014; Razi et al., 2021). Kazemi et al. (2022) evaluated the phenotypic diversity of 60 grapevine cultivars and genotypes available in tropical, subtropical region of Khuzestan province in Iran, by using 105 phenological, morphological, biochemical and pomological traits based on the international descriptor for grapevines. Their results showed, the significant diversity of grapevine cultivars and genotypes existing in vineyards of Khuzestan province showed the superiority of native and local cultivars and genotypes such as 'Soltani' (Sultana), 'Bangi' (Ghermez) and 'Yershi' in some traits compared to other foreign cultivars (Kazemi et al., 2022). The aim of this research was to investigate the phenotypic and morphological diversity of some grape cultivars and genotypes from vineyards in different regions of Markazi province that was located in central of Iran, with a focus on morphological traits affecting drought tolerance, fruit characteristics and yield. Also, to identify and introduce superior genotypes present in native and local populations was another objective of this study.

MATERIALS AND METHODS

The majority of vineyards in Markazi province are located in Hazaveh, Sharra River area, and to some extent in Shazand, Zarandiyeh, and Saveh. The dominant grape cultivars in the grape-growing areas are "Bidaneh Sefid", "Bidaneh Ghermez", "Asgari", "Farahi", "Yaghoti", "Lal", and "Siah" grapes (Organization of Agriculture, 2021). Markazi province, with an area of 29,530 square kilometers, is one of the industrial and agricultural provinces in Iran, located between 33° 30′ to 35° 35′ N and less than 2 percent of the total area of the country. Based on the topography of the region, 75 percent of the province is mountainous and 25 percent is plains.

Table 2. List of grapes cultivars and genotypes tested in Markazi province to investigate morphological diversity.

Row	Cultivar/ Genotype	Location	Row	Cultivar/ Genotype	Location	Row	Cultivar/ Genotype	Location
1	Khalili	Aghbolagh	29	Sahebi	Derman	57	Fakhri	Aghbolagh
2	Khalili	Marzijaran	30	Shirazi	Aghbolagh	58	Fakhri	Marzijaran
3	Khalili	Anjudan	31	Shirazi	Marzijaran	59	Fakhri	Anjudan
4	Khalili	Hazaveh	32	Shirazi	Hazaveh	60	Fakhri	Hazaveh
5	Khalili	Khondab	33	Shirazi	Khondab	61	Fakhri	Khondab
6	Khalili	Enaj	34	Shirazi2	Khondab	62	Fakhri	Enaj
7	Khalili	Derman	35	Shirazi	Enaj	63	Fakhri	Derman
8	Khalili Khani	Marzijaran	36	Shirazi	Derman	64	Fakhri Asgari	Enaj
9	Yaghoti	Aghbolagh	37	Asgari	Anjudan	65	Bidaneh Sefid	Aghbolagh
10	Yaghoti	Marzijaran	38	Asgari	Hazaveh	66	Bidaneh Sefid	Marzijaran
11	Yaghoti	Anjudan	39	Asgari	Khondab	67	Bidaneh Sefid	Anjudan
12	Yaghoti	Hazaveh	40	Asgari	Enaj	68	Bidaneh Sefid	Hazaveh
13	Yaghoti	Khondab	41	Asgari	Derman	69	Bidaneh Sefid	Khondab
14	Yaghoti	Enaj	42	Asgari	Aghbolagh	70	Bidaneh Sefid	Enaj
15	Yaghoti	Derman	43	Asgari bi bazr	Anjudan	71	Bidaneh Sefid	Derman
16	Sahebi	Aghbolagh	44	Asgari Shahrodi	Hazaveh	72	Bidaneh Ghermez	Aghbolagh
17	Sahebi	Marzijaran	45	Asgari gerd	Enaj	73	Bidaneh Ghermez	Marzijaran
18	Sahebi	Anjudan	46	Siah	Marzijaran	74	Bidaneh Ghermez	Hazaveh
19	Sahebi	Hazaveh	47	Siah	Anjudan	75	Bidaneh Ghermez	Khondab
20	Sahebi	Khondab	48	Siah	Hazaveh	76	Bidaneh Ghermez	Enaj
21	Sahebi	Enaj	49	Siah	Khondab	77	Bidaneh Ghermez	Derman
22	Asgari	Marzijaran	50	Siah	Enaj	78	Lal	Aghbolagh
23	Kharvand	Hazaveh	51	Kol Bache	Anjudan	79	Lal	Marzijaran
24	Kharvand	Derman	52	Halvai	Anjudan	80	Lal	Hazaveh
25	Angor Sefid	Aghbolagh	53	Yek Tokhm	Marzijaran	81	Lal	Khondab
26	Kerak	Marzijaran	54	Lorkosh	Hazaveh	82	Lal	Enaj
27	Kole	Aghbolagh	55	Mehdikhani	Hazaveh	83	Lal	Derman
28	Ghazvini	Anjudan	56	Kondori	Hazaveh	84	Moamelan	Derman

Table 3. Some evaluated traits and how to measure them in the investigated grape samples based on the OIV (2007), IPGRI and UPOV (2008) description†.

Row	Trait	Unit	Abbreviation	Measurement method
1	Flowering time	Score	FTI	1= Too early, 2= Very early, 3= Early, 4=Early to medium, 5= Medium, 6= Medium late, 7=Late, 8= Very late, 9= Too late
2	Leafing time	Score	LTIM	1= Early, 3= Medium, 5= Late
3	Growth vigour	Score	BGP	3= Weak, 5= Moderate, 7= Strong
4	Shoot attitude	Score	SATT	1=Erect 3= Semi-erect 5= Horizontal 7= Semi drooping9=Drooping
5	Size of blade	Score	LSI	1= Very small, 3= Small, 5= Medium, 7= Large, 9= Very large
6	Length of teeth	mm	TL	Digital Caliper
7	Petiole length	mm	PL	Digital Caliper
8	Leaf length	mm	LL	Digital Caliper
9	Tendril length	mm	TLE	Digital Caliper
10	Colour of upper surface	Score	CUSL	1=Green yellow 2=Green with bronze spots 3=Yellow 4=Yellow with bronze spots 5=Copper yellow 6=Copper 7=Reddish
11	Number of lobes	Score	NLO	1=Entire leaf (none) 2= Three 3= Five 4=Seven 5=. More than seven
12	Intensity of anthocyanin staining of buds	Score	IASB	0=Absent 1= Very weak 3= Weak 5= Medium 7= Strong 9=Very strong
13	Anthocyanin intensity of young leaves	Score	AIYL	0=Absent 1= Very weak 3= Weak 5= Medium 7= Strong9=Very strong
14	Stomata density in the field of view of forty microscopes	number	SDF40	Counting in the field of view
15	Stomata density in the field of view of Twenty-five microscopes	number	SDF25	Counting in the field of view
16	Internode diameter	mm	ID	Digital Caliper
17	Colour of Ventral Side of Nodes	Score	CVSN	1= Completely green 2= Green and red striped 3= Completely red
18	Colour of Dorsal Side of Nodes	Score	CDSN	1= Completely green 2= Green and red striped 3= Completely red
19	Colour of the ventral side of internodes)	Score	CVSI	1= Completely green 2= Green and red striped 3= Completely red
20	Colour of the dorsal side of internode)	Score	CDSI	1= Completely green 2= Green and red striped 3= Completely red
21	Form of Tip of Young Shoot	Score	FTYS	1=Closed 2= Slightly open 3= Half-open 4= Wide open 5= Fully open
22	Density of erect trichomes on main veins on lower side of blade	Score	DETMB	Absent (0) Very sparse (1) Sparse (3) Medium (5) Dense (7) Very dense (9)
23	Density of erect trichomes on main veins on lower side of blade	Score	DETML	Absent (0) Very sparse (1) Sparse (3) Medium (5) Dense (7) Very dense (9)
24	Density of prostrate trichomes on main veins on lower side of blade	Score	DPTM	Absent (0) Very sparse (1) Sparse (3) Medium (5) Dense (7) Very dense (9)
25	Density of prostrate trichomes between veins	Score	DPTV	Absent (0) Very sparse (1) Sparse (3) Medium (5) Dense (7) Very dense (9)
26	Density of erect trichomes between veins	Score	DETBE	Absent (0) Very sparse (1) Sparse (3) Medium (5) Dense (7) Very dense (9)
27	Density of prostrate trichomes on main veins	Score	DPTM	Absent (0) Very sparse (1) Sparse (3) Medium (5) Dense (7) Very dense (9)
28	Density of erect trichomes on main veins	Score	DETMV	Absent (0) Very sparse (1) Sparse (3) Medium (5) Dense (7) Very dense (9)
29	Density prostrate trichomes of Young Shoot Tip	Score	PTDYS	Absent (0) Very sparse (1) Sparse (3) Medium (5) Dense (7) Very dense (9)
30	Fruit ripening time	Score	FRT	1= Very early, 3= Early, 5= Medium, 7= Late, 9= Very late
31	Bunch size	Score	BZI	3= Small, 5= Medium, 7= Large, 9= Very large

Table 3. (***Continued***). Some evaluated traits and how to measure them in the investigated grape samples based on the OIV (2007), IPGRI and UPOV (2008) description.

Row	Trait	Unit	Abbreviation	Measurement method
32	Bunch density	Score	BDE	3= Open, 5= Medium, 7= Tight, 9= Very tight
33	Density of berry per bunch	Score	DBPB	3 = Open, 5 = Medium, 7 = Compact
34	Bunch number of bush	Count	BNB	Count
35	Brix%	Brix	B	Refractometer
36	Bunch length	mm	BL	Digital Caliper
37	Bunch width	mm	BWII	Caliper
38	The length to width ratio of bunch	mm	LWR	Caliper
39	Bunch weight	g	BWI	Digital scale
40	Bunch shoulder weight	g	BSW	Digital scale
41	Ratio of bunch weight bunch shoulder weight	Ratio	ROBWT	Calculate the ratio of bunch weight to bunch shoulder weight
42	Rachis weight	g	RW	Digital scale
43	Peduncle weight	g	PW	Digital scale
44	Ratio of the Rachis weight to Peduncle weight	Ratio	RRTP	Calculate ratio of the rachis weight to peduncle weight
45	Ratio of bunch weight to Rachis weight	Ratio	RBWR	Calculate ratio of the bunch weight to rachis
46	Ratio of Rachis weight to the bunch weight	Ratio	RBWBS	Calculate ratio of the bunch weight bunch shoulder weight
47	Ratio of the Peduncle weight to the Bunch shoulder weight	Ratio	RRWWB	Calculate ratio of the rachis weight to the weight of bunch shoulder
48	Anthocyanin colouration of fresh	Score	ACF	1=Very slightly coloured 3= Slightly coloured 5= Coloured 7= Strongly coloured 9=Very strongly coloured
49	Skin thickness	Score	STH	3= Thin, 5= Medium, 7= Thick
50	Being juicy	Score	BJ	1= Low water, 2= Slightly watery, 3= Very watery
51	Berry color	Score	BCO	1= Green-yellow, 2= Rose, 3= Red, 4= Red Gray, 5= Dark red-violet, 6= Blue-black
52	Berry hardness	Score	BHA	1=Soft, 2=Slightly hard, 3=Hard
53	Berry shape	Score	BSH	1= Oblong 2= Narrow elliptic 3= Elliptic 4= Round 5= Oblate 6= Ovate 7= Obtuse-ovate 8= Obovate 9= Arched
54	Berry weight	g	BWE	Digital scale
55	Berry length	mm	BLE	Digital caliper
56	Berry width	mm	BWID	Digital caliper
57	The length to width ratio of berry	Calculate	LWRB	Calculate the ratio length to width of berry
58	Berry diameter	mm	BDI	Digital caliper
59	Berry tail length(mm)	mm	BTLE	Digital caliper
60	Berry weight	g	BWE	Digital scale
61	Berry tail weight(g)	g	BTWE	Digital scale
62	Seed weight	g	SW	Digital scale
63	Seed length	mm	SL	Digital caliper
64	Bunch tail Length	mm	BTL	Digital caliper
65	Existence of seeds	Score	ES	1= None 2= Incomplete growth 3= Complete growth
66	Separating from the pedicel	Score	SFP	1= Hard 2= Fairly easy 3= Very easy
67	Fresh weight of bunch shoulder	g	FWBS	Digital scale
68	Dry weight of bunch shoulder	g	DWBS	Digital scale
69	Ratio the fresh weight to dry weight of bunch shoulder	g	RFWDW	Calculate ratio the fresh weight to dry weight of bunch shoulder

† OVI: International Office of the Vine and Wine (www.oiv.int), IPGRI: International Plant Genetic Resources Institute (www.Bioversityinternational.org), UPOV: International Union for the Protection of new Varieties of Plants (www.upov.int).

According to the Islamic Republic of Iran Meteorological Organization (IRIMO, 2023), the average rainfall is 311 millimeters, and the climate of the province is classified as semi-arid according to the second De Martons classification system and dry-cold according to the Amberzhe classification (Asakereh et al., 2022; IRIMO, 2023). Some areas of the Markazi province have suitable climate for cultivation of grapevines, and there are old vineyards in some areas. The first phase of this research involved the investigation, evaluation, and screening of some cultivars and genotypes of grapevines in certain vineyards of Markazi province, which started in March 2019 and continued until December 2022. In this study, the morphological diversity of 84 grape cultivars and genotypes, 7 to 10 years old, in the regions (Tables 1 and 2) were evaluated using 69 morphological traits (34 quantitative and 36 qualitative traits) from March 2019 to December 2022 (Table 3). Three mature vines were selected for each variety and genotype to collect data from various growth stages, phenological stages, leaves, bunch, berry and some quantitative and qualitative traits (Table 3) were measured using different and appropriate methods for each trait. Additionally, some of OIV (OIV 2007), IPGRI (IPGRI 2008), and UPOV (UPOV 2008) as presented in Table 3. In the second phase, for the examination of cultivars, quantitative and qualitative traits were evaluated as described in the following table, using the descriptor of OIV (2007), IPGRI (2008), and UPOV (2008), as well as the number and density of tendrils and berries (Table 3). The genetic diversity was assessed based on morphological indices, with emphasis on phenological traits such as leafing time, flowering time, ripening time, and morphological traits (leaf and fruit characteristics). The measurement of quantitative and qualitative traits was conducted using the coding method based on the grape descriptor of OIV, IPGRI, and UPOV (Table 3).

Statistical analysis

Frequency of traits, descriptive statistics, simple correlations between traits, and cluster analysis were performed using SPSS software (Version 21.0). The coefficient of variation was calculated by dividing the standard deviation of each trait by its mean to measure the variation. Pearson's correlation coefficient was used to determine the correlation between traits. Factor rotation technique and maximum variance method were used to extract factors and factor loadings of 0.4 or higher were considered significant. Cluster analysis and grouping of cultivars and genotypes were performed using the Ward's method or the minimum variance method based on the Euclidean distance and standardized data (Rasouli et al., 2014; Zahedi et al., 2023).

RESULTS AND DISCUSSION

Descriptive statistics and frequency distribution of traits

The minimum, maximum, mean, standard deviation, variance, and coefficient of variation for some important measured traits in the grape cultivars and genotypes are presented in Table 3. Also, some important morphological characteristics measured in the examined grape cultivars and genotypes are mentioned in Table 4.

Table 4. Descriptive statistics of quantitative traits in grape cultivars and genotypes studied in Markazi province.

Row	Trait	Min	Max	Ave	Std	Var	CV.%
1	Internode diameter (mm)	7.15	14.56	11.67	1.80	3.24	15.43
2	Leaf length (mm)	71.33	148.36	98.95	16.26	264.34	16.43
3	Petiole Length (mm)	42.23	133.34	77.50	19.80	392.16	25.55
4	Length of teeth (mm)	3.15	9.53	5.32	1.39	1.93	26.11
5	Tendril length (mm)	8.22	221.33	93.88	37.13	1378.28	39.55
6	Stomata density in the field of view of 40 microscopes	2.14	7.22	4.15	1.10	1.20	26.48
7	Stomata density in the field of view of 25 microscopes	35.32	91.51	56.90	12.53	156.88	22.01
8	Bunch weight (g)	102.51	1000.71	354.40	205.97	42424.78	58.12
9	Bunch shoulder weight (g)	9.53	89.93	34.97	16.66	277.52	47.64
10	Ratio of bunch weight to bunch shoulder weight	6.01	16.82	10.13	2.56	6.54	25.26
11	Rachis weight (g)	1.12	24.51	6.13	4.52	20.39	73.62
12	Peduncle weight (g)	0.11	1.78	0.51	0.34	0.11	65.16
13	Ratio of the rachis weight to peduncle weight	3.36	26.48	12.72	4.94	24.38	38.82
14	Ratio of the bunch weight to rachis	10.72	202.46	68.77	33.58	1127.64	48.83
15	Ratio of the bunch weight bunch shoulder weight	0.00	0.09	0.02	0.01	0.00	58.37
16	Ratio of the rachis weight to the of bunch shoulder weight	0.00	0.06	0.02	0.01	0.00	66.00
17	Fresh weight of bunch shoulder (mm)	8.41	196.69	45.88	32.72	1070.79	71.33
18	Dry weight of bunch shoulder (mm)	2.86	58.10	11.96	8.30	68.91	69.39
19	Ratio the fresh weight to dry weight of bunch shoulder	2.11	5.48	3.86	0.68	0.46	17.61
20	Bunch number of bushes	20.50	81.20	47.43	15.55	241.92	32.79
21	Bunch length (mm)	118.24	310.75	187.59	42.08	1770.98	22.43
22	Bunch width (mm)	36.81	126.64	78.87	17.23	297.01	21.85
23	The length to width ratio of bunch	1.38	4.11	2.44	0.59	0.35	24.39
24	Bunch tail length (mm)	10.12	74.94	29.08	12.74	162.19	43.79
25	Berry weight (g)	0.83	6.99	2.79	1.40	1.97	50.29
26	Berry length (mm)	9.54	32.21	18.45	4.47	19.98	24.23
27	Berry width (mm)	9.27	21.12	14.44	2.53	6.42	17.54
28	The length to width ratio of berry	0.98	1.84	1.27	0.17	0.03	13.81
29	Berry diameter (mm)	9.49	20.99	14.33	2.25	5.08	15.73
30	Berry tail length (mm)	2.89	8.61	6.18	1.36	1.86	22.07
31	Berry tail weight (g)	0.01	0.18	0.03	0.02	0.00	85.36
32	Seed weight (g)	0.00	0.30	0.05	0.05	0.00	93.38
33	Seed length (mm)	0.00	10.33	5.04	2.86	8.21	56.84
34	Brix (%)	14.21	26.96	20.14	2.84	8.06	14.09

According to the results, traits such as bunch weight (58.12%), bunch shoulders weight (47.64%), rachis weight (73.62%), peduncle weight (65.15%) , the ratio of bunch weight to peduncle weight (38.82%), bunch shoulders fresh weight (71.33%), dry weight of the bunch shoulders (69.39%), ratio the fresh weight to dry weight of bunch shoulder (17.61%) berry weight (50.29%), seed weight (93.38%), seed length (56.84%) showed high diversity in cultivars and genotypes and have relatively high coefficients of variation (Table 4). The highest bunch weight was observed in the variety "Sahebi Hazaveh" with an average weight of 1000.71 g (Tables 4 and 5). On the other hand, the lowest bunch weight was observed with

102.51g in "Khalili Anjudan" cultivar (Tables 4 and 5). Also, the maximum number of bunches per vine was found in the cultivar "Asgari Hazaveh" with an average of 81.20 bunches, while the minimum number of bunches per vine was observed in the "Kole Bache Anjudan" cultivar with an average of 20.50 bunches (Tables 4 and 5). In this experiment, the longest bunch length (310.75 mm) was attributed to the cultivar "Fakhri Enaj". In the event that the shortest bunch length (118.24 mm) was found in the variety "Khalili Enaj" (Tables 4 and 5). The "Kharvand Hazaveh", cultivar showed widest bunch width (126.64mm), however the smallest width bunch (36.81mm) was found in the cultivar "Khalili Anjudan". Moreover, the highest berry weight (6.99 g) was measured in "Kondori Hazaveh," cultivar, but the lowest weight of berry (0.83 g) measured in "Yaghoti Anjudan". The maximum sugar content (26.96 Brix) was reported from "Bidaneh Ghermez Derman" cultivar, whereas the minimum amount of sugar content (14.21 Brix) was measured in "Shirazi 2 Khandab" cultivar (Tables 4 and 5). Also, the average amount of Brix (sugar level) was 20.14%, which is close to the normal level of grape Brix. In this part, it can be compared that in terms of bunch weight, number of bunches per plant, maximum bunch width and berry weight, Hazaveh cultivars have a higher ratio compared to the rest of the tested regions, and the cultivars of Anjudan region are almost weaker than the other investigated cultivars and genotypes (Tables 4 and 5). The time of berry ripening was delayed in the cultivars "Sahebi Derman," "Shirazi Khondab," "Kol Bache Anjudan," and "Yek Bazr Marzijaran" compared to other cultivars and genotypes. Regarding flowering time, the cultivars "Kol Bache Anjudan," "Kolehe Aghbolagh,","Angur Sefid Aghbolagh," "Lal Derman," "Lal Hazaveh," "Lal Marzijaran," "Lal Aghbolagh," "Keshmishi Ghermez Enaj," "Keshmishi Sefid Enaj," "Fakhri Derman," "Fakhri Hazaveh," "Fakhri Marzijaran," "Shirazi Aghbolagh," "Sahebi Derman," "Sahebi Hazaveh," "Sahabi Anjudan," "Sahabi Marzijaran," and "Sahebi Aghbolagh" (Tables 4 and 5) had later flowering compared to other cultivars and genotypes, indicating that these cultivars may exhibit better tolerance to early spring frost. Therefore, traits with high diversity can be used for a more accurate evaluation of the studied cultivars and genotypes, considering the differences and variations in phenological and morphological traits. Rasouli et al. (2014) reported the average weight of bunch (85.46 g), bunch shoulder (13 g), rachis (2.57 g) and peduncle (0.3 grams), which was consistent with the findings in some cases of this research, so that the average weight of peduncle was obtained (0.51 g) (Tables 4 and 5). The difference in the values of some traits can be due to the genetic diversity, the age of the vines, different growing conditions of the vineyard and the geographical region. In the present study, seed weight varied from 0 in seedless cultivars to 0.3 g with an average of 0.05 g among cultivars and genotypes, which was consistent with the findings of Mouszadeh et al. (2015). Mousazadeh et al. (2015) reported, on the grape cultivars of the Khorasan Razavi Research Center collection, "Samarghandi Lotfabad" cultivar had the highest seed weight and "Dizmari Rezaieh" cultivar had the lowest seed weight, one of the reasons for the increased seed weight can be the genetic potential of this the figures show that this potential causes the rapid growth of the fruit and the increase of its constituents. Also, findings of this investigation, was consistent with the findings of various researchers (Bodor-Pesti et al., 2023) that the efforts of metric characterization of the grapevine leaf with the introduction of the scientific objectives and reviewing the studies showing the innovations in phenotyping during the last years (Bodor-Pesti et al., 2023). Kazemi et al. (2022) reported that there is a significant variation in the evaluated traits of cultivated cultivars and genotypes and its origin from Khuzestan province, southwest of Iran, which was somewhat in line with the results of the present research.

Table 5. Some important morphological characteristics measured of grape cultivars and genotypes studied in Markazi province.

Row	Cultivar/Genotype	Berry colour	Fruit ripening time	Density of erect trichome between veins	Density of prostrate trichome between veins	Leaf timing	Brix	Berry width	Berry length	Bunch shoulder weight	Bunch weight	Stomata density	Internode diameter
		Score	Score	Score	Score	Score	%	(mm)	(mm)	(g)	(g)	count	(mm)
1	Khalili Aghbolagh	1	1	5	3	5	16.32	14.11	20.11	17.81	190.55	3.85	10.91
2	Khalili Marzijaran	1	1	9	1	1	19.11	13.92	19.65	23.18	219.81	3.42	13.21
3	Khalili Anjudan	1	3	9	1	3	17.13	11.12	13.92	11.23	102.51	4.16	12.25
4	Khalili Hazaveh	1	1	9	5	5	16.77	13.71	19.34	22.58	208.08	3.15	10.81
5	Khalili Khondab	1	5	9	1	5	19.82	15.12	16.52	54.07	541.72	3.66	10.11
6	Khalili Enaj	1	1	9	3	5	16.83	13.91	21.61	13.23	220.11	3.11	11.54
7	Khalili Derman	1	1	7	5	3	18.22	13.45	19.32	23.18	215.81	4.17	7.89
8	Khalili Khani Marzijaran	1	3	9	1	1	18.37	13.95	19.91	36.12	244.32	2.52	13.41
9	Yaghoti Aghbolagh	3	1	9	7	5	17.75	10.11	11.99	25.61	211.09	3.81	10.47
10	Yaghoti Marzijaran	5	3	7	1	1	17.35	9.79	10.91	26.52	261.31	4.33	10.11
11	Yaghoti Anjudan	5	3	3	1	3	17.87	9.27	9.54	9.53	145.12	3.45	9.91
12	Yaghoti Hazaveh	6	1	7	3	5	23.78	10.42	11.23	57.34	688.05	2.14	11.53
13	Yaghoti Khondab	6	3	1	1	5	19.64	9.83	12.61	20.13	245.84	2.52	10.68
14	Yaghoti Enaj	5	1	9	3	5	17.35	10.12	12.42	17.18	227.57	3.16	11.67
15	Yaghoti Derman	6	1	7	5	3	22.12	10.61	11.23	37.42	487.01	3.48	7.15
16	Sahebi Aghbolagh	5	5	7	3	5	21.84	16.89	26.12	42.41	597.06	2.75	13.32
17	Sahebi Marzijaran	5	5	3	0	5	19.51	14.11	15.98	18.61	167.78	5.71	10.71
18	Sahebi Anjudan	5	5	7	1	5	20.83	16.92	21.14	36.55	298.32	3.54	10.48
19	Sahebi Hazaveh	6	5	9	3	5	21.44	20.11	25.81	86.57	1000.71	2.92	11.11
20	Sahebi Khondab	3	5	1	1	5	16.39	15.57	21.41	40.88	367.66	3.32	12.22
21	Sahebi Enaj	5	7	3	0	3	19.47	21.12	24.62	39.12	310.53	5.12	14.12
22	Sahebi Derman	6	9	7	3	3	19.18	18.31	23.99	32.31	389.31	3.51	8.77
23	Shirazi Aghbolagh	1	5	9	1	5	15.72	16.02	22.98	20.91	176.64	5.75	13.64
24	Shirazi Marzijaran	1	7	7	1	5	22.34	12.79	20.01	20.95	194.31	4.51	13.31
25	Shirazi Hazaveh	1	7	9	1	5	17.45	19.23	32.21	36.02	283.82	4.16	12.49
26	Shirazi Khondab	1	3	5	0	5	17.46	15.52	26.22	29.11	175.21	5.16	12.68
27	Shirazi-2 Khondab	1	9	7	1	5	14.21	17.22	22.35	21.42	173.89	6.32	12.42
28	Shirazi Enaj	1	5	7	1	3	16.72	17.51	28.22	41.54	351.49	3.31	13.99
29	Shirazi Derman	1	9	9	1	3	19.86	17.72	27.11	28.52	226.76	4.55	7.56
30	Fakhri Aghbolagh	1	5	3	1	5	24.73	14.96	19.18	45.47	401.02	5.76	12.56
31	Fakhri Marzijaran	1	5	0	1	5	23.52	14.95	20.71	89.93	915.45	4.66	13.59
32	Fakhri Anjudan	1	5	1	1	5	26.10	13.51	22.20	39.07	389.14	4.83	11.15
33	Fakhri Hazaveh	1	5	5	1	5	23.44	16.23	22.52	62.32	901.55	3.32	12.23
34	Fakhri Khondab	1	5	0	0	5	22.11	15.24	21.31	33.12	402.75	5.33	11.48
35	Fakhri Enaj	1	7	1	1	3	16.18	15.22	21.62	42.63	476.72	3.11	13.41
36	Fakhri Derman	1	7	3	1	3	25.17	16.42	21.12	16.37	212.67	4.11	8.82
37	Fakhri Asgari enaj	1	7	1	0	3	21.85	13.55	16.83	34.18	253.32	3.82	12.71
38	Bidaneh Sefid Aghbolagh	1	5	1	1	5	23.23	10.99	12.24	25.01	215.62	2.76	13.71
39	Bidaneh Sefid Marzijaran	1	7	1	1	5	21.27	11.99	14.99	33.14	368.93	3.25	13.12
40	Bidaneh Sefid Anjudan	1	5	3	1	1	18.81	13.42	15.13	20.11	160.13	3.65	9.11
41	Bidaneh Sefid Hazaveh	1	7	3	1	5	23.98	12.25	14.86	38.72	570.55	4.66	13.13
42	Bidaneh Sefid Khondab	1	7	1	0	5	21.76	13.16	16.11	53.87	905.22	6.83	12.11
43	Bidaneh Sefid Enaj	1	7	1	0	5	21.77	11.58	13.57	34.17	364.11	5.15	14.16

Table 5. (*Continued*). Some important morphological characteristics measured of grape cultivars and genotypes studied in Markazi province.

Row	Cultivar/Genotype	Berry colour	Fruit ripening time	Density of erect trichome between veins	Density of prostrate trichome between veins	Leaf timing	Brix	Berry width	Berry length	Bunch shoulder weight	Bunch weight	Stomata density	Internode diameter
		Score	Score	Score	Score	Score	%	(mm)	(mm)	(g)	(g)	count	(mm)
44	Bidaneh Sefid Derman	1	7	1	1	1	24.38	15.32	17.12	20.72	313.09	2.66	9.75
45	Bidaneh Ghermez Aghbolagh	5	5	7	5	5	24.94	12.06	13.98	20.23	227.49	2.5	13.58
46	Bidaneh Ghermez Marzijaran	5	7	1	1	5	20.23	11.96	13.97	25.42	203.11	2.66	12.26
47	Bidaneh Ghermez Hazaveh	3	5	0	5	5	23.15	11.83	14.83	46.33	498.81	4.32	13.52
48	Bidaneh Ghermez Khondab	4	7	1	0	5	24.89	12.83	14.63	48.31	732.65	5.52	12.85
49	Bidaneh Ghermez Enaj	3	7	1	0	5	23.67	12.15	14.24	41.66	340.58	4.66	14.56
50	Bidaneh Ghermez Derman	3	7	1	3	1	26.96	13.95	17.94	25.28	288.66	4.51	8.49
51	Lal Aghbolagh	1	3	7	3	5	18.64	16.15	18.46	42.15	305.32	3.75	10.34
52	Lal Marzijaran	1	5	3	1	5	17.93	16.97	18.89	38.65	289.86	5.31	12.12
53	Lal Hazaveh	1	7	3	1	5	18.27	17.25	22.84	86.64	810.22	4.32	11.25
54	Lal Khondab	3	5	9	1	5	18.52	15.58	20.11	36.42	409.22	5.32	10.99
55	Lal Enaj	1	7	1	5	3	18.16	15.58	20.67	38.66	429.71	4.53	13.22
56	Lal Derman	1	7	9	5	5	21.37	18.21	24.21	42.35	392.39	4.16	8.89
57	Asgari Aghbolagh	1	3	7	0	1	21.15	14.87	17.52	23.51	213.25	4.37	11.22
58	Asgari Marzijaran	1	5	5	0	3	19.14	11.11	14.98	15.96	165.87	5.14	14.11
59	Asgari Anjudan	1	5	1	0	3	21.79	15.42	18.16	37.58	352.51	5.11	10.97
60	Asgari Hazaveh	1	5	7	1	3	18.48	13.66	17.53	58.71	570.28	4.33	13.41
61	Asgari khondab	1	5	1	1	1	18.33	14.71	17.16	32.86	314.19	3.62	13.32
62	Asgari Enaj	1	7	1	0	3	19.97	14.22	17.41	46.11	290.23	6.52	14.15
63	Asgari Derman	1	5	1	1	1	23.26	14.21	15.97	19.48	209.26	4.12	8.43
64	Asgari bi bazr Anjudan	1	5	1	1	3	18.37	12.33	15.57	24.09	210.04	3.42	12.12
65	Asgari Shahrodi Hazaveh	1	5	1	1	3	18.96	13.33	19.54	33.59	381.92	3.13	12.57
66	Asgari gerd Enaj	1	7	1	5	3	18.74	13.21	14.12	42.28	262.12	3.75	12.92
67	Siah Marzijaran	6	7	3	0	5	18.46	14.86	16.12	35.72	245.22	2.42	12.91
68	Siah Anjudan	6	7	9	1	3	21.27	15.43	17.81	32.05	229.76	3.11	12.21
69	Siah Hazaveh	6	5	1	0	3	24.13	16.53	19.42	50.44	721.03	5.85	11.48
70	Siah Khondab	5	5	3	0	5	17.84	14.13	14.94	31.53	239.15	5.23	10.99
71	Siah Enaj	6	5	1	0	3	17.88	14.82	17.11	57.33	382.65	5.83	13.81
72	Kharvand Hazaveh	1	7	5	1	5	16.35	16.44	17.32	73.71	897.51	2.95	10.21
73	Kharvand Derman	1	5	7	5	3	17.37	18.92	19.89	17.62	215.48	3.32	7.81
74	Angor Sefid Aghbolagh	1	7	9	3	5	22.25	14.08	18.13	27.96	251.13	5.14	9.98
75	Kerak Marzijaran	1	5	3	0	5	19.64	13.12	14.88	32.99	430.76	4.75	12.42
76	Kole Aghbolagh	1	5	0	1	3	23.43	14.88	17.26	16.97	220.74	7.22	10.74
77	Ghazvini Anjudan	5	5	3	0	3	24.96	13.62	16.23	22.41	275.22	3.35	13.13
78	Kol Bache Anjudan	1	9	1	1	5	16.34	12.62	12.43	18.96	163.04	3.11	9.98
79	Halvai Anjudan	1	5	5	1	5	19.72	17.28	24.11	20.39	157.71	4.55	12.11
80	Yek bazr Marzijaran	1	9	5	1	5	18.34	11.99	17.95	33.92	283.31	4.28	13.25
81	Lorkosh Hazaveh	1	7	7	1	5	19.35	18.75	20.23	48.96	344.82	4.15	12.45
82	Mehdikhani Hazaveh	1	3	9	1	5	23.24	13.66	25.23	32.33	200.65	3.33	11.15
83	Kondori Hazaveh	6	5	7	1	3	17.25	19.25	25.77	63.23	652.11	5.32	12.81
84	Moamelan Derman	1	5	5	3	3	20.14	14.12	13.98	15.58	188.92	3.81	7.99

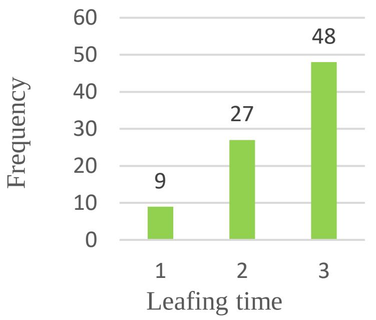

Fig. 1. The frequency of leafing time in different studied grapes varieties and genotypes (1- Early, 3- Medium, 5- Late).

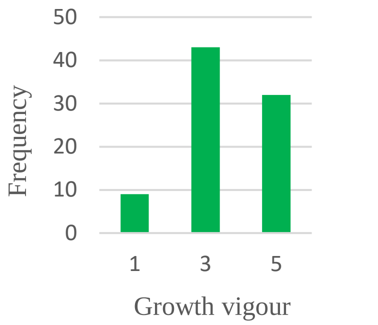

Fig. 2. The frequency of growth vigour in different studied grapes varieties and genotypes (3= Weak, 5= Moderate, 7= Strong)

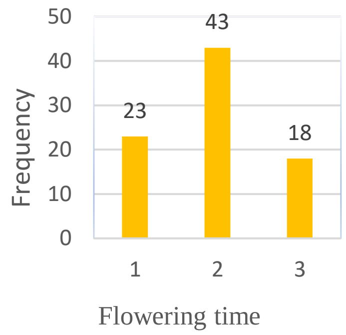

Fig. 3. The frequency of flowering time in different cultivars and genotypes of studied grapes (1- Too early, 2- Very early, 3- Early, 4- Early to medium, 5- Medium, 6- Medium to late, 7- Late, 8- Very late, 9- Too late).

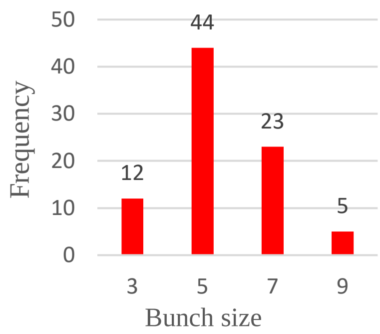

Fig. 4. The frequency of the bunch size in the different investigated cultivars and genotypes of studied grapes (3- Small, 5- Medium, 7- Large, 9- Very large).

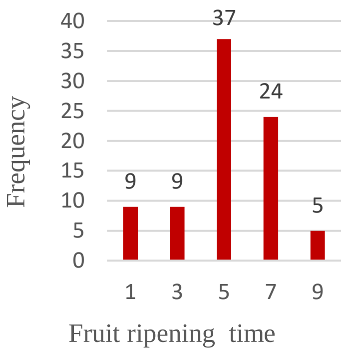

Fig. 5. The frequency of fruit ripening time in different cultivars and genotypes of studied grapes (1= Very early, 3= Early, 5= Medium, 7= Late, 9= Very late).

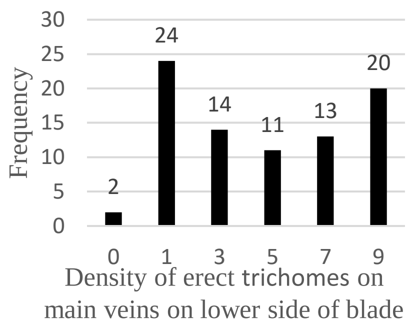

Fig. 6. The frequency of density of erect trichome on main veins on lower side of blade in different cultivars and genotypes of studied grapes (Absent (0), Very sparse (1), Sparse (3), Medium (5), Dense (7), Very dense (9)).

In the study of grape cultivars and genotypes of Khuzestan province, it showed that the most descriptive statistics in the most important quantitative traits are related to fresh weight of bunch (2174.24 g), bunch length (279.68 mm), bunch width (157.03 mm), number of berries per bunch (1088.83 berry), berry fresh weight (6.85 mg), berry diameter (18.60 mm), berry length (30.89 mm) and berry width (22.79 mm) (Kazemi et al., 2022). The frequency distribution of traits such as leafing time, growth power, flowering time, bunch size, fruit ripening time, density of erect trichome on main veins on lower side of blade, density of prostrate trichome on main veins are shown in Figures 1 to 6. In terms of leafing time, most of the genotypes in the studied growth conditions had late leafing, although there were early leafing cultivars such as "Khalili", "Khalili Khani", "Yaghoti Marzijaran", "Bidaneh Sefid Anjudan", "Bidaneh Sefid Derman", "Bidaneh Ghermez Derman", "Asgari Aghbolagh", "Asgari Khondab", and "Asgari Derman" (Fig. 1). Among these cultivars ("Khalili Khani Marzijaran" (2.52), "Yaghoti Hazaveh" (2.14) and "Yaghoti Khondab" (2.52), "Sahebi Aghbolagh" (2.75) and "Sahebi Hazaveh" (2.92), "Bidaneh Sefid" (2.76) and "Bidaneh

Ghermez" (2.5) Aghbolagh, "Bidaneh Sefid Derman" (2.66), "Bidaneh Ghermez Marzijaran" (2.66), "Siyahe Marzijaran" (2.42), and "Kharvand Hazaveh" (2.95) had fewer open stomata in the field of view under a microscope at a magnification of 40. Additionally, the field evaluation for selecting drought-tolerant cultivars in this experiment showed that the cultivars ("Khalili Marzijaran", "Khalili Anjudan", "Khalili Hazaveh", "Khalili Khondab", "Khalili Derman", "Khalili Khani Marzijaran", "Yaghoti Marzijaran", "Yaghoti Hazaveh", "Yaghoti Derman", "Sahabi Anjudan", "Sahabi Hazaveh", "Shirazi Aghbolagh", "Shirazi Hazaveh", "Shirazi Derman", "Lal Derman", "Siyah Anjudan", "Kharvand Derman", "Angor Sefid Aghbolagh", "Lorkosh Hazaveh", " Mahdikhani Hazaveh") had the highest volume of standing trichome between the main leaf veins on the lower surface of the leaf (Tables 4 and 5) (Fig. 8 and Fig. 9). Moreover, there was a relatively high diversity among different cultivars and genotypes in terms of growth power, length, width, weight, shape, and color of the berry. Some important characteristics and average values of the important traits evaluated are mentioned in Table 5. The findings obtained were consistent with the results reported by (Alizadeh, 2004) and (Nejatian, 2006), who reported a wide diversity among the studied cultivars in terms of various traits related to vegetative and fruit parts.

Simple correlation coefficients of traits

Significant correlations existed among variables related to vegetative growth, fruit, and bunch traits in this experiment. The results showed a positive and significant correlation between bunch weight and leaf length (R= 0.31). Bunch shoulders weight also had a positive and significant correlation with bunch weight (R = 0.88). The rachis weight had a positive and significant correlation with bunch weight (R=0.68). But, the ratio of rachis weight to bunch weight had a significant negative correlation with the ratio of bunch weight to rachis weight (R =-0.67). Also, the ratio of rachis weight to bunch weight showed a positive and significant correlation with the ratio of rachis weight to bunch shoulders weight (R=0.71). The bunch shoulders dry weight had a positive and significant correlation with bunch shoulders fresh weight (R=0.96). Although, the number of bunches per vine had a positive and significant correlation with leaf length (R=0.25), bunch weight (R=0.24), and the ratio of bunch weight to rachis weight (R=0.33), its correlation value was not high. The traits of bunch length had a positive and significant correlation with bunch weight (R=0.67), bunch shoulders weight (R=0.60), and rachis weight (R= 0.44). Also, the bunch width had a positive and significant correlation with bunch weight (R=0.84), bunch shoulders weight (R=0.77), and bunch length (R=0.44). Moreover, berry width had a positive and significant correlation with berry weight (R=0.80) and berry length (R=0.82). Also, berry diameter had a positive and significant correlation with berry weight (R= 0.87), berry length (R= 0.79), and berry width (R=0.90). Furthermore, seed length had a positive and significant correlation with berry weight (R=0.62), berry length (R =0.60), and berry width (R=0.60). In general, based on the results of simple correlation of traits in this research, significant correlations existed among some variables related to vegetative growth and fruit traits. These findings are consistent with the findings of Ekhvaia et al. (2009) who reported associations and correlations among various grape vegetative and fruit traits. The consistent with the results of traits correlations mentioned in Table 6 of this research, Leão and Oliveira (2023) reported that most of the phenotypic correlations between morpho-agronomic variables were significant ($p<0.05$), indicating that yield per vine was positively correlated with number of bunches, bunch length, soluble solids content and titratable acidity. Only berry length had a significant negative correlation with yield per vine. The significant negative correlation between berry length and yield per vine can be explained by the fact that in vines whose bunches had longer berries, the number of bunches per vine was reduced (R= -0.537), as well as the bunch length (R= -

0.466). On the other hand, these last two variables have a positive and significant correlation with the yield per vine. Also, Leão and Oliveira (2023) Shown phenotypic correlations showed that the trait number of bunches per vine is highly correlated with yield; however, berry weight, length and diameter were negatively correlated with soluble solids content, titratable acidity and SS/TA ratio. Furthermore, Cargnin (2019) in the study of "Cabernet Sauvignon" cultivar showed that fruit yield (weight) has a positive and significant phenotypic correlation with bunch weight (R=0.98) and berry weight (R=0.98), and selecting a plant with higher bunch and berry weight increases fruit yield, which was somewhat consistent with the present findings. There was also a positive and significant correlation between number of bunches (R=0.78) and pH (R=0.89). The phenotypic correlation between number of bunches with bunch weight (R= -0.83) and berry weight (R= -0.82) was negative and significant. The more bunches per plant, the lower the bunch weight and the lower the berry weight, resulting in lower fruit yield (Cargnin, 2019). Also, Cargnin (2019) obtained similar results in a study of "Cabernet Sauvignon" and showed that fruit yield (weight) had a positive and significant phenotypic correlation with bunch weight (R=0.91) and number of berries per bunch (R =0.88), and these traits indicated high fruit yield potential in the plant. There was a negative and significant correlation between pH and fruit yield traits (R = -0.95), bunch weight (R = -0.99) and number of berries per bunch (R = -0.98).

As fruit yield, bunch weight and number of berries per bunch increase, pH decreases. The results obtained from this research are consistent with the results of other researchers and show that increasing yield components such as number of berries per bunch, berry weight and number of berries per bunch leads to an increase in fruit yield. Some results showed a negative correlation between the number of berries per bunch and berry weight. According to Silva et al. (2009), negative correlations between yield components probably occur mainly due to competition between them (sinks-sources) during plant development in each crop cycle. Positive or negative correlations occur due to genetic and environmental variations in the plant.

Table 6. Eigenvalues, percentage of variance, and percentage of cumulative variance of the 10 main components in this research.

Factor	Eigenvalues	Eigenvalues to percent variance	Percentage of variance cumulative
1	6.142	18.065	18.065
2	4.804	14.128	32.193
3	3.872	11.387	43.580
4	2.618	7.701	51.281
5	2.186	6.430	57.711
6	1.628	4.787	62.499
7	1.508	4.434	66.933
8	1.462	4.299	71.232
9	1.350	3.971	75.202
10	1.080	3.177	78.379

Table 7. Coefficients related first to 10 main components of grapes cultivars and genotypes.

Trait	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
Internode diameter	.250	.014	-.255	-.152	.296	-.650	.131	-.031	.004	.211
Leaf length	.263	.318	-.284	.289	-.013	-.180	-.153	.294	.602	.005
Petiole length	-.050	.143	-.299	.585	-.166	-.042	-.252	-.083	.277	.068
Length of teeth	-.079	-.052	.066	.650	-.107	-.036	-.469	-.043	.038	-.004
Tendril length	.079	.260	.155	.185	-.385	.193	.036	.345	.112	-.253
Stomata density in the field of view of 40 microscopes	.274	-.068	-.020	-.003	.702	.276	.001	-.276	.328	-.035
Stomata density in the field of view of 25 microscopes	.251	-.076	.003	.043	.678	.353	.119	-.333	.311	-.130
Bunch weight	.464	.793	-.194	.019	-.077	.001	.027	-.214	-.094	.072
Bunch shoulder weight	.602	.666	-.006	-.047	-.031	-.209	-.047	-.211	-.156	-.080
Ratio of bunch weight bunch shoulder weight	-.185	.475	-.320	.121	-.123	.433	.161	-.059	.083	.333
Rachis weight	.150	.861	.337	.004	.025	.099	.007	.047	-.034	.055
Peduncle weight	.058	.685	.602	-.046	-.028	-.170	.017	-.147	.064	-.076
Ratio of the rachis weight to peduncle weight	.035	.336	-.433	-.050	.179	.511	.001	.265	-.250	.264
Ratio of bunch weight to Rachis weight	.362	-.317	-.569	.118	-.226	.026	.084	-.201	-.020	-.155
Ratio of rachis weight to the bunch weight	-.308	.352	.626	.047	.155	.184	.122	.369	.110	.010
Ratio of the peduncle weight to the Bunch shoulder weight	-.445	.251	.699	.052	-.047	.035	.172	.054	.244	.020
Fresh weight of bunch shoulder weight	.417	.077	-.172	-.742	.069	-.051	-.137	.301	.222	-.036
Dry weight of bunch shoulder weight	.341	.169	-.124	-.747	.084	-.071	-.276	.293	.209	-.009
Fresh to dry weight ratio of bunch shoulder	.511	-.371	-.198	.006	.026	.113	.516	-.023	.010	-.096
Bunch number of bushes	-.185	.372	-.400	.052	-.166	-.110	.532	.094	.213	-.050
Bunch length	.384	.582	-.227	.291	.322	-.170	.122	.209	-.269	.062
Bunch width	.389	.738	-.176	-.137	-.262	.019	.041	-.290	-.021	-.108
Length to width ratio of bunch	.011	-.103	-.016	.441	.556	-.176	.079	.474	-.267	.164
Bunch tail length	.139	.244	-.029	.380	.370	-.277	-.097	-.006	.115	-.323
Berry weight	.886	-.177	.158	.125	-.105	.029	.044	-.005	-.149	.002
Berry length	.855	-.254	.062	.158	-.204	.116	.102	.179	.063	-.027
Berry width	.810	-.062	.258	.185	-.040	.228	.043	.148	-.086	-.160
Length to width of berry	.162	.232	.154	.105	-.090	-.286	.081	-.178	-345	.476
Berry diameter	-.002	-.121	.068	-.022	.056	.025	.099	.260	-.080	.882
Berry tail length	.626	.247	-.134	-.057	-.058	-.080	.090	.013	-.127	.407
Berry tail weight	.312	.039	-.198	.178	-.076	-.066	-.024	.536	.075	-.055
Seed weight	.130	-.159	-.119	-.262	-.071	.085	-.092	.519	-.161	.439
Seed length	.073	.119	.000	-.142	.147	-.099	-.017	.541	-.285	.590
Brix%	-.002	-.117	.011	-.511	.286	.054	-.076	-.477	.269	-.056

F: Factor.

Factor analysis

Factor analysis was performed to determine the variations of each trait with each factor and ultimately the total (factor-extracted) and specific (residual) variances (Tables 6 and 7). The relative variance of each factor indicates the importance of that factor in explaining the total variance of the traits and is expressed as a percentage. In the factor analysis, a total of 10 independent and principal factors with eigenvalues greater than 1 were able to account for 78.37% of the total variance (Table 6). Table 8 presents the results of the factor analysis, indicating the placement of some important examined traits in different factors with their positive and negative factor loadings (due to the high volume of data, only significant traits with factor loadings are mentioned in the table). According to Tables 7 and 8, cultivars and genotypes were grouped in the first factor (PC1) for traits such as weight, width and diameter of berry and seed length, which accounted for 18.06% of the variance (Table 6). Therefore, this factor can be named the "berry factor." In the second factor (PC2), cultivars were grouped based on traits such as bunch weight, bunch shoulder weight, rachis weight, bunch length and bunch width, which accounted for 14.12% of the variance. This factor can be referred to as the "bunch size factor." The factors PC1 and PC2, where most fruit-related traits were placed, had the most significant role in differentiating cultivars and genotypes from each other, accounting for a total of 32.19% of the total variance (Table 6). Traits such as seed weight, pedicel weight, the ratio of peduncle weight to bunch shoulder weight and the ratio of bunch shoulder weight to bunch weight were placed in the third factor, accounting for 11.38% of the total variance. Traits such as petiole length, Length of teeth, bunch shoulder fresh weight, and bunch shoulder dry weight were placed in the fourth factor, explaining 7.70% of the variance (Table 6). The fifth factor included traits such as the bunch length-to-width ratio and stomata density in the field of view at 25 and 40, which accounted for 6.43% of the total variance (Table 6). In the sixth factor, the internode diameter and the ratio of rachis weight to peduncle weight justified 4.78% of the variance (Table 6). The seventh factor justified 4.43% of the variance and included traits such as the ratio of bunch shoulder fresh weight to bunch shoulder dry weight and the number of bunches per vine (Table 6). The eighth factor, with a variance of 4.29%, included the trait of tendril length (Table 6). The ninth factor accounted for 3.97% of the variance and consisted of the leaf length trait (Table 6). The tenth factor included the trait of seed length and accounted for 3.17% of the variance (Table 6). In a study on the genetic diversity of 20 grape cultivars, morphological traits were analyzed using factor analysis (Hashemzehi., 2010). The results showed that the first three factors accounted for 79.34% of the existing variations among the traits. The first factor explained 31.86% of the variance between traits and played a significant role in justifying variables such as seed length, seed weight, and kernel length. Also, Haddadinejad et al. (2013), for the initial screening, 698 grape genotypes were analyzed based on drought tolerance using factor analysis. In this analysis, seven primary and independent factors with eigenvalues greater than one were able to account for 78.96% of the total variance. Some of their findings were consistent with the results obtained from this study. In the comparison of this research with other similar researches, it was shown that the first factor and the second factor in most of the conducted researches were related to berry and bunch factors (Haddadinejad et al., 2013; Rasouli et al., 2015; Razi et al., 2021; Rasouli & Kalvandi, 2022; Kazemi et al., 2022). Rasouli et al. (2015) results showed that the factor analysis justified 74.22% of the total variance. The investigated factors such as bunch size, bunch density, skin thickness, shape, size, weight, length and width of the berry, seed length were place on first factor. The first factor includes 20.74% of the variance and the berry factor is placed in this first factor. The bunch size factor with 11.79% was also the second factor of this research (Rasouli et al., 2015). Also, Hashemzehi et al. (2010) studied diversity of grape cultivars and they reported factor analysis justified 79.34% of total variance. The results of first and second factors analysis of Hashemzehi et al. (2010) were in line with the results of this research in the berry and bunch factors. Furthermore, Rafiei et al. (2016) reported the percentage of variance showed that the first 5 factors were related to fruit and leaf traits and the first factor with 22.63% of the variance was related to the berry factor and the second factor with 14.71% of the variance was related to most of the bunch traits.

Cluster Analysis

The cluster analysis was performed based on all measured traits (Table 2) using the Ward method for grouping and comparing 84 grape cultivars and genotypes (Fig. 7). At 5 Euclidean distances the cultivars and genotypes were grouped into four main clusters, which include:

Group 1: This group included 30 cultivars and genotypes out of 84 investigated grapes cultivars and genotypes such as "Lal Khondab", "Lal Enaj", "Siah Enaj", "Asgari Anjudan", "Lorkosh Hazaveh", "Lal Derman", "Sahebi Derman", "Fakhri Anjudan", "Kerak Marzijaran", "Bidaneh Sefid Marzijaran", "Bidaneh Ghermeze Enaj", "Asgari Shahroudi Hazaveh", "Fakhri Aghbolagh", "Fakhri Khondab", "Bidaneh Sefid Enaj", "Sahebi Khondab", "Lal Aghbolagh", "Angore Sefideh Aghbolagh", "Sahebi Anjudan", "Sahebi Enaj", "Bidaneh Ghermeze Derman", "Lal Marzijaran", "Asgari Enaj", "Shirazi Enaj", "Bidaneh Sefid Derman", "Asgari Khondab", "Ghazvini Anjudan", "Yek bazre Marzijaran", "Shirazi Hazaveh" and "Shirazi Derman". These genotypes are characterized by medium budburst time, moderate plant growth vigour and moderate bunch weight. The fruits of this group had mostly low to moderately juicy, and the anthocyanin pigments in their flesh were generally absent. They had thin to medium skin thickness and the color of the berries is mostly yellow-green. The berry shape in this group is usually broad-ovate, and the berries are generally slightly firm to firm with medium to large size. The berry density in the bunch ranges from average to compact and the bunch size was mostly medium to large. Overall, these cultivars showed similarity in most of the measured traits, particularly fruit-related characteristics. The highest amount of brix with 26.96 % in "Bidaneh Ghermeze Derman" cultivar that was included in this group. The cultivars and genotypes of this group were geographically from the same place or close (Fig. 9).

Group 2: This group included 37 cultivars out of 84 investigated cultivars and genotypes, covering; "Kharvand Darman", "Mahdikhani Hazaveh", "Fakhri Darman", "Asgari Darman", "Yaghoti Marzijaran", "Khalili Anjudan", "Yaghoti Anjudan", "Halvaii Anjudan", "Shirazi Khondab", "Shirazi 2 Khondab", "Shirazi Marzijaran", "Bidaneh Sefid Anjudan", "Sahebi Marzijaran", "Kool Bache Anjudan", "Asgari Marzijaran", "Fakhri", "Asgari Enaj", "Siah Khondab", "Yaghoti Khondab", "Siah Marzijaran", "Asgari Gerd Enaj", "Siah Anjudan", "Yaghoti Aghbolagh", "Yaghoti Enaj", "Khalili Enaj", "Moa'melan Darman", "Khalili Marijaran", "Khalili Darman", "Asgari Bi Bazr Anjudan", "Khalilkhani Marzijaran", "Bidaneh Sefid Aghbolagh", "Bidaneh Ghermeze Aghbolagh", "Asgari Aghbolagh", "Khalili Aghbolagh", "Khalili Hazaveh", "Bidaneh Ghermeze Marzijaran", "Koole Aghbolagh" and "Shirazi Aghbolagh". These genotypes have a medium density of trichomes on the main leaf veins. In this group, there are cultivars ranging from very early to late maturity cultivars such as "Khalili Khani", "Yaghoti Marzijaran", "Bidane Sefid Anjudan", "Bidaneh Sefid" and "Bidaneh Ghermez Derman", "Asgari Aghbolagh" and "Asgari Khondab" and "Asgari Derman" have earlier leaves than the rest of the investigated cultivars. Most of the cultivars in this group had seeds and seed separation in this group ranges from difficult to relatively easy. The fruits in this group were usually slightly juicy. The flesh of these fruits usually lacks color and the skin thickness ranges from thin to medium with a seed color predominantly yellow-green. The shape of the fruit in this group was usually oval to round and the texture of the fruits is often slightly firm, with small to medium-sized seeds. The seed density in bunches and the bunch density and size in most cultivars of this group were medium. Most cultivars in this group had complete seeds.

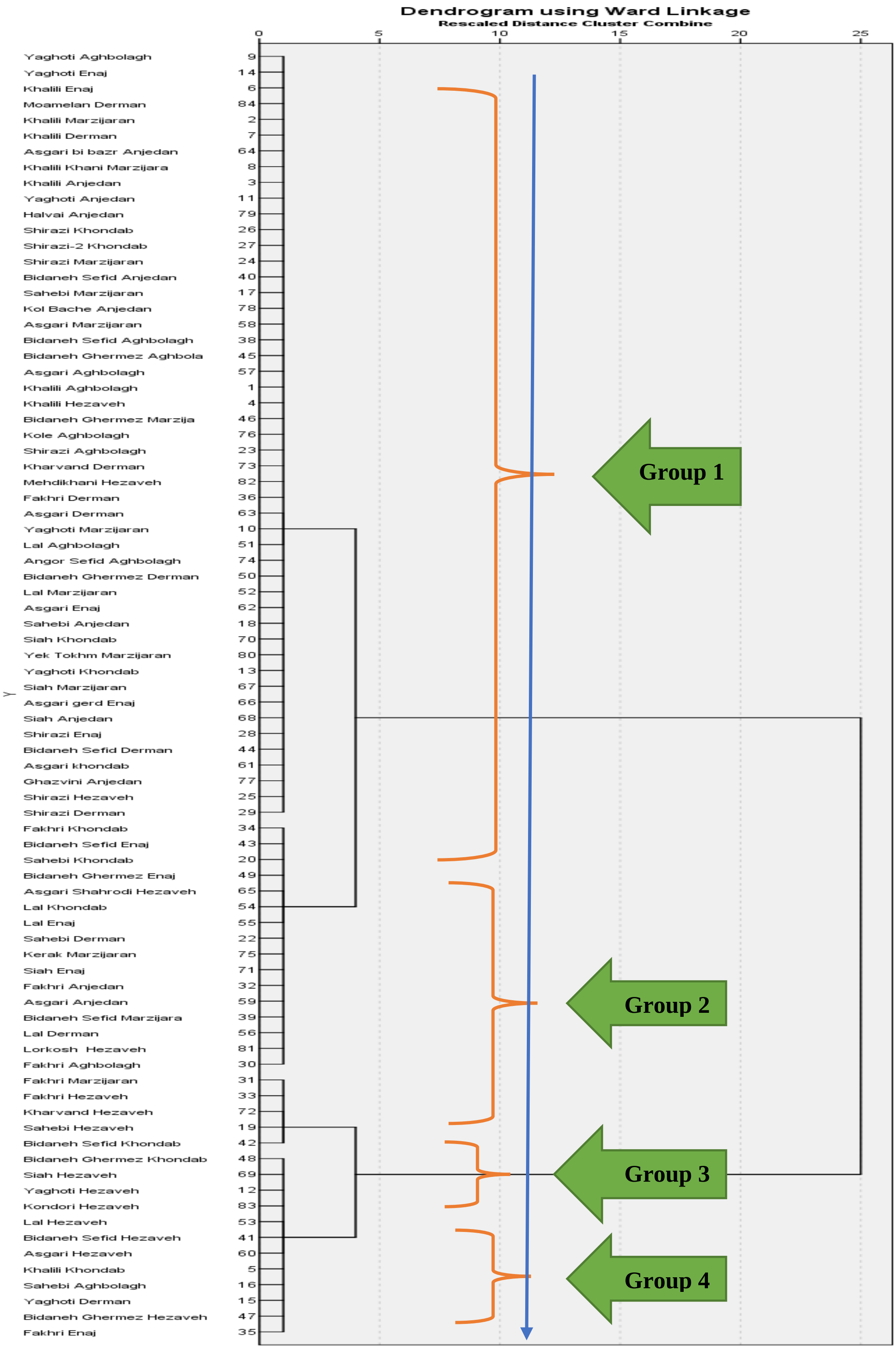

Fig. 7. Dendrogram showing relationship between 84 cultivars and genotypes of grapes, available in the vineyards of Markazi province located in central of Iran, based on studied traits using cluster analysis by Ward method.

Group 3: This group included 5 cultivars and genotypes out of 84 investigated cultivars, such as “Fakhri Marzijaran” and “Fakhri Hazaveh”, “Kharvand Hazaveh”, “Sahebi Hazaveh” and “Bidaneh Sefid Khondab”. The highest bunch weight (1000.71 g) was found in the “Sahabi Hazaveh” cultivar within this group. The “Kharvand Hazaveh” cultivar has a maximum width of the bunch with 126.64 mm that was placed in this group. Also, “Sahebi Hazaveh” has highest average bunch weight with 1000.71 g was included in this group. Among the differences that probably caused the “Bidaneh Sefid” cultivar and “Bidaneh Ghermeze”cultivar of Khondab region to be placed in two separate groups, but one after the other, the difference in Length of teeth, amount of sugar, larger leaf size of the “Bidaneh Sefid” cultivar, amount of anthocyanin in “Bidaneh Ghermeze” cultivar, time the later ripening of “Bidaneh Sefid”, slightly firmer berry in “Bidaneh Sefid” cultivar, average flesh anthocyanin “Bidaneh Ghermeze” cultivar and different peduncle separation of these two cultivars were the same. All genotypes in this group had late budburst and flowering times. The berry density in the bunch of these cultivars was compact to very compact and the bunch size was usually large to very large. The cultivars in this group were exhibited vigorous plant growth. The berry size ranges from small to very large and the berry firmness varies from slightly firm to firm. The berry shape in these cultivars ranges from rectangular to oval and broad-oval to round. The color of the berries was mostly yellow-green and the skin of these cultivars was thick.

Group 4: This group included 12 cultivars out of 84 investigated cultivars, such as “Bidaneh Ghermeze Khondab”, “Siah Khondab”, “Yaghoti Hazaveh”, “Lal Hazaveh”, “Bidaneh Sefid Hazaveh”, “Asgari Hazaveh”, “Khalili Khondab”, “Sahebi Aqbolagh”, “Yaghoti Derman”, “Bidaneh Ghermeze Hazaveh” and “Fakhri Enaj”. The cultivars “Kondori Hazaveh” with 6.99 g berry weight, “Asgari Hazaveh” with 81.20 bunches per vine, “Fakhri Enaj” with 310.75 mm bunch length were placed in this group (Fig. 9). Most of the cultivars in this group had higher bunch weight and length. They also had a high yield per unit area and larger leaves. Flowering in the cultivars of this group was early to moderate, and the leaf size was usually large. The berries in these cultivars were mostly soft. In this group, most of the cultivars had almost the same internode diameter, number of bunches in the plant was almost high and the length and width of the bunch were almost the same. Most cultivars of this group had seeds, round berry, medium to very large bunch size, medium to very compact bunch density, and slightly juicy berry. One important note that can be seen in these cluster analysis groups was the presence of seedless cultivars in the analysis groups, which was one of the reasons for this division, different recording locations with different altitudes, longitudes and latitudes, environmental effects regions, soil type and genetic potential were high among the cultivars and genotypes studied. The findings regarding the effect on some growth and fruit traits were consistent with the results reported by Zinanlou (1993), Alizadeh (2004), Nejatian (2006), Qobadi et al. (2007), and Rasouli et al. (2015) for cultivars from Kermanshah, West Azerbaijan, Qazvin, Isfahan, and Hamedan provinces in terms of various growth-related characteristics, bunch size and weight, berry density in the bunch, berry color, having seeds or being seedless, ripening time, consumption type and genetic relatedness. However, some cultivars in different geographical and soil conditions showed differences in plant growth vigour and sugar content percentage compared to the results of these researchers. In line with the cluster analysis results of this research, Rasouli et al. (2014) studied the morphological diversity of 32 grapes cultivars and genotypes in Hamedan province and reported the cluster analysis at 5 Euclidean distances has been divided cultivars into 7 groups and some cultivars were different from other cultivars in terms of late flowering, sugar percentage, freshness and shelf life. Also, Rafiei et al. (2015) on seeded and seedless cultivars in some regions of the Markazi central province, they concluded that in these cultivars, the groups were classified into two main groups, seeded and seedless, at 25 Euclidean distances. They reported, the samples that were placed in the group of quince cultivars had prominent characteristics such as smaller seeds or seed remains. Also, the size of the berry was smaller and the percentage of soluble solids was higher than the in characteristics of "Bidaneh" cultivars. There were 29 samples in this group, which included the same group. The grapes were "Asgari", "Yaghoti", "Bidaneh Sefid", and, "Khalili". From these researches, it can be concluded that the results of this research are consistent with the researches done on the cultivar of grapes and are in line with the examined cases of this experiment. In a study conducted by Zahedi et al. (2020) on the morphological and pomological characteristics of 55 grape cultivars, significant differences were observed among the studied cultivars for the measured traits. The fruit length ranged from 12.32 to 31.85 millimeters. Additionally, 10 different skin colors were observed, with light green (14 cultivars) and greenish-yellow (15 cultivars) being the predominant colors. Moreover, 20 cultivars initially formed seeds, while seeds were absent in 34 cultivars, and one cultivar had seedless berries. The dendrogram of cluster analysis based on the obtained data revealed three main clusters with several sub-clusters, that their results were somewhat consistent with the cluster analysis results of the present research.

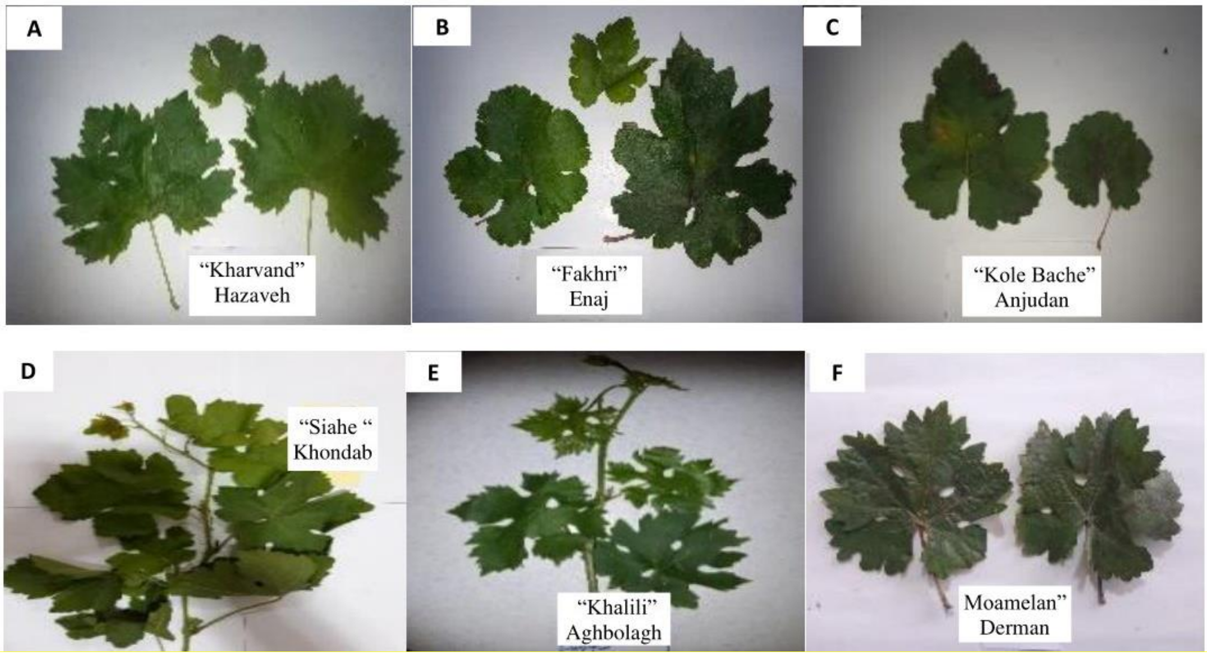

Fig. 8. The leaves of cultivars and genotypes available in vineyards of Markazi province located in central of Iran (A-"Kharvand" Hazaveh, B- "Fakhri", Enaj, C-"Kole Bache Anjudan", D-"Siahe Khondab", E-"Khalili Aghbolagh", F-"Moamelan Derman").

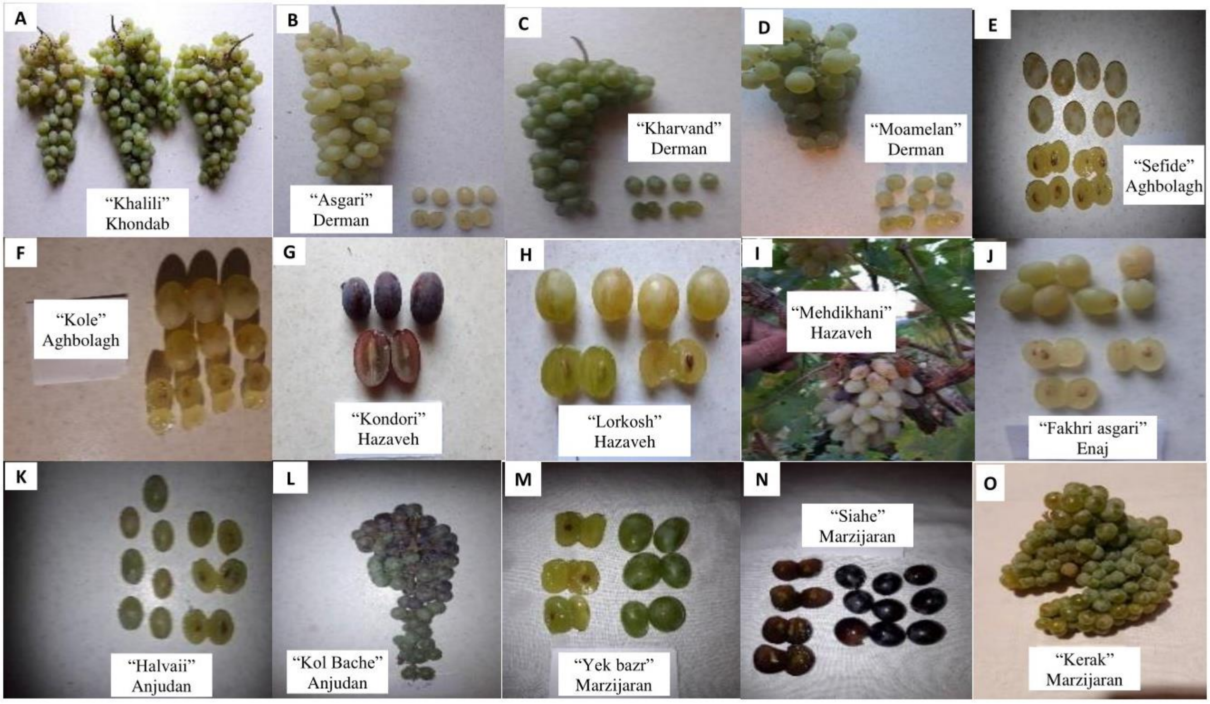

Fig. 9. The fruits of cultivars and genotypes available in vineyards of Markazi province located in central of Iran (A- "Khalili Khondab", B- "Asgari Derman", C- "Kharvand Derman", D- "Moamelan Derman", E- "Sefide Aghbolagh", F- "Kole" Aghbolagh, G- "Kondori" Hazaveh, H- "Lorkosh" Hazaveh, I- "Mehdikhani" Hazaveh, J- "Fakhri asgari" Enaj, K- "Halvaii" Anjudan L- "Kol Bache" Anjudan. M- "Yek bazr" Marzijaran, N- "Siahe" Marzijaran, O- "Kerak" Marzijaran.

CONCLUSION

The main objective of measuring these traits was to assess diversity and identify superior cultivars and genotypes for use in grape breeding programs. Based on the results, cultivars such as ("Yaghoti," Aghbolagh), ("Khalili," Hazaveh, Derman and Khondab), ("Khalilikhani" Marzijaran), ("Mehdikhani" Hazaveh) and ("Kharvand" Darman) exhibited lower density of stomata in the field (25 and 40), while they had higher density of trichome between the main veins and on the main veins. Most cultivars in the Hazaveh and Khondab regions had higher yield, bunch and bunch shoulder weight compared to other regions. The third and fourth groups, including "Khalili Khondab" and "Yaghoti," "Sahebi", "Fakhri", "Kharvand", "Kondori Hazaveh", and "Sahebi" Aghbolagh, were superior to other cultivars and genotypes in terms of yield, bunch length, bunch weight, late budbreak, late flowering, high sugar content, and fruit characteristics. Cultivars such as "Khalili," "Khalilikhani," "Yaghoti" Marzijaran, "Bidaneh Sefid Anjudan", "Bidaneh Sefid" and "Bidaneh Ghermeze" Darman, "Asgari Aghbolagh", "Asgari Khondab" and "Asgari Derman" had earlier budbreak compared to other cultivars and were susceptible to frost damage. The highest sugar content was found in the "Bidaneh Ghermeze" Darman cultivar, which could be attributed to cool night temperatures during the late ripening period in the Derman region. The highest bunch number was observed in the "Asgari Hazaveh" cultivar, which is extensively used for grape syrup production, properly pruned, and well-nourished, resulting in a high number of bunches. The highest bunch weight was found in the "Sahebi Hazaveh" cultivar, as the Hazaveh region followed proper pruning practices, provided timely and appropriate nutrition, and achieved successful stages of development. Most cultivars in this region had very high bunch weights, with "Asgari" being the dominant cultivar. The remaining cultivars were planted minimally in the surrounding vineyards.

Conflict of interest

The authors (S.M.M. Mirfatah, M. Rasouli, M. Gholami and A. Mirzakhani) declare that they have no competing interests.

Acknowledgments

Authors are thankful Malayer University and Markazi Agricultural and Natural Resources Research and Education Center (MANRREC), Arak. The present study was supported by the Ph.D. thesis entitled "Screening, effect of drought stress, rootstock and scion on some morphological and physiological characteristics (*Vitis vinifera* L.) In climatic conditions of Markazi province", which was funded by the Vice Chancellor for Research, Malayer University.

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