



RESEARCH ARTICLE

Phenotypic diversity of native melon cultivars in Sar-e Pol Province, Afghanistan based on morphological traits

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Abstract

Afghanistan is a significant source of melon landraces, known for its rich genetic diversity and a wide range of traditional, locally adapted varieties. The phenotypic and genotypic diversity in the country makes them a valuable resource for identification, classification, genetic conservation and crop improvement studies. This experiment was conducted to investigate the phenotypic diversity of native melons of Sar-e Pol province, Afghanistan based on morphological traits. The results demonstrated that there was a significant variation among phenotypic attributes of native melon cultivars from Sar-e Pol province. Based on germination performance, the Azqalani cultivar showed the highest germination rate (100 %), while Kanawari recorded the lowest (80 %). Regarding to 50 % flowering, the Tordar cultivar flowered earliest (33.5 days), while Aqchaye was the latest (44.5 days). In terms of fruit maturity, the Tordar cultivar matured earliest (83 days), whereas Gargak Sabz required up to 94.5 days to reach 50 % maturity. The finding also showed that Tordar produced the highest yield per plant (12.24 kg), while Gorgak Safeed had the lowest (4.89 kg). In addition, other investigated qualitative traits showed the considerable variation among the cultivars. Cultivars such as Sakhtcha, Kanawari, Kok Gorgak, Gorgak Sabz, Nabatk Safeed, Alapochaqh and Garagozh showed the highest phenotypic stability. These genotypes should be prioritized in breeding programs for development into improved cultivars. Overall, this study focused solely on morphological variation among cultivars. Therefore, further studies on genotypic diversity using molecular markers are crucial to validate genetic relationships.

Keywords: cultivars; diversity; melon; native; phenotypic

Introduction

Morphological characterization of melon varieties is essential for assessing the degree of diversity among them. Melon (*Cucumis melo* L.; $2n = 2x = 24$) one of the most important plants of the Cucurbitaceae family with its sweet taste, pleasant aroma, rich fiber, minerals, beta-carotene and vitamin C (1). Melon cultivation improvement has always been closely related to ethnic traditions and the existence of good social interactions has led to the spread of melon throughout Central Asia. The first origin of melon is Africa (2, 3). While the second origin is Afghanistan, Iran, India, Turkmenistan, Tajikistan, Uzbekistan, Turkey, China, Spain, Korea and Portugal (4, 5).

Melon is one of the important horticulture products that its cultivation date back to the ancient times in the southern and northern province of Afghanistan (6, 7). Among the cucurbit vegetables, melon has the highest polymorphism and diversity (8, 9).

Melon has a large diversity particularly at the fruit level. Phenotypic traits such as sex expression, fruit size and shape, skin color, mesocarp (flesh) color and seed size can be used to classify melon into distinct horticultural groups and sub-groups (10).

Significant phenotypic among accessions was observed for many traits including those related to agronomical performance (11, 12).

Developing inbred melon lines with diverse phenotypic and genotypic profiles is essential for assembling hybrid varieties with enhanced genetic characteristics, potentially resulting in superior cultivars (13, 14).

Cultivated melons exhibit larger leaves and fruits, thicker, non-bitter flesh and larger seeds compared to their wild counterparts. While many cultivated melons contain cucurbitacin which contributes to bitterness in leaves or roots none have bitter fruit (15).

Over millennia, farmers have influenced the diversity of melons through both positive and negative selection, leading to the preservation of mutations with adverse effects in gene banks, absent from traditional cultivars. These characteristics can be regarded as indicators of domestication. However, the genetic control of phenotypic traits associated with melon domestication remains poorly understood. Notably, fruit size and the absence of bitterness are clearly identifiable domestication traits (16–18).

Melon is an annual creeping plant with significant morphological and phenological polymorphisms in flower type and leaf shape (6). The main root system develops secondary roots that penetrate deeply into the soil. The stem is covered with small thorns, measuring 2 cm in diameter and up to 3 m long. Leaves can be circular, oval, triangular or pentagonal, typically 8–16 cm wide and 3–5 lobed, with wavy edges; petioles range from 4 to 10 cm in length and tendrils are simple (6, 19, 20). Botanically, melon fruits are classified as fleshy and come in oval, cylindrical or round shapes. The skin color of commercial melons varies from green to white to yellow, changing due to chloroplast accumulation (21, 22). They contain a mix of chlorophylls, carotenoids and flavonoids, with mesocarp colors in red, orange, green and white. Fruit quality encompasses internal factors such as sugar content, acidity, tissue and taste, as well as external characteristics like size, shape and skin color (23–25).

Commonly cultivated melon varieties include round melons (*C. melo* var. *cantalupensis*), winter or common melons (*C. melo* var. *inodorus*), snake melon (*C. melo* var. *flexuosus*), and pocket melon (*C. melo* var. *dudaim*) (26, 27). Nonetheless, scientific studies on the phenotypic traits, genetic potential and stability of Afghan native melons are limited. Investigating phenotypic diversity is crucial for genetic conservation, breeding and market potential. Therefore, this study aims to characterize the morphological diversity of native melons, evaluate native types and examine the quantitative traits related to yield among existing cultivars in Sar-e Pol province of Afghanistan.

Materials and Methods

The study was conducted under open-field conditions at the Sar-e Pol University Faculty of Agriculture Research Station (36°15'24" N, 65°55'82" E, 593 m asl) from March 14 to June 24, 2023. A total of 13 melon cultivars, differing in seed appearance, were collected from various districts of Sar-e Pol province. Prior to laying out the research design, the germination ability of the seeds was tested in the laboratory due to a lack of information regarding their germination capacity. The experiment followed a Randomized Complete Block Design (RCBD) with two replications. Each treatment (cultivar) consisted of six plants. Plant-to-plant spacing was maintained at 60 cm, while block-to-block spacing was set at 2.5 m, arranged in rows. After land preparation, pits measuring 30 × 40 cm were dug and filled with soil enriched with 400 g of well-decomposed animal manure. Two seeds were sown per pit at a depth of 3 cm after soaking for 12 hr to enhance germination. Thinning was performed 20 days after emergence, retaining the more vigorous, pest- and disease-free seedling per pit. Furrow irrigation was applied based on soil moisture, atmospheric conditions and plant growth stage.

Data was collected from four randomly selected plants within each treatment. Quantitative data, such as the number, weight, length and width of fruits, as well as the amount of plant residues, were recorded at different intervals according to cultivar type. Fruit weight was measured using a digital balance and results were estimated per square meter. Parameters including mesocarp diameter, fruit length and width, seed diameter, stem length, leaf length and width were measured with a ruler. Fruit skin and mesocarp colors were determined using the Horticulture Products Standard Color Table or RHS color chart. Qualitative data was assessed based on sensory evaluations conducted by a panel of ten

instructors and students. Attributes such as texture (smoothness and roughness), sweetness, aroma and mesocarp tissue structure were evaluated. Total Soluble Solid (TSS, Brix) levels were measured using an ATC portable digital refractometer (0–40 %). Seeds were placed in tagged disposable plastic cups. After 4–6 days, the surrounding debris was washed and cleaned. The seeds were then laid out on disposable plates to dry at room temperature until they reached normal moisture levels. Subsequently, seeds were sorted into standard and non-standard categories and the weight of 100 seeds was recorded using a digital balance. Data were analyzed using SAS 9.0 software through the General Linear Model procedure (PROC GLM). Mean comparisons were conducted using the Least Significant Difference (LSD) test at a 5% significance level.

Results

Analysis of variance

Analysis of variance (ANOVA) revealed significant differences ($P < 0.05$) among the 13 melon cultivars for all studied quantitative traits, including germination percentage, days to 50 % germination, days to 50 % flowering and maturity, leaf area index, seed dimensions, 100-seed weight, fruit sugar content (Brix), number of fruits per plant, fruit yield and harvest index (Table 1).

Germination traits

Days to 50 % germination varied significantly among cultivars. Gorgak Seya germinated the earliest (3.5 days), while Tordar was the latest (7 days). Cultivars such as Kok Gorgak, Gorgak Ablaq, Gorgak Safeed and Gorgak Sabz did not have significant differences in germination time. In terms of days to 50 % flowering, Tordar entered the flowering stage earlier (33.5 days), whereas Aqhchaye was the latest (44.5 days) (Table 2).

Growth parameters

The cultivars exhibited high diversity in morphological growth, fruit yield and fruit traits. Among the 13 cultivars, Tordar, Azqhalane, Aqhchaye, Garagozh, Gorgak Seya, Gorgak Safeed and Gorgak Sabz demonstrated higher yields. The increased yield in these cultivars was attributed to the production of more secondary stems and female flowers, which showed significant differences compared to others. Tordar, Azqalani, Aqhchaye and Garagozh (long or inodorous varieties), along with Gorgak Seya, Gorgak Safeed and Gorgak Sabz (round or cantalupensis melons), yielded higher in Sar-e Pol province's climatic conditions.

Yield and fruit quality

Significant differences were also recorded in yield parameters. The number of fruits per plant was significantly affected by cultivar, with Aqhchaye producing the highest number of fruits, showing significant differences from all other cultivars studied. Conversely, Sakhtcha had the lowest number of fruits per plant but did not have significant differences from several other cultivars, including Gorgak Seya, Kok Gorgak, Gorgak Ablaq, Garagozh, Nabatak Safeed, Kanawari, Azqalani, Tordar, Alapochaqh, Gorgak Safeed and Gorgak Sabz.

Fruit yield per plant also exhibited statistically significant variation, with Tordar yielding the highest (12.285 kg) and Gorgak Ablaq the lowest (4.895 kg). Other cultivars like Gorgak Seya, Kok Gorgak, Garagozh, Saqhtcha, Nabatak Safeed, Kanawari, Azqalani, Alapochaqh, Gorgak Safeed and Gorgak Sabz did not show

Table 1. Mean square of ANOVA table for different dependent traits as affected by cultivars

Variations	Degree of freedom	Germination (%)	No of days to germination	No of days to flowering	No of days to maturity	Leaf area index	Length of seed area
Cultivars	12	55.929*	2.199*	18.821*	17.051*	1405.1*	52.2521*
Block	1	3.846*	3.846*	9.846*	26*	3358.5*	2.5862*
Error	12	80.929	2.429	6.346	6.346	581.4	0.257
Variations	Diameter of seed area	Weight of 100 seeds	Fruit sugar (Brix)	No of fruit per plant	Yield (kg)	Harvest index	
Cultivars	5.02032*	0.81237*	4.83301*	0.6538*	9.776*	11968*	
Block	0.09846*	0.01888*	0.01885*	0.1538*	5.247*	6309*	
Error	0.13596	0.01835	0.22468	0.4872	9.846	6448	

*Significant at ($p < 0.05$).**Table 2.** Quantitative traits as affected by cultivars

Cultivars	Germination percentage	Days to 50 % germination	Days to 50 % flowering	Days to 50 % maturity	Leaf area index	Seed area length (cm)	Seed area diameter (cm)	100 seed weight	TSS (Brix)	Fruit number	Fruit yield (Kg)	Harvest index
Gorgak Seya	92.5 ^{ab}	3.5 ^b	36.5 ^{cde}	86.5 ^b	165.00 ^c	13.00 ^g	7.00 ^{ef}	6.85 ^{ab}	19.75 ^a	3.5 ^{ab}	7.440 ^{ab}	328 ^{ab}
Kok Gorgak	90.0 ^{ab}	4.5 ^{ab}	34.0 ^{de}	85.5 ^b	160.75 ^c	12.65 ^g	7.30 ^{de}	7.25 ^a	18.85 ^{abc}	3.5 ^{ab}	5.670 ^{ab}	198 ^{bcd}
Gorgak Ablaq	92.5 ^{ab}	5.5 ^{ab}	38.5 ^{bcde}	84.5 ^b	176.00 ^{bc}	11.15 ^h	6.35 ^f	5.90 ^c	16.80 ^{ef}	3.0 ^{ab}	4.895 ^b	241.5 ^{abcd}
Garagozh	87.5 ^{ab}	6.0 ^{ab}	42.5 ^{ab}	84.0 ^b	224.00 ^{ab}	22.70 ^{bc}	6.95 ^{ef}	6.00 ^c	19.40 ^{ab}	3.5 ^{ab}	10.540 ^{ab}	206 ^{abcd}
Saqhtcha	97.5 ^{ab}	5.5 ^{ab}	40.5 ^{abc}	88.0 ^b	177.50 ^{bc}	19.25 ^d	8.25 ^c	7.25 ^a	18.30 ^{cd}	2.0 ^b	5.680 ^{ab}	144.5 ^{cd}
Nabatak Safeed	95.0 ^{ab}	6.5 ^{ab}	39.0 ^{bcd}	87.0 ^b	146.50 ^c	16.50 ^e	11.20 ^a	6.85 ^{ab}	14.45 ^g	2.5 ^{ab}	7.690 ^{ab}	180.5 ^{bcd}
Kanawari	80.0 ^b	6.0 ^{ab}	41.5 ^{abc}	84.0 ^b	156.00 ^c	19.75 ^d	8.00 ^{cd}	7.30 ^a	16.95 ^e	3.5 ^{ab}	8.900 ^{ab}	138 ^d
Azqalani	100.0 ^a	5.0 ^{ab}	38.5 ^{bcde}	85.0 ^b	197.00 ^{abc}	23.75 ^b	8.00 ^{cd}	5.20 ^d	15.90 ^f	3.0 ^{ab}	8.525 ^{ab}	208 ^{abcd}
Tordar	85.0 ^{ab}	7.0 ^a	33.5 ^e	83.0 ^b	193.00 ^{abc}	21.90 ^c	7.75 ^{cde}	7.30 ^a	17.60 ^{de}	3.5 ^{ab}	12.285 ^a	322 ^{ab}
Alapochaqh	90.0 ^{ab}	5.0 ^{ab}	39.0 ^{bcd}	85.0 ^b	177.75 ^{bc}	17.55 ^e	9.50 ^b	6.35 ^{bc}	19.50 ^a	2.5 ^{ab}	6.500 ^{ab}	377.5 ^a
Aqhchaye	87.5 ^{ab}	4.0 ^{ab}	44.5 ^a	86.0 ^b	237.25 ^a	29.20 ^a	7.75 ^{cde}	6.85 ^{ab}	18.95 ^{abc}	4.0 ^a	11.080 ^{ab}	184 ^{bcd}
Gorkag Safeed	87.5 ^{ab}	4.0 ^{ab}	39.0 ^{bcd}	88.0 ^b	166.50 ^c	14.90 ^f	10.85 ^a	6.70 ^{ab}	17.45 ^{de}	2.5 ^{ab}	7.555 ^{ab}	291 ^{abcd}
Gorgak Sabz	90.0 ^{ab}	4.5 ^{ab}	39.0 ^{bcd}	94.5 ^a	164.00 ^c	16.50 ^e	10.50 ^a	6.75 ^{ab}	18.45 ^{bcd}	3.0 ^{ab}	7.980 ^{ab}	315.5 ^{abc}
Critical Difference	19.60	3.40	5.50	5.30	52.50	1.10	0.80	0.30	1.00	1.50	6.80	175.00

Mean value sharing the same letter in each column for each trait has a non-significant difference at 5 % significance level.

significant differences in yield. The highest harvest index was observed in Alapochaqh (377.5), while Kanawari had the lowest (138), revealing significant differences among them. Cultivars such as Gorgak Seya (328) and Tordar (322) did not differ significantly from each other, but had significant differences compared to Gorgak Sabz (315.5), Gorgak Ablaq (241.5), Garagozh (206) and Gorgak Safeed (291).

Sensory traits

The cultivars were categorized based on mesocarp flesh softness and hardness (Table 3). Gorgak Seya, Kok Gorgak, Gorgak Ablaq, Alapochaqh, Gorgak Safeed and Gorgak Sabz had soft flesh, while Garagozh, Saqhtcha, Nabatak Safeed, Kanawari, Azqalani and Tordar had hard mesocarp flesh. Flesh color showed significant differences among cultivars such as Gorgak Seya, Gorgak Ablaq and Gorgak Sabz shared the same color (RHS 140C), while Kok Gorgak (RHS 142C) differed from Gorgak Safeed (RHS 157D). Garagozh (RHS 149B) exhibited significant differences from Nabatak Safeed (RHS 143D), Saqhtcha and Aqhchaye (RHS 149C), Kanawari and Tordar (RHS 149D), as well as Azqalani and Alapochaqh (RHS 150D). The cultivars were also divided based on the softness and roughness of fruit skin (Table 3). Gorgak Seya, Garagozh, Azqalani, Tordar,

Alapochaqh, Aqhchaye and Gorgak Sabz had rough skin, while the others had soft skin. Regarding fruit skin thickness, cultivars were classified into three categories (Table 3) such as Gorgak Seya, Kok Gorgak and Saqhtcha had thin skin; Gorgak Ablaq, Garagozh, Azqalani, Alapochaqh, Gorgak Safeed and Gorgak Sabz had medium thickness; and Nabatak Safeed, Kanawari and Tordar had thick skin. In terms of aroma, cultivars such as Gorgak Seya, Kok Gorgak, Gorgak Ablaq, Garagozh, Azqalani, Tordar, Alapochaqh, Aqhchaye, Gorgak Safeed and Gorgak Sabz had weak aroma, whereas Nabatak Safeed and Kanawari exhibited moderate aroma.

Discussion

The results of the current study demonstrated significant phenotypic diversity among cultivars, indicating their suitability as sources for various traits essential for developing pure lines. These traits include early maturity, fruit quality, yield, yield components, seed dimensions, flesh color and total soluble solids (TSS). Among the cultivars, Gorgak Seya germinated the earliest (3.5 days), while Tordar was the latest to germinate (7 days). This aligns with the earlier findings (6, 28), noted that germination rates, growth and yield performance are influenced by cultivar differences.

Table 3. Qualitative traits as affected by cultivars

Cultivars	Fruit flesh structure	Fruit flesh color	Fruit smell	Fruit skin thickness	Fruit skin rough and softness
Gorgak Seya	Soft	RHS140C	Strong	Thin	Rough
Kok Gorgak	Soft	RHS142C	Medium	Thin	Soft
Gorgak Ablaq	Soft	RHS140C	Medium	Medium	Soft
Garagozh	Hard	RHS149B	Weak	Medium	Rough
Saqhtcha	Hard	RHS149C	Weak	Thin	Soft
Nabatak Safeed	Hard	RHS143D	Medium	Thick	Soft
Kanawari	Hard	RHS149D	Medium	Thick	Soft
Azqhalani	Hard	RHS150D	Weak	Medium	Rough
Tordar	Hard	RHS149D	Weak	Thick	Rough
Alapochaqh	Soft	RHS150D	Weak	Medium	Rough
Aqhchaye	Hard	RHS149C	Weak	Thick	Rough
Gorgak Safeed	Soft	RHS157D	Weak	Medium	Soft
Gorgak Sabz	Soft	RHS140C	Weak	Medium	Rough

The number of days to 50 % flowering showed a direct relationship with final fruit yields in most tested cultivars, suggesting that early-flowering cultivars tend to produce higher yields. Tordar, which had the highest yield (12.285 kg) and Gorgak Ablaq, with the lowest yield (4.895 kg), were significantly different from each other, although both were statistically similar to the other cultivars ($P < 0.05$). These results are consistent with earlier findings (29), which reported that melon yield is correlated with traits such as days to flowering, number of fruits per plant, mean stem count, number of branches per mean stem and internode length.

Aqhchaye exhibited the largest leaf area index among the cultivars, a key indicator of growth, photosynthetic rate, light penetration and energy balance. This finding reveals that leaf area index is an important biometric measure for assessing variation among different varieties in both field and greenhouse research (30). Significant differences were also observed among cultivars for fruit TSS, aroma, flesh color, structure, skin color, shape and thickness, in agreement with earlier studies (31, 32). Similarly, significant variations were noted among melon cultivars in traits such as days to first maturity, fruit weight, number of fruits per cluster, cluster count per vine, fruit thickness, yield per plant and TSS (33, 34).

In this study, a positive correlation was found between TSS and fruit flesh diameter, as well as between seed length and seed diameter. This contrasts with another findings, which reported a negative relationship between seed traits in Indonesian melon cultivars. Such divergence may be attributed to differences in genetic backgrounds, environmental conditions or specific selection pressures in various regions. Additionally, qualitative traits like fruit structure, flesh colour, aroma and skin texture varied significantly among cultivars, consistent with previous observations (35, 36).

Conclusion

This study revealed substantial morphological variation among native melon cultivars from Sar-e Pol province. Key phenotypic traits such as germination rate, flowering and maturity duration, leaf area index, seed dimensions and fruit yield demonstrated wide variability, providing a valuable foundation for selection and genetic improvement. Traits like flesh color, fruit weight and TSS emerged as particularly desirable for breeding purposes, while other parameters showed moderate significance. These findings underscore the genetic richness of local landraces and the need for further exploration in Sar-e Pol and other regions of Afghanistan to support conservation efforts and the development of improved melon varieties.

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Authors' contributions

MAA conceived the study and contributed to the overall conceptualization. MAA, KWG and SMF designed the methodology. MAA, SMF, QI and MIA collected the data. KWG, MAA and SMF performed data analysis and interpretation. MAA, KWG and SMF wrote, reviewed and edited the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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