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EVALUATION OF MORPHOLOGICAL CHARACTERISTICS IN SOME APPLE VARIETIES (MALUS PUMILA MILL.) FROM NORTHEASTERN ALGERIA

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Abstract

The current investigation is centered on the characterization of specific apple cultivars in the Garza region, within the Teniet El Abed municipality, situated 55 km east of Batna (NE-Algeria). Utilizing descriptors outlined by UPOV 2015 pertaining to apples, the study focuses on morphological parameters of leaves, fruits, and terminal shoots across three varieties: Golden Delicious, Royal Gala, and Starkrimson. Additionally, soil analysis was conducted to ascertain its suitability for apple cultivation. The examination revealed limited morphological diversity among the investigated apple cultivars, with some descriptors, particularly those related to fruit traits, showing insignificant differences between cultivar types. Overall, the studied varieties - Golden Delicious, Royal Gala, and Starkrimson - exhibit distinct physiological and morphological characteristics. Variations in size, shape, skin color, flesh attributes, as well as sugar and acid content, contribute to the uniqueness of each variety. Whether one prefers sweet or tart apples, or favors larger or smaller fruits, there exists an apple variety to cater to individual tastes. Our findings complement molecular analyses and underscore the need for further exploration of apple germplasm, alongside sustained conservation efforts.

Keywords: apple, agronomy, conservation, orchard, fruit, genetic diversity

1. INTRODUCTION

The apple tree (*Malus pumila* Mill.) stands as the most cultivated fruit species globally, especially within the temperate zone (Houmani 1999 [1]; Chouinard et al. 2000 [2]). The apple ranks as the third most significant fruit crop worldwide, following citrus and banana, in terms of production volume. Its widespread cultivation across all continents, thriving under diverse environmental conditions, underscores its remarkable adaptability to varying ecological settings (Ercisli 2004 [3]; Gharghani et al. 2009 [4]; Radivojevic et al. 2014[5]). In Algeria, the cultivation of apples has experienced notable advancement, with cultivated areas expanding from 39,852 ha in 2010 to 40,553 ha by 2018. Concurrently, yields have demonstrated an upward trend, ranging from 72,233 kg/ha in 2010 to 171,635 kg/ha in 2020. Consequently, apple production has shown substantial growth, escalating from 378,637 tons in 2010 to 566,824 tons in 2020 (FAO 2022 [6]).
Nevertheless, the yields of 171,635 kg per hectare still lag behind European standards, such as those observed in France, which average 323,007 kg/ha (FAO 2022 [6]). This disparity appears to stem from various factors, notably inadequate mastery of cultivation techniques and suboptimal varietal adaptation. In the Aures region of eastern Algeria, apple cultivation serves as a significant socio-economic endeavor, particularly in Batna. The area dedicated to apple cultivation surpassed 4,380 ha in 2017, with a production reaching 900,000 quintals. This sector represents 19% of the total arboricultural area and is concentrated in mountainous zones, specifically in the towns of Arris, Ichemoul, Teniet El Abed, and Marouana.
The morphological characterization of Malus species has proven indispensable for providing thorough descriptions of germplasm collections, as well as informing breeding programs (Bozovic et al. 2015 [7]) and taxonomic studies (Hofer et al. 2014 [8]; Wagner et al, 2014 [9]). Genetic markers, particularly microsatellites, are favored over phenotyping due to their stability and cost-effectiveness in providing information (Reddy et al, 2002 [10]; Ban et al, 2014 [11]), the examination of agricultural germplasm through morphological traits remains relevant and valuable in diversity analysis (Bozovic et al. 2015 [7]; Kiraly et al. 2015 [12]; Kumar et al. 2018 [13]). Consequently, studies on apple morphological descriptions have been conducted in various regions including Bosnia and Herzegovina (Gasi et al. 2011 [14]), Canada (Watts et al. 2021 [15]), Hungary (Kiraly et al. 2015 [12]), India (Dolker et al. 2021 [16]), Iran (Farrokhi et al. 2013 [17]), Italy (Martinelli et al. 2008 [18]), the Kashmir Valley (Dar et al. 2015 [19]), Macedonia (Kiprijanovski et al. 2020 [20]), Montenegro (Bozovic et al. 2015 [7]), Serbia (Mratinic et al. 2012 [21]) and Turkey (Karatas, 2022 [22]), reporting high morphological diversity. The most frequently utilized morphological descriptors in these studies adhere to international guidelines such as IBPGR (1982 [23]) and UPOV (2005 [24]) with a primary focus on fruit characteristics. This emphasis on fruit traits aligns with the sensory characteristics and consumer preferences associated with apples (Pereira-Lorenzo et al, 2018 [25]).

This study primarily focuses on the agro-ecological and numerical characterization of specific varieties of apple trees (*Malus pumila* Mill.) within the Oued Abdi region, situated in the Garza area approximately 55 km southeast of Batna. It entails the examination of various morphological parameters of key organs, including annual shoots, flowers, leaves, and fruits. The objective is to analyze the distribution, homogeneity, and stability of the species, thereby contributing to future breeding programs in Algeria from both environmental and economic perspectives. Moreover, this research lays the groundwork for further agronomic and sensory studies aimed at enhancing the morphological description of apples. By providing valuable insights, it aims to advance our understanding of apple genetic resources.

2. MATERIALS AND METHODS

Soil analysis

Soil analysis was conducted in December, during the winter rest period, at four different depths. Commonly used analysis methods were employed for this purpose. The soil samples were analyzed at the regional laboratory of the National Institute of Soil, Irrigation, and Drainage (INSID) located in Oum El Bouaghi, eastern Algeria.

Plant material

The plant material utilized in this study comprises three varieties of apple trees - Golden Delicious, Royal Gala, and Starkrimson - grafted onto the MM 106 rootstock. These trees were planted in 2000 in Garza, situated 55 km southeast of Batna (NE-Algeria), at an altitude of 1600 m. A model orchard spanning one hectare was selected for the study, accommodating a total of 800 trees with varied planting distances. The planting arrangement includes a mixture of the three apple varieties.

For irrigation, a submersion system sourced from a well with an average depth of 40 m was employed. Fertilization was carried out using organic manure. The study focuses on a sample of 10 representative trees from each variety throughout the vegetative cycle. These specific references were chosen due to their widespread cultivation in Algeria.

Study methods

A comprehensive set of morphological descriptors, totaling 23, was evaluated for three organs: fruits, flowers, and shoots. These descriptors were sourced from UPOV (2015[26]). A total of 40 fruits and 40 flowers, along with 32 shoots per variety, were collected from various orientations within the tree crown for assessment.

Tree characterization

The tree characterization process encompassed the assessment of several key parameters, namely habitus (HAB), maturation time (MAT), and the length of terminal annual shoots (LTAS) categorized by orientation (E: east, W: west, N: north, S: south). This evaluation spanned from stage A of BAGIOLINI to stage A, signifying final fruit maturity. Throughout this period, the growth of terminal shoots originating from each variety's vegetative buds was meticulously tracked on a weekly basis, considering their orientation until complete apex drop. Measurements of the length of terminal shoots were conducted using a digital caliper, with recorded results in millimeters (mm).

Flower characterization

The parameters studied for flower characterization include flowering period (FLOW), flower color (FLC), flower diameter (FLD), petal floral composition (PETF), floral stamen position relative to anthers (STPAN), as well as NPET (number of petals), NSEP (number of sepals), PETL (petal length), PETW (petal width), SEPL (sepal length), PISL (pistil length), NPIS (number of pistils), STAL (stamen length), and NSTA (number of stamens).

Fruit characterization

We have identified the following parameters for fruit characterization: fruit weight (WEIG), fruit length (LENG), fruit width (WIDT), fruit shape index (SHIN), fruit shape (SHAP), and fruit color (COLO), as outlined in Table 5. Fruit analyses were conducted on an average sample of 100 fruits per genotype, considering their orientation on the tree. Fruit weight (WEIG) was determined using an analytical balance of "type: Metler 1200," with results expressed in grams with a precision of 0.01 g. Fruit length (LENG) and fruit width (WIDT) were measured using digital calipers. The fruit shape index (SHIN) was calculated using the formula SHIN = length / width.

To determine the significance of the differences among the varieties concerning the studied tree and fruit characteristics, an analysis of variance (ANOVA) was conducted, followed by the application of the Tukeys (0.05%) test using SAS 2000 V. 9.0 software.

3. RESULTS AND DISCUSSION

Soil characterization

The results of physico-chemical analyses are depicted in tables 1 and 2. The soil type identified exhibits variable texture with depth, generally categorized as clay-sandy. This presence of fine elements suggests a potential risk of root asphyxiation, particularly when these particles become saturated with water, especially during periods of heavy rainfall or intensive irrigation. Given the fine structure of this soil type, there is an anticipated risk of compaction due to poor permeability. Clay-sandy-loamy soils are typically considered most conducive for fruit tree cultivation (Benaziza et al. 2007 [27]). The optimal organic matter content typically ranges from 3 to 4%. For the species under consideration, a humus content between 1.5 to 3% is deemed satisfactory. In our case, the total soil calcium content is classified as very low, measuring less than 2%. Typically, calcium levels ranging from 2 to 10% are considered low, while levels exceeding 25% are regarded as very high.

The results indicate that the pH of the analyzed soils ranges from neutral to alkaline, specifically between 7.15 and 7.39, posing no risks for cultivation (Table 2). In the case of alkaline soil, the addition of organic matter and

nitrogen can help buffer the pH and enhance tree nutrition and growth. A recommended application rate is five kilograms of sheep manure and 500 grams of urea (46% nitrogen). Soil salinity levels are interpreted based on the standards established by Aubert (1978 [48]). According to these standards, the studied soil is not considered salty, with salinity levels falling between 0.43 and 0.48.

Table 1. Physical analysis results of soil in the studied orchard

Elements	Soil Depth (cm)			
	00-20	20-40	40-60	60-80
Granulometry	International Method (Sieving and Sedimentation) (International Standard ISO 11277)			
Clay	40.06	36.71	37.40	45.22
Fine Sand	03.86	17.70	19.09	11.61
Coarse Sand	16.92	08.19	08.73	10.01
Fine Silt	21.56	19.04	17.38	18.16
Coarse Silt	17.60	18.39	17.41	14.81
Total Silt	20.78	25.89	27.82	21.62
Total Sand	39.16	37.43	34.79	32.97
Texture	Clayey-sandy			

Table 2. Soil chemical analysis in the studied orchard

Depth	pH	EC (dS/m)	Lim (%)	OM (%)
00-20 cm	7.15	0.48	1.47	3.71
20-40 cm	7.27	0.45	0.74	3.39
40-60 cm	7.32	0.48	0.74	1.17
60-80 cm	7.39	0.43	0.00	1.69
EC: Electrical Conductivity; Lim: limestone; OM: organic material				

Characterization of Trees and Annual Shoots

The habitus for the tree of each variety is spread out, no noticeable difference between them. The analysis of the results revealed no considerable differences between cultivars for their phenological behavior. The three genotypes started their vegetative activity in April; however, the vegetative growth was marked from spring to autumn without any summer pause (Table 3).

Table 3. The growth habit of apple trees and the length of annual shoots. *Means with the same letters are not significantly different at p< 0.05 (Tukey Test).*

Traits (mm)	*Golden Delicious*	*Royal Gala*	*Starkrimson*
HAB	Spread	Spread	Spread
LTAS-N	652.87^{A}	474.61^{B}	325.03^{C}
LTAS-S	401.37^{A}	345.94^{B}	277.53^{C}
LTAS-E	645.59^{A}	447.49^{B}	390.91^{C}
LTAS-W	411.11^{A}	384.19^{B}	215.46^{C}
HAB: Habitus; LTAS: Length of terminal annual shoots; N: North; S: South; E: East; W: West			

The length of annual shoots exhibits significant and variable impacts based on the considered variety. The orientation factor plays a crucial role in determining orchard cultivation practices, particularly regarding light exposure. Average final lengths range from 21.55 cm (Starkrimson) to 65.29 cm (Golden Delicious). The 'Golden Delicious' cultivar displayed the longest shoots, measuring at 92.42 cm, while the 'Royal Gala' variety exhibited the shortest, at 2.20 cm.

For 'Golden Delicious' and 'Royal Gala', shoots facing North demonstrated the highest growth rates, followed by those facing East, West, and South respectively. Conversely, in the case of the Starkrimson variety, shoots oriented towards the East displayed the highest growth rates, succeeded by North-facing shoots, South-facing shoots, and finally West-facing shoots.

Figure 1. Trees of apple *Malus pumila* at flowering and fruiting period for the three studied varieties from Garza (NE-Algeria)

Table 4. Flower characteristics of the three apple varieties. *Means with the same letters are not significantly different at p< 0.05 (Tukey Test).*

Traits (mm)	Golden Delicious	Royal Gala	Starkrimson	P
FLOW	Early May	End-April	Early May	--
FLC	Pale pink	Pale pink	Pale pink	--
DFL	Medium	Medium	Medium	--
PETF	Overlap.	Overlap.	Overlap.	--
STPAN	Below	Below	Below	--
NPET	5^{A}	5^{A}	5^{A}	NS
NSEP	5^{A}	5^{A}	5^{A}	NS
PETL	$2{,}26\pm0{,}10^{A}$	$2{,}34\pm0{,}11^{A}$	$2{,}29\pm0{,}27^{A}$	0.565
PETW	$1{,}61\pm0{,}09^{A}$	$1{,}48\pm0{,}07^{B}$	$1{,}68\pm0{,}16^{A}$	0.002
SEPL	$0{,}77\pm0{,}13^{A}$	$0{,}81\pm0{,}12^{A}$	$0{,}85\pm0{,}07^{A}$	0.268
PISL	$1{,}04\pm0{,}10^{A}$	$0{,}97\pm0{,}09^{A}$	$0{,}83\pm0{,}07^{B}$	<0.001
NPIS	5^{A}	5^{A}	5^{A}	NS
STAL	$0{,}85\pm0{,}09^{A}$	$0{,}90\pm0{,}06^{A}$	$0{,}87\pm0{,}06^{A}$	0.343
NSTA	$19\text{-}20^{A}$	$18\text{-}20^{A}$	$19\text{-}20^{A}$	0.087
FLOW: flowering time; FLC: flower color; DFL: diameter of the flower; PETF: petal floral composition; STPAN: stamen position relative to the anthers; NPET: number of petals; NSEP: number of sepals; PETL: petal length; PETW: petal width; SEPL: sepal length; PISL: pistil length; NPIS: number of pistils; STAL: stamen length; NSTA: number of stamens				

There was a minor variation observed among the species in terms of flowering time, categorized as medium and late (Table 4). Royal Gala trees typically flower towards the end of April, while the remaining two varieties initiate flowering during the first week of May. Across the same variety, the flowering duration spans from 10 to 15 days. The different apple varieties exhibit maturity throughout the year (Bretaudeau and Fauré 1991 [29]; Boré and Fleckinger 1997 [30]).

There is no risk of frost affecting the flowers. However, in regions where frost during flowering is a possibility due to altitude, it may be advisable to opt for varieties that flower later in the season (Šebek 2011 [31]).
Typically, the color of apple flowers is white, pink, or red (Mišić 2002 [32]). The flowers of the varieties examined in this study predominantly exhibited a pale pink hue and were of moderate size. The position of the stigmas relative to the anthers was above.
The results presented in Table 4 indicate slight variations in the length and width of the sepals, petals, pistils, and stamens among the three varieties. However, for the majority of the parameters measured, all three varieties are grouped together. Two exceptions were noted: the average petal width for the Royal Gala variety was slightly lower (1.48 mm) compared to Golden Delicious and Starkrimson (1.61 mm and 1.68 mm, respectively), and the average pistil length for the Starkrimson variety was slightly lower (0.83 mm) than the other two varieties. No differences were observed in the number of each flower component across all varieties.

Characterization of fruits

The quality of the fruit is defined by the degree of excellence or superiority in terms of sensory properties, nutritional values, mechanical properties, and functional properties. In the case of apples, the most influential quality indicators are the external indicators (skin color, size) and internal indicators (texture, taste, aroma), based on consumer preference studies (Kühn & Thybo, 2001 [33]; Pathare, Opara & Al-SAID, 2013 [34]).

Table 5. Characteristics of Fruits. ***Means with the same letters are not significantly different at p< 0.05 (Tukey Test).***

Traits (mm)	*Golden Delicious*	*Royal Gala*	*Starkrimson*	*P*
WEIG	129,74 ±14,56^{B}	138,20 ±19,86^{A}	140,32 ±17,75^{A}	<0.001
LENG	63,81 ±3,84^{A}	62,45 ±5,83^{B}	59,47 ±3,72^{C}	<0.001
WIDT	67,91 ±3,74^{C}	71,86 ±5,84^{A}	70,04 ±4,06^{B}	<0.001
SHIN	0.94^{A}	0.87^{B}	0.85^{B}	<0.001
SHAP	Oval	Circular	Conical Strangled	/
COLO	Yellow	Orange -Red	Red -Purple	/
MAT	Middle of October	Middle of September	End of October	/

WEIG: weight; LENG: length; WIDT: width; SHIN: shape index; SHAP: shape; COLO: color; MAT: Maturity time

The studied varieties exhibit yellow, orange-red, and red-purple colors. The fruit of "Golden Delicious" features a surface that is 100% yellow, while "Royal Gala" displays an orange-red color, and "Starkrimson" showcases a red-purple hue, according to UPOV standards (2015 [26]).
The background color of the apple is linked to its ripeness. The reduction in green coloring intensity occurs due to the breakdown of chlorophyll, leading to a yellowing of the skin (Grierson and Kader, 1986 [35]).
The flesh (mesocarp) color of all three varieties is white, consistent with the findings of Tomić et al. (2011 [36]). Additionally, alongside white, cream and greenish hues are also observed in the flesh.
The weight, length, width, shape index, and shape of the fruit are detailed in Table 5. Apple varieties exhibited a wide range of fruit weights, spanning from 98g to 224g. The Tukey test revealed a significant difference between the varieties concerning fruit weight. "Royal Gala" and "Starkrimson" varieties were classified in the first group, displaying higher weights, whereas the first variety "Golden Delicious" was placed in the second group, featuring the lightest fruits.
In comparison to other studies, Ozrenk et al. (2011 [37]) investigated local apple varieties of Eastern Anatolia in Turkey, revealing a variation in fruit weight ranging from 20.9 to 139.3 g. Similarly, Mratinić and Fotirić-Akšić (2012 [21]) conducted research in southern Serbia, reporting fruit weights between 70 and 193.33 g. The majority of fruits fell within the weight range of 100 to 200 g, consistent with findings from studies by Mratinić and Fotirić-Akšić (2011 [38]), Tomić et al. (2011 [36]), and Šebek (2013 [39]).
The length of the fruits ranged from 51.62 to 81.47 mm, while the width varied between 59.35 and 89.70 mm. Comparing our data with other authors, such as Zovko et al. (2010 [40]), Šebek (2011 [31]), and Tomić et al. (2011 [36]), it can be concluded that the dimensions of the fruits fall within a similar range. This suggests that fruits with similar weights tend to have similar dimensions, indicating a correlation between these characteristics. The coefficient of variation (CV) for fruit weight was found to be 3.36%, indicating that fruit weight is the least variable property. This is attributed to the fact that fruit weight is more influenced by environmental factors compared to dimensions (Šebek 2011 [31]). The coefficient of variation (CV) is 2.93% for fruit length and 2.31% for fruit width.
The lowest fruit shape index of 0.75 was observed in "Starkrimson," while the fruits of "Golden Delicious" with a shape index of 1.04 were the longest.
Considering the fruit ripening period, the first selection would be 'Royal Gala,' as its fruits ripen in September. 'Golden Delicious' and 'Starkrimson' are the latest ripening cultivars, with fruits ripening in October.
The shape of the fruit varied among selections, with oval, circular, and conical constricted fruits all observed among the apple trees.
The significance of studying these characteristics was highlighted by Mulas and Cani (1999 [41]), who noted a significant correlation between fruit weight and volume, as well as between fruit weight and seed weight per fruit. Characterizing new cultivars enhances our understanding of the properties and variability of the species, thereby providing initial insights into potential uses of different cultivars. For instance, the color and shape of the berries are valuable in selecting ornamental cultivars, while the correlation between shoot length and the number of nodes is crucial for fruit yield.

4. CONCLUSIONS

The three cultivated apple tree varieties exhibited significant variation across most of the parameters examined. Distinctions were evident in terms of vegetative growth of annual shoots, fruit weight, and color, while variations in floral and fruiting dimensions were less pronounced. This diversity holds significant implications for the sustainable development and consumption of apples. Given the microclimate of the region, these cultivated varieties present compelling prospects for further development and preservation. Commercial and agronomic attributes carry substantial weight and warrant detailed evaluation, serving as invaluable information for future selection and dissemination programs. This characterization relies heavily on quantitative traits, which can be challenging to measure and at times subjective. Establishing rigorous protocols is imperative to ensure the reliability and repeatability of observations, utilizing measurable and more precise characteristics.

Although this study is limited in scope, conducted on a restricted number of varieties, its repetition and expansion, particularly across additional criteria such as flowers, fruits, and shoots, would enhance its reliability and decisiveness. Supplementing morphological characterization with molecular analysis to pinpoint agronomically important genes, map each variety, and obtain its genetic fingerprint would greatly enhance local and national-level cultivation efforts.

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