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Morphological Characterization of Hawthorn Types (*Crataegus* spp.) Widespread in Northwestern Syria

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Abstract

This research was carried out in Idlib Governorate, located in northwestern Syria, between 2021 and 2022. The types of wild and cultivated hawthorn spread in the study area were identified and described. The results showed that there were significant differences between the types in most of the studied leaf characteristics (leaf length and width, lobulation depth, leaf area, and leaf wet and dry weight), as well as in flower characteristics (floral cluster length, number of flowers per cluster, and flower petiole length). The types varied in the characteristics of the fruit, whether quantitative (fruit length and width, fruit petiole length, and fruit size weight) or qualitative characteristics (color of the fruit) and in the seed characteristics (length, width, weight, and size of the seed). The correlation analysis table showed a high positive linear correlation between leaf area and leaf wet weight, between fruit size and fruit weight, and between seed size and seed diameter and weight. The results of the cluster analysis showed that the studied types are grouped into two main clusters. The first cluster includes 3 subgroups, while the second cluster includes one subgroup. Principal components analysis (PCA) indicated that there were three main factors responsible for 100% of the variances between the types. The factor PC1 was responsible for 69.3%, the variables combined by PC2 were responsible for 17.3% of the variances, while the PC3 accounted for 13.4%. Finally, the study showed the spread of the Azarolus types mainly in the northwestern region of Syria, and to a lesser extent Monogyna, as well as the great relationship between the wild type Aronia and the cultivated types, Yellow Azarolus and Red Azarolus.

Key words: Hawthorn، *Crataegus*، Phenotypes، Morphological Characterization

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Introduction

Hawthorn trees are among the important trees in preserving soil, preventing erosion, and resisting desertification. In addition to their economic, horticultural, ornamental, and medicinal importance. This is what makes the hawthorn genus (*Crataegus*) and its types a plant material worthy of attention and study. The hawthorn belongs to the genus *Crataegus*, which in turn belongs to the subfamily Maloideae (or Pomoideae) and the family Rosaceae (Tutin *et al.*, 1990; Phipps *et al.*, 1991; Lippert 1995). The Maloideae includes about 28 genera and 940 species of trees and shrubs ecologically and economically important (Judd *et al.*, 1999). Hawthorn (*Crataegus* spp.) is widespread in temperate regions of the Northern Hemisphere. Some species are grown for food or medicinal purposes in Asia, North and Central America, and Mediterranean countries, while others are used as ornamental plants in Europe and North America (Christensen, 1992; Dönmez, 2008).

There is no consensus on the number of species belonging to *Crataegus* (Fineschi *et al.*, 2005). According to Judd *et al.* (1999), *Crataegus* includes 265 species. Other researchers hypothesized that counting all geographically and morphologically divergent groups resulted in a larger number of species (Albarouki and Peterson, 2007; Khadivi-Khub *et al.*, 2015). The most accepted view is that the number of *Crataegus* species could range between 150 and 1200 (Christensen, 1992; Albarouki and Peterson, 2007; Wrońska-Pilarek *et al.*, 2013). Roskov *et al.* (2019) explained that there are more than a thousand species of the genus *Crataegus* all over the world.

Undoubtedly, the *Crataegus* has puzzled plant taxonomists more than any other genus of phanerogamic plant and poses a taxonomic problem due to high variation, hybridization, and polyploidy, with the result that it is difficult to accurately identify the species (Dönmez, 2008; Dvirna *et al*., 2021). Evans and Campbell (2002) and Ma and Lu (2016) emphasized that the classification of existing hawthorn varieties is historically complex, and its classification and evolution are still not well understood. Taxonomic problems and the description of many new species are the result of hybridization between species (Phipps, 2005). Problems in *Crataegus* arise because of several factors. Firstly, species are inherently variable, for example in *C. meyeri* and *C. monogyna* There are different species in the leaf blade (which may be of taxonomic importance in other varieties) that occur randomly in many occurrence groups. Second, hybridization, introgression, polyploidy, or mixing may occur later, blurring the lines between species. Third, it is often difficult to obtain all taxonomically important structures simultaneously, and it may be necessary to revisit the same populations or individuals at flowering and fruiting time (Christensen, 1992; Dönmez, 2008; Mezhensʹka and Mezhensʹkiĭ, 2013; Wrońska-Pilarek *et al.*, 2013).

Many studies have indicated that the *Crataegus* contains 140-200 species (Lo, 2008; Dai *et al.*, 2009, 2013), and hawthorn classification has relied on variation in morphological characters, a method that suffers from low numbers of independent characters and is often genetically weak (Archak *et al.*, 2003. Rahmani *et al.*, 2015). According to the guidelines issued by the International Union for the Protection of New Varieties of Plants (UPOV) and previous studies by Christensen (1992) and Khadivi-Khub *et al.* (2015), 30 neutral characters were selected for analysis of morphological and taxonomic variation of *Crataegus*. Among the 50-100 species of *Crataegus*, the varieties in Europe, North Africa, and West Asia are characterized as having small leaves with 1-4 pairs of lobes, usually extending 0.5 times or more from the width of the lamina to the vein, and enlarging ventrally or smooth pedicles (Christensen, 1992).

Morphological characteristics are the first step in characterizing germplasm before in-depth biochemical and molecular studies (Hoogendijk and Williams, 2002). Morphological characterization of plants helps in their preliminary study and is important for adopting conservation strategies for plant genetic resources and establishing germplasm collections (Podgornik *et al.*, 2010). Several researchers have adopted it in their study of *Crataegus* (Khadivi *et al.*, 2019; Stoenescu and Cosmulescu, 2020). Some studies confirm that the weight, length, diameter, moisture, and dry matter of the fruit, the length, width, and area of the leaf, the number of leaves per node, and the weight and length of the seed are the characteristics responsible for the differences between varieties in the first two components, which indicates that they are useful in evaluating the genetic material of hawthorn (Erfani- Moghaddam, 2016).

Some have emphasized that the morphological characteristics of the fruit are important for identifying species, and many researchers have studied the differences between species according to morphological characteristics (Alaghwani and Naser, 2013; Mehebub *et al.*, 2019). One study also relied on the morphological, biochemical, and molecular differences of 22 genotypes of hawthorn belonging to three different species. The characteristics of fruits (fruit length, fruit width, fruit weight, seed weight, and soluble solid content) and leaves (leaf length, leaf width, leaf petiole) were the main factors in the difference between the studied genotypes (Yildiz et al., 2022). Also, some studies showed that when analyzing plant morphology, the coefficient of variation for 13 traits was > 20%, indicating a high degree of variation (Ma and Lu, 2016).

There are four species in Syria in the natural state: the common hawthorn, *Crataegus azarolus* L., the single-pistillate hawthorn, *Crataegus monogyna* Jaoq., the thorny hawthorn, *Crataegus oxycantha* L., and the Sinai hawthorn, *Crataegus siniaca* Boiss. (Nahal *et al.*, 1989; Muterde, 1983). A study of hawthorn species was conducted in As-Suwayda Governorate in Syria, based on both plastid DNA sequences and morphological data. In the investigated area, there are three morphologically distinguishable species, *C. azarolus* var. *aronia* L., and *C. × siniaca* Boiss. ssp. *sinaica* and *C. monogyna* var. *monogyna* Jacq. *Crataegus azarolus* can be clearly distinguished morphologically from *C. monogyna* by color, size, fruit structure, number of seeds, flowering time, maturity, the density of spines, tree shape, and leaf shape (Albarouki and Peterson, 2007). Christensen (1992) distinguished four varieties of *C. azarolus*, namely *C. azarolus* var. *Azarolus*, *C. azarolus* var. *aronia*, *C. azarolus* var. *chlorocarpa*, and *C. azarolus* var. *pontica*. It was explained that all the samples isolated in Syria are of the Aronia variety, and all the hawthorn samples represent *C. azarolus* var. *aronia* and *C. monogyna*. This is consistent with what was confirmed by Khatib (1999), who found that the botanical characteristics of this tree are consistent with the description given by Linne for the Aronia variety, which indicates that the hawthorn trees found in Syria are of the Aronia variety.

The genetic resources of the genus *Crataegus* are threatened by erosion. Indeed, many of the native plants of this genus have disappeared rapidly over the past decades (Rahmani *et al.*, 2015; Emami *et al.*, 2018). It is necessary to collect and evaluate the plant materials of the hawthorn and determine its types accurately and systematically, as well as work to protect it in the sites of its spread and even expand its cultivation, because of the forestry, horticultural, food, and medicinal importance this tree has. Therefore, the main goal of this research is to study the morphological diversity of the hawthorn types spread in the Idlib region and work to preserve them and expand their study.

Materials and Methods

Experiment Location:

A survey was conducted of the sites where hawthorn trees spread in Idlib Governorate, and after determining the sites of the trees from which samples were to be taken, these sites were visited several times and at different dates that correspond to the stages of growth of flowers, leaves, and fruits to collect samples of these plant parts to characterize them, and the formal characteristics of the selected trees were recorded. Table (1) shows the areas where hawthorn samples were collected from the places where it spread in Idlib Governorate.

Table (1): Areas for collecting hawthorn samples in Idlib Governorate

Region	Subsites				Type
Jabal Al-Zawya	Bazabour	Balshoun	Arrami	Kansafra	Azarolous
Ariha	West Ariha	Kafar Zyba	East Ariha	Mohambel	Azarolous
Idlib	West Idlib	Idlib city	East Idlib		Azarolous
Darkoush	Wastany	West Darkoush	East Darkoush		Azarolous
Armanaz	Armanaz	Kafar Takharim			Azarolous
Ma'aret Mesrin	Ma'aret Mesrin	Killi			Azarolous
Harem	Harem	Harem-Salqin			Azarolous
Salqin	Salqin	Haj Naief	Azmaren		Azarolous
Jisr Al-Shogour	Za'inia	Janodieh	Azar	Al-Modi'a	Monogyna

Plant material:

The plant material for this research included all species that could be collected during the research. Several wild and cultivated trees were studied, and readings were taken on trees of each type and from each site studied during the years 2021 and 2022.

Selecting the studied samples:

Initial keys were identified to identify the type from the first field observation (during March, when wild and cultivated species were in the process of forming shoots). A complete characterization was conducted for three trees of one species in each environmental site studied. 10 leaves were taken from each direction of the tree, for a total of 40 leaves per tree. Also, 20 floral inflorescences were taken from each tree (5 inflorescences from each direction), and 10 fruits were taken from every tree.

Readings and morphological description:

We relied on morphological characters that had previously been used in previous studies on hawthorn (Albarouki and Peterson, 2007; Makhoul and Mahfoud, 2007; Layka *et al.*, 2009; Deeb *et al.*, 2015). Measurements were taken on the various plant parts as follows:

Leaves:

- Qualitative Characteristics: leaf color - leaf thickness - leaf surface - leaf lobulation - leaf apex shape - leaf base shape.
- Quantitative Characteristics: leaf length (cm) - leaf width (cm) - leaf petiole length (cm) - leaf blade area (cm^2) - shape index (length/width) - wet weight (g) - dry weight (g) - depth of leaf lobulation. Measurements were made from the middle of fresh branches formed during the growing season.

Flowers:

- Qualitative Characteristics: flowering date - flower color - flower petiole surface - flower density in the cluster - flower petiole thickness.
- Quantitative Characteristics: length of floral cluster (cm)- number of flowers per cluster - length of flower petiole (cm). Measurements were made along the entire circumference of the tree.

Fruits:

- Qualitative characteristics: fruit color - fruit surface - fruit lobulation - fruit taste.
- Quantitative characteristics: fruit length - fruit diameter - fruit shape index (length/diameter) - fruit weight - fruit size. The fruits were collected from the four sides of the tree and then measurements were made on them.

Seeds:

- Qualitative characteristics: seed color - seed shape - seed apex shape - seed surface shape.
- Quantitative characteristics: seed weight - seed size - seed length - seed width - seed shape index (length/width) - number of seeds per fruit.

Results and Discussion

Identifying the types of hawthorns in the study area:

As a result of the study, two different types of wild hawthorn and two types of cultivated hawthorn were identified. It was found that Yellow-Azarolus and Aronia are widespread in all regions, while Monogyna and red Azarolus are widespread in the Jisr Al-Shogour area only. Readings were taken on 3 trees of each identified type.

3-2- Morphological description:

3-2-1- Leaf characteristics:

The leaves of the hawthorn types were collected from the study areas, and the required quantitative and qualitative readings and measurements were taken. Fig. (1) shows the leaf shape in the studied hawthorn types, and Table (2) and Table (3) also show the qualitative and quantitative leaf characteristics (respectively) in the studied hawthorn types.

Fig. (1): Leaf shape in the studied hawthorn types (1- Aronia, 2- Monogyna, 3- Red Azarolus, 4- Yellow Azarolus)

Table (2): Leaf qualitative characteristics of the studied hawthorn types

Type	Color	Thickness	Surface	Lobulation	Apex shape	Base shape
Aronia	Dusty green	Medium	Dusty	3-5	Medium pointed	Sharp often
Monogyna	Bright green	Thin	Natural	3-5-(7)	Thin pointed	Obtuse often
Red Azarolus	Dark green	Thick	Shiny	3-5	wide	Sharp often
Yellow Azarolus	Dark green	Thick	Shiny	3-5	wide	Sharp often

We note from Table (2) the differences between the studied types in the qualitative characteristics of the leaf. In the characteristics of leaf color and thickness, the leaf color was dark green and of medium thickness in Aronia, the leaf color was bright green and had a thin thickness in Monogyna, and the leaf color was dark green and thick in Red Azarolus and Yellow Azarolus. The leaf surface was dusty in Aronia and normal in Monogyna, and the leaves were shiny in Red Azarolus and Yellow Azarolus. As for the leaf apex, it was moderately pointed in Aronia and wide in the Yellow Azarolus and Red Azarolus types, while in Monogyna it had a slightly pointed end. As for the shape of the leaf base, it is often sharp in the Yellow Azarolus, Red Azarolus, and Aronia models, and often obtuse in the Monogyna type.

Table (3): Leaf quantitative characteristics of the studied hawthorn types

Type	Length (cm)	Width (cm)	Petiole length (cm)	Lobulation depth (cm)	Shape index (length /width)	Blade area (cm^2)	Wet weight (g)	Dry weight (g)
Aronia	2.80^{b}	1.69^{b}	0.60^{b}	1.00^{b}	1.66^{a}	2.36^{b}	0.06^{b}	0.03^{b}
Monogyna	2.91^{b}	2.42^{ab}	1.15^{a}	1.53^{ab}	1.21 ^{a}	3.22^{b}	0.06^{b}	0.05^{b}
Red Azarolus	4.32^{a}	2.54^{ab}	0.43^{b}	2.22^{a}	1.99 ^{a}	7.35^{ab}	0.27^{ab}	0.13^{ab}
Yellow Azarolus	4.19^{a}	3.12^{a}	0.70^{b}	1.65^{ab}	1.35 ^{a}	10.85^{a}	0.47^{a}	0.27^{a}
Mean	3.56	2.44	0.72	1.60	1.55	5.95	0.22	0.12
L.S.D	0.66	1.07	0.31	0.88	1.06	4.77	0.30	0.21
C.V.%	9.80	23.30	22.8	29.20	36.30	42.60	74.40	92.80
F. pr.	<.001	0.08	0.00	0.07	0.39	0.01	0.04	0.10

It is noted from Table (3) that the studied hawthorn types varied in terms of leaf length. There were highly significant differences between the wild and cultivated types. The longest leaf length was in the Red Azarolus type and reached 4.32 cm, and the smallest leaf length was in the Aronia type and amounted to 2.80 cm. Both Yellow Azarolus and Red Azarolus (with no significant differences between them) outperformed Aronia and Monogyna with significant differences, and there were no significant differences between Aronia and Monogyna. Compared with the study of Khadivi *et al.* (2019), leaf length ranged from 1.98 to 5.31 cm in *C. monogyna*.

As for leaf width, the largest leaf width was 3.12 cm in the Yellow Azarolus type, and it was superior to the Aronia type with significant differences. The leaf width was 1.69 cm in Aronia, while there were no significant differences between it and the other types. Regarding the length of the leaf petiole, the Monogyna type outperformed the other types with highly significant differences of 1.15 cm. There were no significant differences between the other types. As can be seen from Table (3), the Red Azarolus was superior to the Aronia in terms of leaf lobation depth, and the values were respectively 2.22 cm and 1.00 cm. There were no significant differences between it and Monogyna and Yellow Azarolus, and there were no significant differences between Yellow Azarolus and Monogyna and Aronia. As for the shape index, there were no significant differences between the studied types.

By comparing the values in Table (3) for leaf area, we find that the Yellow Azarolus outperformed both Aronia and Monogyna, and the values were, respectively, 10.85 cm^2, 2.36 cm^2, and 3.22 cm^2, while there were no significant differences between the Yellow Azarolus and the Red Azarolus in which the leaf area was 7.35 cm^2, and there were no significant differences between Red Azarolus, Aronia, and Monogyna.

As for the wet weight of the leaf, the Yellow Azarolus was superior to both Aronia and Monogyna with a value of 0.47 g, with significant differences. There were no differences between Aronia and Monogyna, and the wet weight of each of them reached 0.06 g, and there were no differences between the Red Azarolus and the other types. Likewise, in terms of leaf dry weight, the Yellow Azarolus was superior to both Monogyna and Aronia with a value of 0.27 g, with significant differences, where the values reached 0.05 and 0.03, respectively. There were no differences between Yellow Azarolus and Red Azarolus, and there were no differences between Red Azarolus and Aronia and Monogyna.

3-2-2- Flower characteristics:

The flowers of the hawthorn types were collected from the study areas, and the required quantitative and qualitative readings and measurements were taken. Fig. (2) shows the shape of the flowers in the studied hawthorn types, and Table (4) and Table (5) also show the qualitative and quantitative flower characteristics (respectively) in the studied hawthorn species.

Fig. (2): Flower shape in the studied hawthorn types (1- Aronia, 2- Monogyna, 3- Red Azarolus, 4- Yellow Azarolus)

Table (4): Flower qualitative characteristics of the studied hawthorn types

Type	**Flowering date**	**Color**	**Petiole surface**	**Density / cluster**	**Petiole thickness**
Aronia	April	white	Fluffy	Dense	Medium
Monogyna	Mid-March	White /pink	Smooth	Unique	Thin
Red Azarolus	April	white	Fluffy	Dense	Thick

Yellow Azarolus	April	white	Flu ffy	Den se	Thic k

As shown in Table (4), the Monogyna type excelled in early flowering date, as it was in mid-March, while there were no differences in flowering date between the types Aronia, Red Azarolus, and Yellow Azarolus, as their flowering was in April. In terms of flower color, it was white in the Aronia, Red Azarolus, and Yellow Azarolus types, while it was white or pink in the Monogyna type. As for the surface of the flower petiole, it was fluffy in the types Aronia, Red Azarolus, and Yellow Azarolus, and smooth in the Monogyna type. As for the density of flowers in the cluster, it was dense in the Aronia, Red Azarolus, and Yellow Azarolus types, and unique in the Monogyna type. As for the thickness of the flower petiole, it was thin in the Monogyna type, medium in the Aronia type, and thick in the cultivated types Red Azarolus and Yellow Azarolus.

Table (5): Flower quantitative characteristics of the studied hawthorn types

Type	Cluster length (cm)	Number of flowers/ cluster	Flower petiole length (cm)
Aronia	4.28^{b}	11.67^{a}	0.25^{b}
Monogyn a	3.58^{c}	5.33^{b}	1.24^{a}
Red Azarolus	8.70^{a}	12.67^{a}	0.25^{b}
Yellow Azarolus	8.53^{a}	10.00^{ab}	0.38^{b}
Mean	6.27	9.92	0.53
L.S.D	0.48	5.24	0.24
C.V.%	4.10	28.10	24.10
F. pr.	<.001	0.05	<.001

We note from Table (5) that the two types, Red Azarolus and Yellow Azarolus, were superior in terms of inflorescence length, with highly significant differences, to the two types, Aronia and Monogyna, while there were no significant differences between them, and the inflorescence length in them was, respectively, 8.70 cm and 8.53 cm. The Aronia type, with a value of 4.28 cm, outperformed Monogyna, with a value of 3.58 cm. As for the number of flowers on the cluster, Red Azarolus and Aronia outperformed Monogyna, with significant differences amounting to 12.67, 11.67, and 5.33, respectively, while there were no significant differences between Yellow Azarolus and the other types, which had a value of 10. As for the length of the flower petiole, the Monogyna type outperformed the other type with highly significant differences, with a value of 1.24 cm, while there were no significant differences between the other types, reaching 0.38 cm for the Yellow Azarolus and 0.25 cm for both the Red Azarolus and Aronia.

3-2-3- Fruit characteristics:

The fruits of the hawthorn types were collected from the study areas, and the required quantitative and qualitative readings and measurements were taken. Fig. (3) shows the shape of the fruits in the studied hawthorn types. Table (6) and Table (7) also show the qualitative and quantitative characteristics of the fruit (respectively) in the studied hawthorn types.

Fig. (3): Fruit shape in the studied hawthorn types (1- Aronia, 2- Monogyna, 3- Red Azarolus, 4- Yellow Azarolus)

Table (6): Fruit qualitative characteristics of the studied hawthorn types

Type	Color	Surface	Lobulation	Taste
Aronia	Yellow-orange	Fluffy	Lobulated	Acidic
Monogyna	Red	Smooth	Not lobulated	Natural
Red Azarolus	Red	Fluffy	Not lobulated	sweet
Yellow Azarolus	Yellow	Fluffy	Lobulated	sweet

It is clear from Table (6) that the color of the fruit in the Aronia type was yellow with orange at maturity, while the fruit in the Yellow Azarolus type was yellow, and as for the Monogyna and Red Azarolus types, the fruit color was red. Regarding the outer covering of the fruit, Aronia, Yellow Azarolus, and Red Azarolus types were fluffy, while the fruit in the Monogyna type was smooth. In terms of the lobularity of the fruit, Aronia and Yellow Azarolus were lobed (about five lobes), while the Red Azarolus and Monogyna were not lobed. Regarding the taste of the fruit, the taste was sour in the Aronia type, natural in the Monogyna type, and sweet in the Yellow Azarolus and Red Azarolus types.

Table (7): Fruit quantitative characteristics of the studied hawthorn types

Type	Length (cm)	Diameter (cm)	Shape index (length/diameter)	Weight (g)	Size (cm^3)
Aronia	1.16^{b}	1.40^{b}	0.84^{a}	2.72^{b}	2.97^{b}
Monogyna	0.76^{c}	0.55^{c}	0.80^{a}	0.38^{c}	0.49^{c}
Red Azarolus	1.58^{a}	1.82^{ab}	0.88^{a}	4.55^{ab}	5.89^{a}
Yellow Azarolus	1.56^{a}	2.08^{a}	0.80^{a}	6.34^{a}	7.51^{a}
Mean	1.291	1.462	0.83	3.50	1.87
L.S.D	0.3042	0.4222	0.1642	2.23	25.50
C.V.%	11.8	14.5	9.9	31.90	<.001
F. pr.	0.001	<.001	0.614	0.00	1.87

We notice from Table (7) that the types differ in terms of fruit length. Red Azarolus and Yellow Azarolus, with values reaching 1.58 cm and 1.56 cm respectively (with no significant differences between them), outperformed the Aronia and Monogyna types, while the Aronia type outperformed the Monogyna type, with values reaching 1.16. cm and 0.76 cm respectively. In terms of fruit diameter, Yellow Azarolus was superior to Aronia and Monogyna, with values reaching 2.08 cm, 1.40 cm, and 0.55 cm, respectively, while there were no significant differences between Yellow Azarolus and Red Azarolus, whose values reached 1.82 cm. As for the shape index, there were no significant differences between the studied types. In terms of fruit weight, the Yellow Azarolus was superior to Aronia and Monogyna, with values reaching 6.34, 2.72, and 0.38 g, respectively, while there were no significant differences between it and Red Azarolus, which had an average fruit weight of 4.55 g. Likewise, Red Azarolus was superior to Aronia and Monogyna with no significant differences between it and Aronia, whose fruit weight reached 2.72 g, while the Monogyna type, whose fruit weight reached 0.38 g. In terms of fruit size, Yellow Azarolus, and Red Azarolus outperformed the other types with values of 7.51 cm^3 and 5.89 cm^3, respectively, while Aronia outperformed Monogyna with values reaching 2.97 cm^3 and 0.49 cm^3, respectively.

Our results are consistent with the results of Stoenescu and Cosmulescu (2020) when they analyzed 22 genotypes of *Crataegus monogyna* divided into three groups to determine their diversity within the forest ecosystem, where the weight of the fruit ranged between 0.18 g and 1.15 g, and the height of the fruit ranged between 0.64 cm and 1.26 cm, and the diameter of the fruit ranged between 0.58 cm and 1.39 cm. The results were close to those of Khadivi *et al.* (2019), where the weight of the fruit ranged between 0.31 g and 1.28 g in *Crataegus monogyna*.

3-2-4- Seed characteristics:

The fruits of the hawthorn types were collected from the study areas and the required quantitative and qualitative readings and measurements were taken. Fig. (4) shows the shape of the seeds in the studied hawthorn types. Table (8) and Table (9) also show the qualitative and quantitative seed characteristics (respectively) in the studied hawthorn types.

Fig. (4): Seed shape in the studied hawthorn types (1- Aronia, 2- Monogyna, 3- Red Azarolus, 4- Yellow Azarolus)

Table (8): Seed qualitative characteristics of the studied hawthorn types

Type	**Color**	**Shape**	**Apex shape**	**Surface shape**
Aronia	Light brown	Flattened	Pointed	Smooth
Monogyna	Dark brown	Spherical	Spherical	Grooved
Red Azarolus	Light brown	Flattened	Pointed	Smooth
Yellow Azarolus	Light brown	Flattened	Pointed	Smooth

Table (8) shows that the seed color was light brown in Aronia, Yellow Azarolus, and Red Azarolus types, and dark brown in Monogyna type. The shape of the seed was Flattened in Aronia, Yellow Azarolus, and Red Azarolus types, and it was spherical in Monogyna type. The seed apex was pointed in Aronia, Yellow Azarolus, and Red Azarolus, and spherical in Monogyna. The seed surface was also smooth in Aronia, Yellow Azarolus, and Red Azarolus types, and had grooves in Monogyna type.

Table (9): Seed quantitative characteristics of the studied hawthorn types

Type	**Length (cm)**	**Width (cm)**	**Weight (g)**	**Size**	**Shape index (length /width)**	**Number of seeds /fruit**

				(cm^3)		
Aronia	0.73^{ab}	0.36^{b}	2.69^{a}	2.22^{a}	2.01^{a}	2-3
Monogyna	0.52^{b}	0.37^{b}	1.24^{a}	0.91^{a}	1.41^{b}	1
Red Azarolus	0.73^{ab}	0.39^{ab}	1.80^{a}	2.80^{a}	1.83^{a}	2-3
Yellow Azarolus	0.97^{a}	0.52^{a}	3.99^{a}	3.43^{a}	1.85^{a}	2-3
Mean	0.74	0.41	2.43	2.34	1.78	2.13
L.S.D	0.41	0.14	3.62	2.71	0.42	
C.V.%	29.80	18.60	79.20	61.40	12.70	
F. pr.	0.18	0.11	0.38	0.25	0.06	

Table (9) shows that the Yellow Azarolus type was superior to the Monogyna type in seed length with a value of 0.97 cm, while there were no significant differences between it and the Red Azarolus and Aronia types, as the seed length in them reached 0.73 cm, and there were no significant differences between them and Monogyna type whose seed length is 0.52 cm. As for seed width, the Yellow Azarolus type with a value of 0.52 cm outperformed the types Monogyna and Aronia with values of 0.37 cm and 0.36 cm, respectively, while there were no significant differences between the Red Azarolus and the other types, which had a seed length of 0.39 cm. Regarding seed weight and size, there were no significant differences between the studied types. The average seed weight was 2.43 g and the average seed size was 2.34 cm^3 for all studied types. As for the seed shape index, Aronia, Yellow Azarolus, and Red Azarolus types, with values reaching 2.01, 1.85, and 1.83, respectively, outperformed the Monogyna type which had a seed shape index of 1.41.

3-3- Correlation analysis:

A correlation analysis was conducted between the different traits of the studied hawthorn types. Table (10) shows the results of the correlation analysis.

Table (10): Analysis of the correlation between the studied traits

Pearson Correlation	Leaf length	Leaf petiole	Lobulation depth	Leaf width	Leaf area	Leaf wet weight	Leaf dry weight	Floral cluster	N flowers/cl	Fl petiole length	Fruit length	Fruit diameter	Fruit weight	Fruit size	Seed length	Seed width	Seed weight	Seed size	Number of seeds
Leaf length	1																		

Leaf petiole length	-0.556	1																	
Lobulation depth	0.824	-0.300	1																
Leaf width	0.761	0.082	0.620	1															
Leaf area	0.905	-0.333	0.586	0.898	1														
Leaf wet weight	0.879	-0.369	0.510	0.860	**.995****	1													
Leaf dry weight	0.815	-0.239	0.444	0.895	**.984***	**.989***	1												
Floral cluster length	**.986***	-0.657	0.735	0.694	0.903	0.894	0.822	1											
N flowers/cluster	0.480	**-.995****	0.201	-0.156	0.274	0.319	0.191	0.593	1										
F petiole length	-0.479	**.958***	-0.088	0.078	-0.366	-0.427	-0.319	-0.609	**-.973***	1									
Fruit length	0.885	-0.788	0.502	0.526	0.840	0.863	0.785	0.950	0.752	-0.803	1								
Fruit diameter	0.798	-0.802	0.350	0.441	0.791	0.831	0.758	0.885	0.782	-0.858	**.986***	1							
Fruit weight	0.839	-0.674	0.386	0.597	0.888	0.921	0.870	0.909	0.646	-0.744	**.976***	**.981***	1						
Fruit size	0.886	-0.688	0.473	0.623	0.903	0.927	0.869	0.945	0.652	-0.731	**.988***	**.977***	**.995****	1					
Seed length	0.643	-0.549	0.097	0.516	0.807	0.864	0.844	0.738	0.548	-0.703	0.870	0.920	**.950***	0.916	1				
Seed width	0.652	-0.098	0.232	0.847	0.912	0.932	.971*	0.670	0.069	-0.238	0.670	0.673	0.800	0.777	0.848	1			
Seed weight	0.370	-0.342	-0.214	0.391	0.642	0.717	0.734	0.478	0.369	-0.568	0.660	0.752	0.793	0.731	0.944	0.818	1		
Seed size	0.787	-0.754	0.317	0.479	0.815	0.858	0.795	0.875	0.736	-0.829	**.978***	**.997****	**.990****	**.981***	0.948	0.726	0.798	1	
Number of seeds	-0.629	0.634	-0.826	-0.111	-0.238	-0.186	-0.061	-0.595	-0.565	0.391	-0.469	-0.354	-0.275	-0.359	0.027	0.179	0.350	-0.286	1

***** Correlation is significant at the 0.05 level; ** Correlation is significant at the 0.01 level***

Table (10) shows that there is a high positive linear correlation between the leaf area and the wet weight of the leaf and a positive correlation between the dry weight of the leaf and the wet weight and the leaf area. Regarding flower characteristics, there is a positive correlation between the length of the cluster and the length of the leaf, and the length of the flower petiole and the length of the leaf petiole. As for fruit characteristics, fruit weight was positively and highly correlated with its size, and there was a positive correlation between the diameter of the fruit and the length of the fruit, and a positive correlation between the weight and size of the fruit with the length and diameter of the fruit. As for the seed, the length of the seed was positively correlated with the weight of the fruit, and the size of the seed was positively correlated. With both fruit length and fruit size, there was also a strong positive correlation between seed size, fruit diameter, and fruit weight. We also notice from Table (10) that there are strong negative correlations between the number of flowers on the cluster and the length of the leaf petiole and a negative correlation between the length of the flower petiole and the number of flowers on the cluster.

3-4- Cluster analysis:

Hierarchical cluster analysis gave the results shown in Fig. (5).

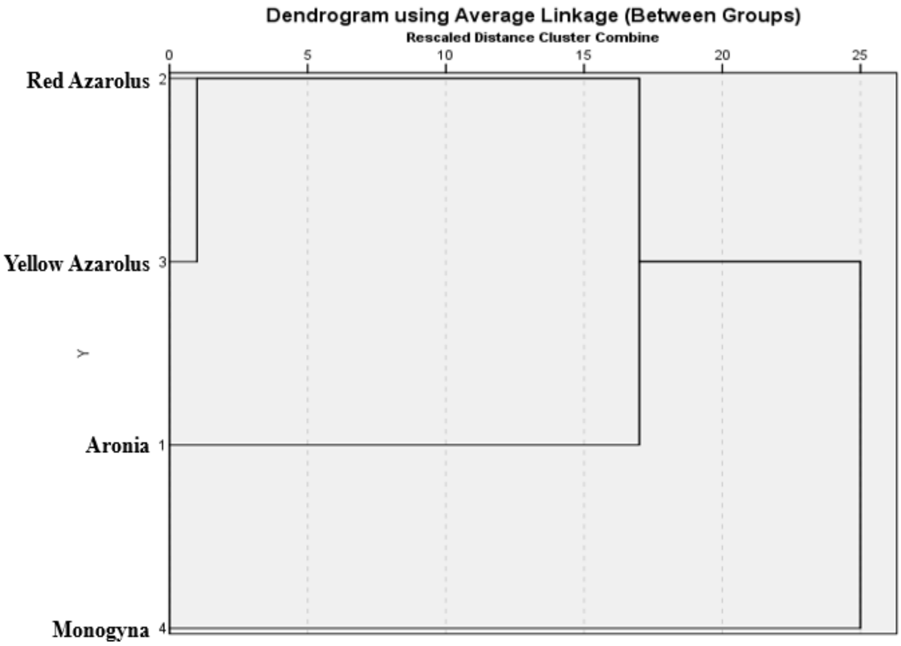

Fig. (5): Hierarchical cluster analysis of the studied types

We notice from Fig. (5) that the types were divided into two main groups: Group (A) included three types, divided into two subgroups: the first subgroup included the Yellow Azarolus, and the Red Azarolus (we notice a very high similarity between the two types), and the second subgroup included the Aronia type. Group B included only Monogyna type. Cluster analysis is useful in determining the degree of relatedness between the studied types, which is important in breeding and hybridization programs between species and varieties, by reducing the number of inputs used in the hybridization and pollination processes and relying on genetically divergent parents, which ensures obtaining a broad genetic base (Thanh *et al.*, 2006). Cluster analysis has been used to determine the degree of morphological relatedness between hawthorn species (Albarouki and Peterson, 2007; Layka *et al.*, 2009; Ma and Lu., 2016; Erfani-Moghadam, 2016; Yildiz, 2022).

3-5- PCA analysis:

Tables (11 and 12) and Fig. (6) show the results of the analysis of the principal components responsible for the variation between the hawthorn studied types.

Table (11): The main factors responsible for the total variance

Total Variance Explained									
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	13.157	69.247	69.247	13.157	69.247	69.247	9.408	49.518	49.518

2	3.297	17.353	86.600	3.297	17.353	86.600	6.462	34.009	83.527
3	2.546	13.400	100.000	2.546	13.400	100.000	3.130	16.473	100.000
4	1.154E-15	6.074E-15	100.000						
5	7.205E-16	3.792E-15	100.000						
6	4.298E-16	2.262E-15	100.000						
7	3.849E-16	2.026E-15	100.000						
8	2.746E-16	1.445E-15	100.000						
9	1.966E-16	1.035E-15	100.000						
10	1.724E-16	9.075E-16	100.000						
11	-3.398E-17	-1.788E-16	100.000						
12	-1.375E-16	-7.236E-16	100.000						
13	-2.127E-16	-1.120E-15	100.000						
14	-2.445E-16	-1.287E-15	100.000						
15	-2.834E-16	-1.492E-15	100.000						
16	-3.460E-16	-1.821E-15	100.000						
17	-5.413E-16	-2.849E-15	100.000						
18	-7.293E-16	-3.838E-15	100.000						
19	-1.402E-15	-7.377E-15	100.000						

Extraction Method: Principal Component Analysis.

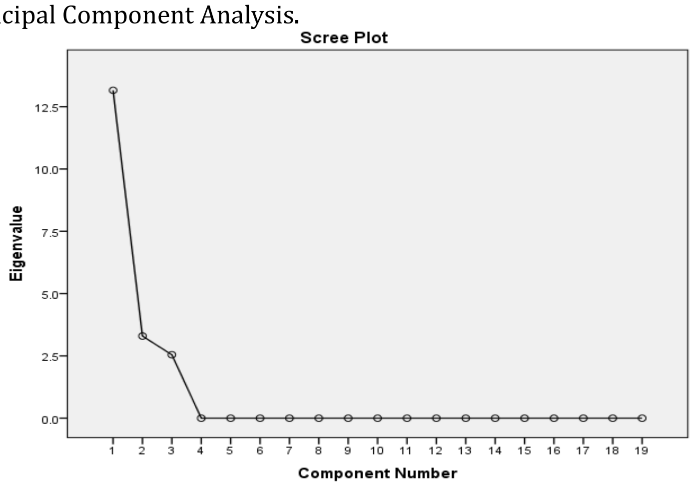

Fig. (6): Factors constituting variance

Table (12): The main components of the factors responsible for the variance

Component Matrix[a]			
	Component		
	1	2	3
Fruit size	0.999	-0.031	0.030
Fruit weight	0.992	-0.011	0.125

Fruit length	0.983	-0.182	-0.008
Seed size	0.972	-0.130	0.197
Fruit diameter	0.966	-0.202	0.158
Cluster length	0.953	-0.057	-0.298
Leaf wet weight	0.940	0.337	-0.060
Leaf area	0.919	0.359	-0.160
Seed length	0.907	0.105	0.407
Leaf length	0.901	0.021	-0.434
Leaf dry weight	0.884	0.466	-0.019
Seed wide	0.791	0.588	0.168
Seed weight	0.720	0.236	0.653
Flower petiole length	-0.702	0.634	-0.324
N flowers/cluster	0.624	-0.766	0.153
Leaf petiole length	-0.664	0.745	-0.061
Leaf wide	0.655	0.664	-0.362
Lobulation depth	0.498	-0.029	-0.866
N seeds/fruit	-0.362	0.586	0.725

Extraction Method: Principal Component Analysis

Principal components analysis (PCA) Fig. (6), Table (11) and Table (12) indicate that there are 3 main factors responsible for 100% of the variances between the types, and the factor PC1 was responsible for 69.25% of the variances, which was positively determined by fruit size (+0.999), fruit weight (+0.992), fruit length (0.983), seed size (0.972), fruit diameter (0.966), floral cluster length (0.953), leaf wet weight (0.940), leaf area (0.919), seed length (0.907), leaf length (0.901), leaf dry weight (0.884), seed width (0.791), seed weight (0.720), number of flowers per cluster (0.624), leaf width (0.655), and the lobulation depth in the leaf (0.498). As for the variables that were combined by PC2, which accounted for 17.35% of the variances, they were positively identified by leaf wet weight (0.337), leaf area (0.359), seed length (0.105), leaf length (0.021), leaf dry weight (0.466), seed width (0.588), seed weight (0.236), flower petiole length (0.634), leaf petiole length (0.745), leaf width (0.664), and the number of seeds per fruit (0.586). As for the third factor, PC3, it accounted for 13.40% of the variances, and the positive variables included fruit size (0.030), fruit weight (0.125), seed size (0.197), fruit diameter (0.158), seed length (0.407), seed width (0.168), seed weight (0.653), the number of flowers per cluster (0.153) and the number of seeds per fruit (0.725).

Conclusion

The The results showed that there were significant differences between the hawthorn types in most of the studied leaf characteristics (leaf length and width, leaf lobation depth, leaf area, leaf wet and dry weight), as well as in the characteristics of the floral cluster (cluster length and flower petiole length). and they. The hawthorn studied types also varied in the characteristics of the fruit, whether quantitative (fruit length and width, fruit petiole length, fruit size, fruit weight) or qualitative characteristics of the fruit (fruit color), and in the characteristics of the seeds (length, width, weight, size, and number of seeds per fruit).

The correlation analysis table showed that there is a high positive linear correlation between the leaf area and the leaf wet weight, between the fruit size and the fruit weight, and between the seed size and the seed diameter and weight.

The results of the cluster analysis of the characteristics showed that the studied hawthorn types were grouped into two main clusters. The first cluster included 3 subgroups (Aronia, Yellow Azarolus, and Red Azarolus), while the second cluster included one subgroup, Monogyna.

Principal component analysis (PCA) showed that there were 3 main factors responsible for 100% of the variances between the types. The PC1 factor was responsible for 69.3%. It was positively determined by fruit size and fruit weight, fruit length and seed size, fruit diameter, floral cluster length, leaf wet weight, leaf area, seed length, leaf length, leaf dry weight, seed width, seed weight, number of flowers per cluster, leaf width, and lobulation depth. As for the variables combined by PC2, it was responsible for 17.4% of the variances, and the third factor, PC3, accounted for 13.4% of the variances between the types.

The Azarolus types spread mainly in the northwestern region of Syria, and to a lesser extent the Monogyna. There is also a great genetic relationship between the wild type Aronia and the cultivated types, Yellow Azarolus and Red Azarolus.

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