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Morphological diversity in different almond varieties based on DUS descriptor

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ABSTRACT

Almond (*Prunus dulcis* Mill.) is among the most popular nut trees worldwide. In the present study, 13 almond varieties grown at ICAR-Central Institute of Temperate Horticulture, Srinagar Kashmir, India were evaluated for different morphological characters. A total of 30 characteristics, mainly released by the PPV & FRA (Protection of Plant Varieties and Farmer's Rights Authority) DUS descriptor, were used to describe the tree, flowers, leaves, nuts, kernels for two consecutive years (2022 & 2023). The results displayed a high level of variability among all the selected varieties. The nut characteristics such as nut weight, shape, shell color intensity, softness of shell, and kernel weight, which determine the quality and marketability of almonds exhibited enormous variations. Moreover, the results suggest that the description of these varieties based on notes may be used as a reference for the protection of new varieties under PPV & FRA rules. The study is also useful for comparison against new candidate varieties.

Key words: *Prunus dulicus* Mill, DUS, morphology, PPV&FRA, variability.

INTRODUCTION

Almonds (*Prunus dulcis* Mill., synonym *Prunus amygdalus* Batsch) are important popular nuts, ranked second in global consumption after peanuts (Statista Nuts, 20). It belongs to the Rosaceae family, subfamily Prunoideae and genus *Prunus*. Almond is one of the treasurer perennial woody plants that were often seen as trees or as shrubs in wild genus. The western and central Asia is presumed to be the origin of almond (Kester and Gradziel, 10). The history and culture of almonds in Asia dates back about ten thousand years BC. Some botanists consider that almond is Iranian native as more than 20 species of wild almonds are available in Iran (Rahemi, 18). Since ancient times, almonds are consumed as snack due to their rich protein and mostly unsaturated fat contents and without cholesterol having maximum dietary fiber and minerals (Barreca *et al*., 2). Almond is one of the vital and desirable tree crops to flower in early February in temperate regions (Kester and Gradziel, 11). It is a diploid (2*n* = 16) species with bisexual flowers in color pink to white. The nut shape is round to ovate. Almonds are grown in over 50 countries and United States of America, Spain, Iran, Italy, Turkey, Tunisia, Morocco, Syria, Greece, and Australia are the ten major producers of almonds (Barreca *et al*., 2). The modern almond industry needs special commercial cultivars with high quality and clear identification of traits both qualitatively and quantitatively. Genetic and phenotypic diversity is necessary; especially when rich genetic resources in local almond varieties are available and these resources must be investigated for use in almond breeding programs (Esgandaripirmorad *et al*., 7). The marketed product is the edible seed (the kernel), which is used for direct consumption and baked products and confections (Kester *et al*.,12). The cultivated almond was probably domesticated during the 3rd millennium BC. Two ecotypes have evolved: Mediterranean and Central Asian (Ma *et al*., 17). According to Kester *et al*. (12), many related wild almond species are found growing in the mountains and deserts of Central Asia. These native almond species are utilized for oil extraction, soil erosion control, reforestation, rootstocks and as a source of novel genes in breeding programs. Precise characterization of almond seedling cultivars and rootstocks is essential for the identification of clones that will guarantee uniformity of commercial orchards. The characterization of germplasm is basic requirement for any crop improvement program as it provides necessary information on the valuable traits/ genes. The evaluation of morphological traits is also essential to document and study the genetic diversity within the accessions/genotypes.

The commercial cultivation of almonds on marginal lands under non-irrigated conditions could not spread much on account of intrinsic problems like spring frosts and hail storms during the blossoming time. However, still majority of the almond production comes from seedling trees of primitive populations

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grown under rain fed conditions of Kashmir valley with different morphological and biological characteristics. To select varieties among these diverse types, the characterization and evaluation of these genotypes is indispensable. Most of the commercial almond cultivars grown throughout the world have been selected by chance from the diverse gene pool of almond seedlings (Kester *et al*., 12). Therefore, the present study was undertaken to assess the level of uniformity of characteristics and stability of expression of almond. The present study is aimed to evaluate the agro-morphological attributes of 13 almond varieties as per the DUS descriptor. This data will be useful for future commercial and breeding programs along with their protection through Protection of Plant Varieties and Farmer's Rights Authority (PPV&FRA).

MATERIALS AND METHODS

In the present study, the morphological diversity of 13 almond verities *viz*., Merced, IXL, Non-Pariel, Makhdoom, California Paper Shell, Waris, Tady Non-Pariel, Primoskij, Pranyaj, Ferralise, Farregnesse, and Drake were evaluated, at ICAR-Central Institute of Temperate Horticulture (CITH, 33.98° N, 74.79° E), Srinagar, Jammu & Kashmir, India. The study was performed in a randomized block design with three replications and the spacing adopted was 3.0 m ×3.0 m. The study was conducted under temperate climatic conditions. The data regarding the different parameters for different years is given in Tables (1 & 2). Morphological characterization of different varieties for diversity analysis at the phenotypic level was carried out as per the UPOV (International Union for Protection of New Varieties of Plants) and PPV&FRA guidelines published in 2011 and 2012, respectively and recently modified in 2019. On an average, the age of trees range from 18-20 years and the data was observed for two consecutive years (2022 & 2023). Thirty morphological characters including tree characteristics like vigour, habit and ramification (branching method) were made during dormancy. Tree vigour was checked from November to December. It was characterized as weak, medium, strong, and very strong, and was rated as per descriptor as, Weak = 3, Intermediate = 5, and Strong = 7. Similarly, during November and December months, tree growth habit was measured in terms of the extent of the canopy in two different directions i.e., East-West and North-South, and was graded accordingly as Upright =1, Upright to spreading =2, Spreading =3 and Drooping =4. The method of branching (ramification) from sparse to dense was graded according to the classification of the descriptor mentioned as sparse = 3, intermediate = 5 and dense = 7. The hull which covers the nut splits along the suture in August/September in the Kashmir valley. The harvested date from the reference date for harvest (RDH = 1st August) was recorded when 50% splitting of the hull. The nuts harvested before the 10th of August were considered very early. Accordingly, the harvest dates between 11-20th August, 21-30th August, 31st August-9th September, and over 10th September were considered early, mid, late, and very late respectively. The notes for these descriptors are: (a) before 10th Aug. (Very Early) = 1, (b) 11th to 20th Aug. (Early) = 3, (c) 21st to 30th Aug. (Medium) =5, (d) 31st Aug. to 9th Sept. (Late) =7 and (e) after 10th Sept. (Very Late) =9. Leaf characteristics were recorded from fully developed leaves of the middle third of the current season's shoot. Stone shape was assigned according to DUS guidelines. Further, stone and kernel weight were measured with the help of a digital balance and expressed in grams (g).

RESULTS AND DISCUSSION

A considerable variation among 13 varieties of almond for all qualitative morphological characters related to vegetative and reproductive stages (growth

Table 1. Meteorological data at ICAR-Central Institute of Temperate Horticulture, Srinagar campus during the year 2022.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max. Temp.	6.5	10.3	19.7	23.5	25.4	26.8	28.5	28.0	27.7	21.7	13.1	9.4
Min. Temp.	-0.3	0.3	7.8	10.8	13.6	15.6	20.6	18.9	15.7	7.6	3.2	-1.7
Rainfall	99.8	101.3	20.1	35.0	48.5	107.9	123.7	36.8	36.6	24.1	73.4	7.1

Table 2. Meteorological data at ICAR-Central Institute of Temperate Horticulture, Srinagar campus during the year 2023.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max. Temp.	6.1	11.9	17.4	18.6	21.3	27.9	27.4	30.0	28.4	20.9	13.9	8.9
Min. Temp.	-1.1	2.4	6.3	7.8	10.8	16.7	18.7	18.9	15.9	8.3	3.0	-1.8
Rainfall	90.3	40.2	27.4	146.4	85.6	62.6	187.4	8.7	27.0	42.7	36.0	17.6

habit, flower, leaf, and nut characteristics) was noticed. Plant growth habit refers to the overall shape of a plant, and it describes several components such as stem length and development, branching pattern, and texture. In the present study, descriptive data of various tree characters such as tree vigour, growth habit, and ramification are presented in Table 3 and Fig. 1, 2a, & 2b.

The results showed that most of the varieties were either intermediate (9 varieties), followed by strong (4 varieties) and weak (1 varieties), respectively with respect to tree vigour (Table 3). Strong tree vigour was found in California Paper Shell, Waris and Pranyaj; whereas, weak tree vigour was found in Drake. However, rest of the varieties revealed intermediate tree vigour. The upright tree habit was observed in many varieties (IXL, Shalimar, Non-Pariel, California Paper Shell, Farregnesse and Drake) than drooping one (Primorskij). Likewise, the spreading tree habit was observed in Merced, Makhdoom, Waris, Taddy Non-Pariel, Pranyaj and Ferralise. Further, out of 13 studied varieties, six each were upright and spreading; whereas only one variety showed drooping growth habit behavior. Intermediate ramification was observed in Drake, Farregnesse, Shalimar, Makhdoom, Waris, Taddy Non Pariel, and Ferralise; but it was sparse in California Paper Shell. However, Merced, IXL, Non- Pariel and Primorskij, and Pranyaj exhibited dense ramification. The blooming time is an important feature in *Prunus* species. It may change every year based on the weather conditions before and during bloom. Blooming time is considered a quantitative trait and it is reported that transmission

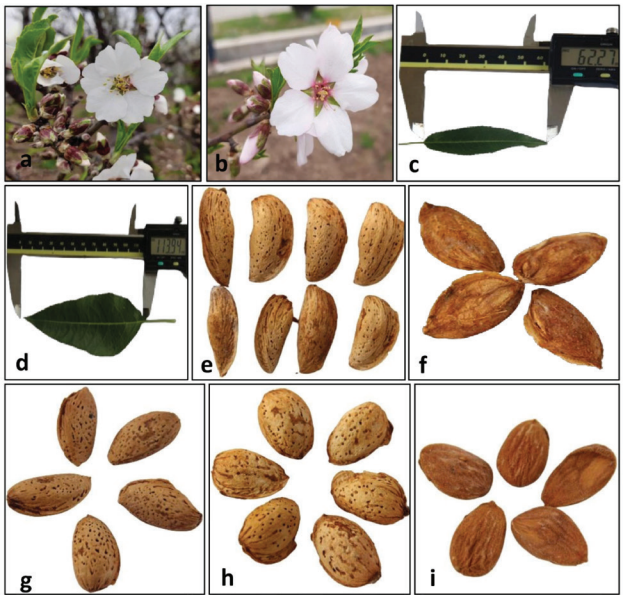

Fig. 1. Morphological variability in almond varieties. (a) Light color flower in IXL. (b) Pink color flower in Merced. (c) Short Leaf size Merced. (d) Long Leaf size Makhdoom. (e) Elongated shape of nut in California Paper Shell. (f) Cordate shape of nut in non-Pariel. (g) Oblong shape of nut in Ferralise. (h) Ovate shape of nut in Drake. (i) Cordate shape of kernel in Farregnesse

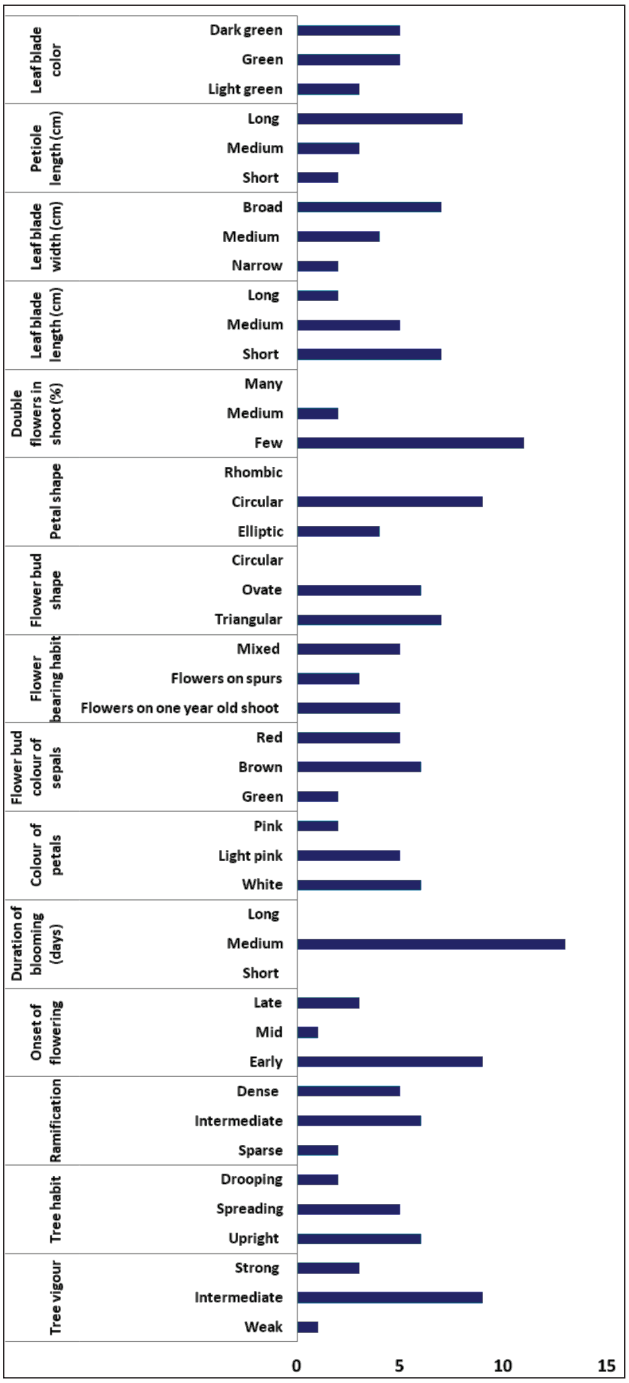

Fig. 2a. Frequency distribution of 13 almond varieties based on 30 morphological characters.

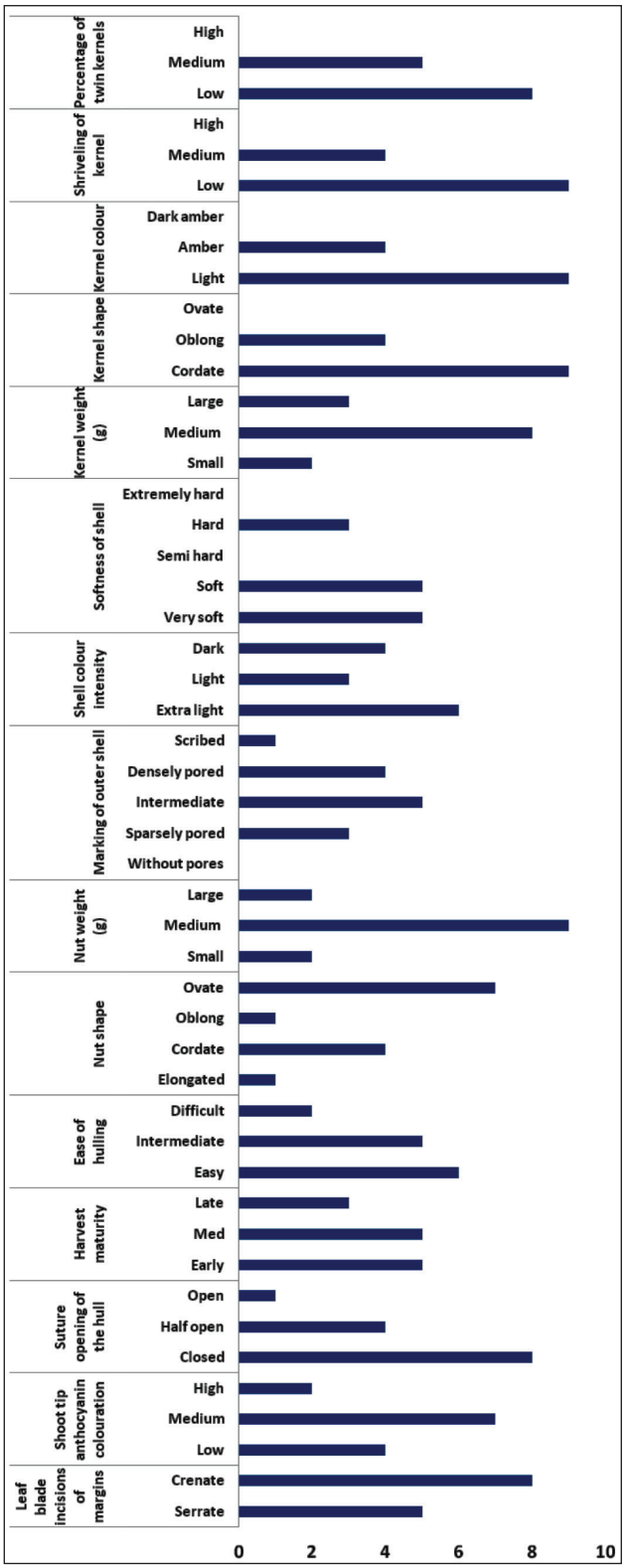

Fig. 2b. Frequency distribution of 13 almond varieties based on 30 morphological characters.

of blooming time is inherited quantitatively (Kester and Gradziel, 18). In the present study, blooming time varied in almond varieties. Early season flowering was noticed in IXL, Shalimar, Non-Pariel, Makhdoom, California Paper Shell, Waris, Primorskij, Pranyaj, and Drake. Similarly, Merced showed mid-season flowering while late season flowering was observed in Taddy Non-Pariel, Ferralise, and Farregnesse. Flowers on one-year old shoot were numbered in Shalimar, Makhdoom, Taddy Non-Pariel, Ferralise, and Farregnesse. While Merced, IXL, and Non-Pariel varieties have flowers only on spurs. Mixed flowering was found in California Paper Shell, Waris, Primorskij, Pranyaj, and Drake. According to Gradziel and Lampinen (9), by targeted genetic selections or cultural management, the spur development and spur-renewal along with trees size and architecture are promising targets for almond improvement.

The color of petals also plays a crucial role in attracting the pollinators. Pink petals were reported in Merced, and Makhdoom; whereas Shalimar, Non-Pariel, Pranyaj, Ferralise, and Drake showed light pink petals. The rest of varieties (IXL, California Paper Shell, Waris, Taddy Non-Pariel, Primorskij, and Farregnesse) have light colored petals. Almond is a self-incompatible crop that requires cross-pollination for nut set. The flower petals of many angiosperms may favour pollinator's attraction by visual, tactile and olfactory clues (Whitney *et al*., 21). Further, the colour of sepals varied from green, brown to red. Brown coloured sepals were noticed in most of the varieties such as Merced, Non-Pariel, Waris, Taddy Non-Pariel, Ferralise, Farregnesse, and Drake. Red colour sepals were seen in Shalimar, Makhdoom, California Paper Shell, and Primorskij. In the same way, green-coloured sepals were observed only in two varieties namely IXL, and Pranyaj. Among these varieties, majority (Merced, IXL, Non- Pariel, Makhdoom, California Paper Shell, Waris, Primorskij, Farregnesse, and Drake) have rhombic petal shape and others (Shalimar, Taddy Non-Pariel, Pranyaj, and Ferralise) depicted circular petal shape. Another character presence of double flowers in shoots was observed in these almond varieties. Merced, IXL, Shalimar, Non- Pariel, California Paper Shell, Waris, Taddy Non-Pariel, Primorskij, Pranyaj, Farregnesse, and Drake depicted less than 25% of such flowers. However, 25-50% double flowers were observed in Makhdoom, and Ferralise.

The high level of variation was seen in leaf characteristics among the presently studied almond varieties. Short leaf blade length (<8 cm) was recorded in Merced, IXL, Non- Pariel, California Paper Shell, Waris, Taddy Non-Pariel, and Drake. It was medium (8-10 cm) in Shalimar, Primorskij, Pranyaj, Ferralise, and Farregnesse. Long leaf blade (>10 cm) was found

Table 3. Characterization of almond varieties based on DUS descriptors.

Character / Variety	Tree vigour	Tree habit	Ramification	Onset of flowering	Duration of blooming (days)	Colour of petals	Flower bud colour of sepals	Flower bearing habit	Flower bud shape	Petal shape	Double flowers in shoot (%)	Leaf blade length (cm)	Leaf blade width (cm)	Petiole length (cm)	Leaf blade colour	Leaf blade incisions of margins	Shoot tip anthocyanin colouration	Suture opening of the hull	Harvest maturity	Ease of hulling	Nut shape	Nut weight (g)	Marking of outer shell	Shell colour intensity	Softness of shell	Kernel weight (g)	Kernel shape	Kernel colour	Shrivelling of kernel	Percentage of twin kernels
Merced	5	5	7	5	5	3	5	5	1	5	1	3	3	3	7	5	5	1	5	5	7	5	7	3	3	5	5	3	3	3
IXL	5	3	7	3	5	1	3	5	1	5	1	3	5	3	7	3	3	5	5	5	7	5	7	7	1	5	3	3	5	1
Shalimar	5	3	5	3	5	2	7	3	1	3	1	5	7	7	7	3	5	1	3	3	3	3	5	5	3	5	3	3	3	1
Non-Pariel	5	3	7	3	5	2	5	5	3	5	1	3	5	5	5	5	5	1	3	3	3	5	3	5	3	5	3	3	3	1
Makhdoom	5	5	5	3	5	3	7	3	3	5	2	7	7	7	7	3	7	1	3	3	7	5	5	7	3	7	3	3	3	3
Calforina Paper Shell	7	3	3	3	5	1	7	7	1	5	1	3	3	5	3	5	3	1	3	3	1	7	5	3	1	5	3	5	3	1
Waris	7	5	5	3	5	1	5	7	3	5	1	3	5	7	3	5	3	1	5	5	7	5	5	5	1	7	5	3	3	1
Tady Non-Pariel	5	5	5	7	5	1	5	3	1	3	1	3	5	7	5	5	5	3	7	3	7	3	7	5	1	3	5	5	3	1
Primoskij	5	7	7	3	5	1	7	7	3	5	1	5	7	7	7	5	5	1	3	3	3	5	7	3	3	5	3	5	5	2
Pranyaj	7	5	7	3	5	2	3	7	3	3	1	5	7	7	5	3	5	3	5	5	7	7	9	5	1	7	3	3	5	2
Ferralise	5	5	5	7	5	2	5	3	1	3	2	5	7	7	5	5	3	1	7	5	5	5	3	7	7	3	3	3	5	1
Farregnesse	5	3	5	7	5	1	5	3	1	5	1	5	7	7	3	3	5	3	5	7	3	5	3	7	7	5	3	3	3	1
Drake	3	3	3	3	5	2	5	7	3	5	1	3	7	5	5	5	7	3	7	7	7	5	5	5	7	5	5	5	3	3

in Makhdoom only. On the other hand, narrow leaf blade (< 2 cm) was observed in Merced, and California Paper Shell. Others, such as IXL, Non- Pariel, Waris, and Taddy Non-Pariel have medium leaf blade (2-2.5 cm). The broad leaf blade (>2.5 cm) was seen in Shalimar, Makhdoom, Primorskij, Pranyaj, Ferralise, Farregnesse, and Drake. The variations in leaf blade are in accordance with Chalak *et al*. (5). According to Bayazit (3) the leaf length values varied between 1.57-3.36 cm selected wild almond types in Nevsehir Goreme. Similarly, Baninasab and Rahemi (1), found the leaf lengths of three wild almonds (*P*. *orientalis*, *P*. *scoparia*, and *P*. *webbii*) as 2.76, 3.28 and 3.41cm respectively. Hence, the values of leaf length obtained at present are similar to the results of previous researchers. The petiole length was recorded short (<1.5cm) in Merced, and IXL. Whereas, it was medium (1.5 -2 cm) in Non-Pariel, California Paper Shell, and Drake. However, Shalimar, Makhdoom, Waris, Taddy Non-Pariel, Primorskij, Pranyaj, Ferralise, and Farregnesse revealed long petiole length (>2 cm). Bayazit (3) observed petiole length as 0.51-0.57 cm in almonds. The results obtained in the present study are compatible with previous studies. The leaf color observed presently in 13 varieties of almond showed diversity as light green (California Paper Shell, Waris, and Farregnesse), green (Non-Pariel, Taddy Non-Pariel, Pranyaj, Ferralise, and Drake) and dark green (Merced, IXL, Shalimar, Makhdoom, and Primorskij) type of leaves. A study previously carried from the Ayranci region reported green and gray-green leaf color in different varieties of almond (Bayazit, 3). The variability in character leaf blade incisions of margins ranged from serrate to crenate. Varieties such as IXL, Shalimar, Makhdoom, Pranyaj, and Farregnesse bear serrate type of incisions of margins, whereas Merced, Non-Pariel, California Paper Shell, Waris, Taddy-Non Pariel, Primorskij, Ferralise, and Drake exhibited crenate type of margins. The shoot tip anthocyanin coloration was lower in IXL, California Paper Shell, Waris, and Ferralise; while it was medium in Merced, Shalimar, Non- Pariel, Taddy Non-Pariel, Primorskij, Pranyaj, and Farregnesse. Makhdoom, and Drake showed high shoot tip anthocyanin coloration.

At present suture opening of the hull was observed to be closed in Merced, Shalimar, Non-Pariel, Makhdoom, California Paper Shell, Waris, Primorskij, and Ferralise. It was half open in Taddy Non-Pariel, Pranyaj, Farregnesse, and Drake. However, in IXL, it was completely open. The fruit maturity has been divided into two categories, *viz*. physiological maturity and harvest maturity. Physiological maturity is the stage when a fruit is capable of further development or ripening when it is harvested, i.e. ready for eating or processing. Harvest maturity refers to the stage of development when plant and plant parts possess the prerequisites for use by consumers for a particular purpose, i.e. ready for harvest. Determination of maturity indices helps us to ensure sensory quality like flavor, colour, aroma, and texture as well as nutritional quality to ensure an adequate shelf life. Shalimar, Non-Pariel, Makhdoom, California Paper Shell, and Primorskij showed early maturity. Merced, IXL, Waris, Pranyaj, and Farregnesse revealed mid harvesting; whereas rest of the varieties exhibited late harvesting. The ease of hulling is an important characteristic for almonds. It was easy in Shalimar, Non-Pariel, Makhdoom, California Paper Shell, Taddy Non-Pariel, and Primorskij. Hulling was intermediate in Merced, IXL, Waris, and Pranyaj but difficult in Farregnesse, and Drake.

The shape and size of fruit are significant physical attributes. They are used as an indicator for marketing quality of the agricultural products and for identification of plant cultivars/varieties. The elongated nut shape was observed in California Paper Shell and oblong in Ferralise. Some varieties (Shalimar, Non-Pariel, Primorskij, and Farregnesse) depicted cordate nuts; whereas Merced, IXL, Makhdoom, Waris, Taddy Non-Pariel, Pranyaj, and Drake showed ovate nuts. The nut weight, another important feature of almond was reported to be lesser in Shalimar and Taddy Non-Pariel; while it was medium in Merced, IXL, Non-Pariel, Makhdoom, Waris, Primorskij, Ferralise, Farregnesse, and Drake. The highest nut weight was observed in California Paper Shell and Pranyaj. Sakar *et al*. (19) reported the range of 2.72-4.57 g for nut weight in five almond cultivars from northern Morocco. The character on marking of outer shell for the presence of pores varied in all the presently studied varieties. Most of the varieties (Shalimar, Makhdoom, California Paper Shell, Waris, and Drake) were observed having intermediate pores. However, Merced, IXL, Taddy Non-Pariel, and Primorskij have densely pore on their outer shell. The nuts of Pranyaj were scribed, but sparsely pored in Non-Pariel, Ferralise, and Farregnesse. Further, no almond nut was observed without pores. These results are in agreement with earlier one's (Esfahlan *et al*., 6). The shell colour intensity changed from extra light to dark among different nuts of presently studied almonds. Merced, California Paper Shell, and Primorskij nutshells were extra light in colour; while Shalimar, Non-Pariel, Waris, Taddy Non-Pariel, Pranyaj, and Drake displayed light shell colour. On the other hand, IXL, Makhdoom, Ferralise, and Farregnesse showed dark colored shells. One of the most important goals in almond breeding programs is shell softness. In the presently studied almonds, very soft shell was present in IXL, California Paper Shell, Waris, Taddy Non-Pariel, and Pranyaj. However, it was soft in Merced, Shalimar, Non-Pariel, Makhdoom, and Primorskij. The hard shell was found in Ferralise, Farregnesse, and Drake. As per the literature, the resistance to pests and diseases is higher in hard-shell genotypes than in soft-shell genotypes (Gradziel and Martinez-Gomez, 8; Khadivi-Khub and Etemadi-Khah, 14; Ledbetter and Shonnard, 16). Therefore, the type of genotype used has a considerable effect on the breeding programs. Furthermore, in the case of soft-shell genotypes, identification of individuals that are resistant to fungi and insects is a priority; while in the case of semi-soft-shell genotypes, breeders seek to select genotypes having an acceptable shelling (Khadivi *et al*., 13).

The almond kernel is an edible part of the nut with a high nutritional value. These contain high level of oil, rich in mono saturated fatty acids, mainly oleic acid. Kernel weight is one of the vital characters of almond that varies among different genotypes. In this study, significant differences were noted in kernel weight. The small kernels (weight >1 g) were recorded in Taddy Non-Pariel and Ferralise. The medium (1-2 g). Kernels were noticed in Merced, IXL, Shalimar, Non-Pariel, California Paper Shell, Primorskij, Farregnesse, and Drake. However, the large (<2 g) kernels were observed in Makhdoom,Waris, and Pranyaj. Sakar *et al*. (19) reported the kernel weight in five almond cultivars from northern Morocco to be 0.82-1.12 g. It has been observed that kernel size is directly related to kernel weight. Large kernels increase the marketable value of almond as they meet the standards of quality required by the market. Thus, identifying the characters that improve the kernel size is imperative. Additionally, the kernel shape displayed variations from cordate (IXL, Shalimar, Non- Pariel, Makhdoom, California Paper Shell, Primorskij, Pranyaj, Ferralise, and Farregnesse) to oblong (Merced, Waris, Taddy Non Pariel, Drake). At present, the kernel color ranged from light (9 varieties) to amber (4 varieties) (Table 3). The light kernel color is preferred over dark one. It has also been reported that a greater pubescence is associated with darker kernel color

and is less desirable for nuts to be consumed as raw (Kodad *et al*., 15). The data on kernel shriveling was recorded for all the 13 varieties. The results revealed low kernel shriveling in Merced, Shalimar, Non- Pariel, Makhdoom, California Paper Shell, Waris, Taddy Non-Pariel, Farregnesse, and Drake; but medium in IXL, Primorskij, Pranyaj, and Ferralise.

The percentage of twin kernel changed from low to high. The varieties IXL, Shalimar, Non-Pariel, California Paper Shell, Waris, Taddy Non-Pariel, Ferralise, and Farregnesse have low double kernel percentage. Primorskij and Pranyaj have medium double kernel percentage but double kernel percentage was higher in Merced, Makhdoom, and Drake. Beigi and Khadivi (4) recorded a range of 0.00% -90.00% with a mean of 13.18% double kernel percentage in almond from Iran. However, according to Kodad *et al*. (15), double kernel is a negative phenomenon that causes kernel distortion and decreases its marketable value. Furthermore, the percentage of double kernel has a noteworthy consequence on crop quality and marketing (Kester and Gradziel, 12). The low temperature in the pre-flowering phase significantly influences double kernel formation in addition to other environmental conditions (Kester and Gradziel, 10,11). This phenomenon can be reduced by application of proper plant nutrition and selection of proper genotypes.

In this study, the knowledge of morphology, floral biology, leaf properties, fruit and nut attributes of the almond varieties could be useful to select the appropriate varieties to be grown under different climatic conditions or used as parents in future breeding programs.

AUTHORS' CONTRIBUTION

Conceptualization of research (JIM); Designing of the experiments (AHL, SMJ); Contribution of experimental materials (JIM, WHR, MKV, OCS); Execution of field/lab experiments and data collection (AHL, SMJ, SY); Analysis of data and interpretation (AHL, SMJ, SY, MI, VD, SUN, GM); Preparation of the manuscript (AHL, SMJ).

DECLARATION

The authors declare no conflict of interest.

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REFERENCES

1. Baninasab, B. and Rahemi, M. 2006. Evaluation of three wild species of almond on the basis of their morphological characters. *J. Cent. Eur. Agric*. **7**: 619-26.

2. Barreca, D., Nabavi, S.M., Sureda, A., Rasekhian, M., Raciti, R., Silva, A.S., Annunziata, G., Arnone, A., Tenore, G.C., Süntar, I. and Mandalari, G. 2020. Almonds (*Prunus dulcis* Mill. D. A. Webb): A source of nutrients and health-promoting compounds. *Nutrients* **12**: 672.

3. Bayazit, S. 2007. Phenological, morphological, pomological and molecular characteristics of the wild almond genotypes collected from different ecotypes of Turkey. Ph.D. Thesis. Cukurova Universitesi Fen Bilimleri Enst. Adana. (In Turkish).

4. Beigi, F. and Khadivi, A. 2023. Selection of superior late-blooming almond (*Prunus dulcis* [Mill.] D.A. Webb) genotypes using morphological characterizations. *Food Sci. Nutr*. **44**: 857.

5. Chalak, L., Chehade, A. and Kadri, A. 2007. Morphological characterization of cultivated almonds in Lebanon. *Fruits.* **62**: 177-186.

6. Esfahlan, A.J., Esfahlan, R.J., Jamei, R. and Esfahlan, A.J. 2012. Morphology and physicochemical properties of 40 genotypes of almond (*Amygdalus communis* L.) fruits. *Euro. J. Exp. Biol*. **2**: 2456-64.

7. Esgandaripirmorad, F., Karcı, H., Paizila, A., Topçu, H. and Kafkas, S. 2022. Molecular characterization of almond cultivars using simple sequence repeat markers. *Erwerbs-Obstbau* **64:** 463-74.

8. Gradziel, T.M. and Martinez-Gomez, P. 2002. Shell seal breakdown in almond is associated with the site of secondary ovule abortion. *J. Am. Soc. Hortic. Sci.* **127**: 69-74.

9. Gradziel, T. and Lampinen, B. 2011. Defining the limits of almond productivity to facilitate marker assisted selection and orchard management. *Acta Hortic*. **912**: 47-52.

10. Kester, D.E. and Gradziel, M. 1996a. Almonds. *In*: Fruit Breeding, Janick, J., Moore, J.N. (eds.), Vol. III. J. Wiley and Son, Inc. New York, USA, p. 1-97.

11. Kester, D.E. and Gradziel, T.M. 1996b. Almonds. *In*: Janick, J., Moore, J.N. (eds.).1996. Fruit breeding, Vol III: Nuts. John Wiley and Sons, New York, p1-96.

12. Kester, D.E., Gradziel, T.M. and Grasselly, C. 1990. Almond. *In*: Moore, J.N. and JR Jr Ballington (eds). Genetic resources of temperature fruit and nut crops. Institute of Horticulture Sciences, Wageningin. The Netherlands, p701-758.

13. Khadivi, A., Goodarzi, S. and Sarkhosh, A. 2019. Identification of late-blooming almond (*Prunus dulcis* L.) genotypes with high kernel quality. *Euphytica*. **215**: 1-12.

14. Khadivi-Khub, A. and Etemadi-Khah, A. 2015. Phenotypic diversity and relationships between morphological traits in selected almond (*Prunus amygdalus*) germplasm. *Agrofor. Syst*. **89**: 205–16.

15. Kodad, O., Alonso, J.M., Sanchez, A., Oliveira, M.M. and Company, R.S.I. 2008. Evaluation of genetic diversity of S alleles in an almond germplasm bank. *J. Hortic. Sci. Biotech.* **83**: 603-05.

16. Ledbetter, C.A. and Shonnard, C.B. 1992. Evaluation of selected almond (*Prunus dulcis* (Miller) D.A. Webb) germplasm for several shell and kernel characteristics. *Fruit Var. J*. **46**: 79–82.

17. Ma, R.C., Yong, X., Yan, M., Hua, X., Yuan-Qing, J., Ming Qing, C., Chun-Hui, G., Xue-Shi, H., Yo-Xiang, L., Jian-Ting, L. and Tian Xi, Z. 2003. Molecular analysis of almond germplasm in China. *Options Mediterr*. **63**: 281-90.

18. Rahemi, A. 2010. Investigation of the genetic diversity, *S*-alleles and nut characteristics in some wild almond species native to Iran. Ph. D. Thesis, Islamic Azad University, Science and Research Branch, Tehran, Iran.

19. Sakar, E.H., Yamani, M.E. and Rharrabti, Y. 2020. Fruit gravimetrical traits in almond [*Prunusdulcis* (Mill.) D.A.Webb]: Combined effects of genetic control and environmental drivers. *Erwerbs-Obstbau* **62**: 37–46.

20. Statista Nuts. 2023. https://www.statista.com/statistics/1030815/tree-nut-global consumption-by type/

21. Whitney, H.M., Bennett, K.M.V., Dorling, M., Sandbach, L., Prince, D., Chittka, L. and Glover, B.J. 2011. Review: Part of a special issue on sexual plant reproduction. Why do so many petalshave conical epidermal cells? *Ann. Bot*. **108**: 609-16.

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