



## A Cytogenetic Review of Chromosomal Diversity and Karyotype Variation in Endemic Plants of El-Jabal El-Akhdar, Libya

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### A B S T R A C T

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The El-Jabal El-Akhdar region in northeastern Libya constitutes one of the most important centers of plant endemism within the country; however, cytogenetic information on its flora remains scarce. This review compiles available data on chromosome numbers and karyotype characteristics for 61 endemic taxa (54 species and 7 subspecies) belonging to 48 genera and 28 families, based on previously published studies and chromosome information documented in IPCN database. Somatic chromosome numbers have been reported for only (17/61≈27.87%) of these taxa, varying from  $2n = 8$  to  $2n = 96$ , with diploidy representing the most common ploidy level (14.75%). Available karyotype studies indicate considerable variation in ploidy levels, karyotype symmetry and asymmetry, chromosome size, and the occurrence of satellite chromosomes. Marked chromosomal differences among closely related species highlight the value of karyotype data in plant taxonomy. Nevertheless, the majority of endemic taxa remain cytogenetically unexplored, highlighting the urgent need for comprehensive cytogenetic investigations to clarify evolutionary relationships and to support effective conservation strategies.

## 1 Introduction

Libya is recognized as one of the largest countries in North Africa, with an estimated area of approximately 1.7 million km<sup>2</sup>. The landscape is predominantly dominated by desert and semi-deserts environments, whereas Mediterranean-type vegetation is largely confined to the coastal zones (Thor & Nascimbene, 2010). The main centers of plant diversity are located along the coastal strip and the adjacent mountainous regions bordering the Mediterranean Sea (Radford, 2011). The flora of Libya comprises 2,118 species distributed among 864 genera and 161 families. Angiosperms constitute the majority, accounting for 2,088 species distributed across 844 genera and 145 families. In contrast, gymnosperms are presented by 15 species within 8 genera and 6 families, while pteridophytes comprise 15 species belonging to 12 genera and 10 families (Mahklouf & Etayeb, 2018). In general, the proportion of endemic species within the

Libyan flora remains relatively low, not exceeding 7%. The total number of endemic taxa is estimated at around 80-81 species, which are unevenly distributed across four principal centers of endemism. These include El-Jabal El-Akhdar (44 species), the coastal zone encompassing Jabal Nafusah and the Marmarica plateau (26 species), the central Sahara (8-9 species), and the plateaus of Ghat, Tibesti, and Aweinat (2 species) (Mahklouf & Etayeb, 2018).

The term "endemic" can apply to any taxonomic level that is restricted to a specific biogeographic unit. Endemic species are typically concentrated in a limited number of taxa and do not represent a random taxonomic distribution (Dhar, 2002). Endemic species can be found across a wide range of spatial scales, extending from continental regions to much smaller areas such as islands or mountain peaks. Endemic plant species can be categorized as local (restricted to a small area), provincial (limited to the borders of a province), national (limited to the borders of a country), regional

(limited to a geographical region), or continental (limited to a continent) based on their distribution scale (Ladle & Whittaker, 2011).

Karyotyping is considered one of the most important analytical tools in studying endemism (Siljak-Yakovlev & Peruzzi, 2012; Sun et al., 2019). The technique was first applied to endemic flora by Chiarugi (1949). Favarger and Contandriopoulos (1961) proposed four categories of endemism based on ploidy levels: paleoendemism (diploids or paleopolyploids), patroendemism (ancient diploid endemics originating from their progenitor polyploid taxa), schizoendemism (retaining the same chromosome number as their progenitor), and apodemism (in contrast to patroendemism, apodemism are polyploid derivatives from widespread diploids). Stebbins and Major (1965), on the other hand, suggested two categories of endemism based on geographical distribution: paleoendemism (ancient taxa confined to a specific region with a relict distribution, whose endemism resulted from habitat loss) and neo-endemism (recently originated taxa that have not spread to other regions).

Polyploidy, involving genome duplication, is often considered a mechanism that can lead to rapid sympatric speciation, alongside structural chromosomal changes including deletions, insertions, inversions, gene duplications, and reciprocal translocations within or between chromosomes, plays a significant role in shaping plant evolutionary processes (Van de peer et al., 2017; Villa et al., 2022).

According to Villa et al. (2022), the separation between paleo-endemic and neoendemic taxa is often unclear defined. Although the classification of endemic plant species based on their evolutionary origin has received considerable attention (Favarger & Contandriopoulos, 1961; Stebbins & Major, 1965), a clear cut temporal boundary distinguishing neo- from paleo-endemism has not yet been established.

This review aims to compile and critically analyze the available cytogenetic data on endemic plants of the El-Jabal El-Akhdar region, including chromosome numbers, karyotype features, and ploidy levels. By synthesizing data from published studies and the IPCN database, this study seeks to identify gaps in current knowledge, highlight chromosomal patterns relevant to taxonomy and evolution, and provide a foundation for future cytogenetic and conservation research in the region.

## 2. Endemism and Taxonomic Composition in El-Jabal El-Akhdar

The region situated in northeastern Libya forms part of the Mediterranean Basin hotspot of biodiversity (Myers et al., 2000; Mittermeier et al., 2011) (Fig.1). Despite covering only approximately 1% of Libya's total land area, it harbors nearly 65% of the national flora, including about 50% of Libya's endemic plant

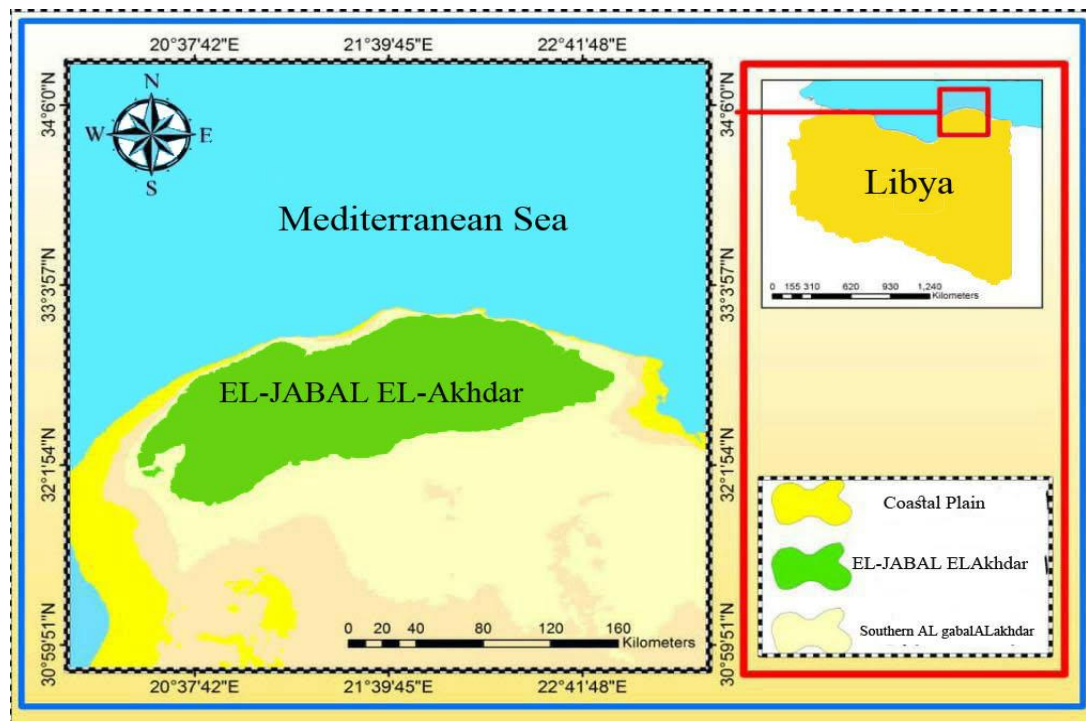
species. As a result, the region is widely recognized as one of the principal centers of plant endemism in the country (Elshatshat, 2009; Radford, 2011; El-Barasi & Saaed, 2013). High levels of endemism are often associated with increased extinction risk; thus, regions with substantial endemic richness are considered priorities for biodiversity conservation (Myers et al., 2000; Lamoreux et al., 2006).

The remarkable concentration of endemic flora in this region may be attributed to its unique climatic and physiographic conditions, which differ significantly from most of the country. The area experiences a Mediterranean-type climate characterized by dry summers, with spring representing the primary growing season. The rocky, stony terrain is crossed by numerous wadis (valleys), and receives 250–600 mm of annual rainfall, with soils predominantly of terra rossa or heavy clay type. Geographically, the region represents a distinctive habitat island, isolated by the surrounding desert in the south and the Mediterranean Sea along its northern and western boundaries (Sharaf, 1971; Hunt et al., 2024). These conditions have created an environmental refuge that supports the restricted distribution of several endemic plant species (Qaiser & El-Gadi, 1984; Al-Sodany et al., 2003; El-Darier & El-Mogaspi, 2009).

Environmental factors, including climate, soil characteristics, and topography, are widely recognized as key determinants of plant endemism. However, this perspective may overlook the significant role of natural hybridization processes. Ietswaart (1980) and Martin et al. (2020) emphasize that hybridization plays a central role in speciation, with ecological factors acting as supporting influences. Therefore, both natural hybridization and polyploidy should be considered alongside ecological factors when interpreting patterns of plant endemism.

Endemic plants carry unique genetic diversity within a country's flora. Libya's flora is not particularly rich in endemic species, and there are no endemic plant families in the country. However, three endemic genera exist, each represented by a single plant species: *Pachytenium mirabile* (Umbiliferae), *Libyella cyrenaica* (Gramineae), and *Oudneya africana* (Cruciferae). The first two genera are found in the El-Jabal El-Akhdar region, whereas the third is confined to the desert region (Mahklof & Etayeb, 2018).

El-Jabal El-Akhdar, considered the most important natural habitat in Libya, faces numerous environmental challenges. Endemic taxa are increasingly threatened by the loss of genetic diversity as a result of harvesting of medicinal and woody plant species for local consumption and trade. Additional pressures include intensive grazing, agricultural expansion, recurrent drought events, and other widespread environmental stresses characteristic of the region (El-Darier & El-Mogaspi, 2009).



**Figure 1.** Picture of El-Jabal El-Akhdar, Libya

Chromosomes are unique, stable and definite structures in any living organism, and their number, form, and size have been used alongside morphological and ecological differences to circumscribe plant populations (Adeigbe *et al.*, 2013). The flora of the study area is distinguished by its rich diversity of endemic plants. However, cytological data from this region are not comprehensively studied, highlighting the scarcity of available data. This underscores the need to document chromosomal diversity at the regional level. Chromosomal information plays a key role in species delimitation, provides insight into relationships based on chromosomal variation and similarities, and contributes to accurate taxonomic identification.

A list of endemic plant species names and their geographical distributions in the El-Jabal El-Akhdar region is documented in Table 1 (Ali & Jafri, 1976-1989; Dobignard & Chatelain, 2010-2013; POWO, 2024). The flora of the El-Jabal El-Akhdar region includes 61 endemic species (54 species and 7

subspecies) belonging to 48 genera and 28 families, with updated scientific names for 15 endemic species and 7 families. The dominant families in the region are Lamiaceae (12 species, 19.67% of endemics), and Asteraceae (10 species, 16.39% of endemics). The families Crassulaceae, Plumbaginaceae, and Caryophyllaceae are represented by 3 species each (4.92% of endemics), while Apiaceae, Poaceae, Geraniaceae, Asparagaceae, Caprifoliaceae, Plantaginaceae, and Iridaceae are represented by 2 species each (3.28% of endemics). Furthermore, Orchidaceae, Amaryllidaceae, Araceae, Convolvulaceae, Liliaceae, Ericaceae, Euphorbiaceae, Hypericaceae, Orobanchaceae, Polygalaceae, Primulaceae, Rubiaceae, Ranunculaceae, Rhamnaceae, Santalaceae, and Papaveraceae are each represented by one species (1.64% of endemics) (Fig.2). Photographs of some endemic plant taxa from Green Mountain (El-Jabal El-Akhdar) were taken in their natural habitats (Fig.3).

**Table 1.** Check list of the plants endemic to the El-Jabal El-Akhdar region.

No.	Scientific name	Accepted name	Family	New family
1	<i>Stachys rosea</i> (Desf.) Boiss.		Lamiaceae	
2	<i>Ballota andreuziana</i> Pamp.		Lamiaceae	
3	<i>Micromeria guichardii</i> (Quez. & Zaff.) Brullo & Furnari		Lamiaceae	
4	<i>Micromeria Juliana</i> var. <i>conferta</i> Coss. & Daveau	<i>Micromeria conferta</i> (Coss. & Daveau) Stefani	Lamiaceae	
5	<i>Nepeta cyrenaica</i> Quézel & Zaffran		Lamiaceae	
6	<i>Nepeta vivianii</i> (Coss.) Bég. & Vacc.		Lamiaceae	
7	<i>Origanum cyrenaicum</i> Bég. & Vacc.		Lamiaceae	
8	<i>Teucrium apollinis</i> Maire & Wailler		Lamiaceae	
9	<i>Teucrium barbeyanum</i> Asch. & Taub.		Lamiaceae	
10	<i>Teucrium davaeanum</i> Coss.		Lamiaceae	
11	<i>Teucrium zanonii</i> Pamp.		Lamiaceae	
12	<i>Thymbra linearifolia</i> (Brullo & Furnari) Brauchler		Lamiaceae	
13	<i>Cicerbita haimanniana</i> Beauverd	<i>Lactuca haimanniana</i> Asch.	Asteraceae	
14	<i>Tolpis vurgata</i> subsp. <i>apolloniae</i> Brullo & Furnari		Asteraceae	
15	<i>Anthemis toubertii</i> Barratte & E.A.Durand		Asteraceae	
16	<i>Anthemis cyrenaica</i> var. <i>radiata</i> Pamp.	<i>Anthemis cyrenaica</i>	Asteraceae	
17	<i>Centaurea cyrenaica</i> Bég. & Vacc.		Asteraceae	
18	<i>Pallenis cyrenaica</i> Alavi		Asteraceae	

19	<i>Echinops cyrenaicus</i> E.A.Durand & Barratte		Asteraceae	
20	<i>Onopordum cyrenaicum</i> Maire & Weiller		Asteraceae	
21	<i>Picris mauginiana</i> Pamp.		Asteraceae	
22	<i>Senecio trilobus</i> L.		Asteraceae	
23	<i>Sedum mirum</i> Pamp.	<i>Umbilicus mirus</i> (Pamp.) Greuter	Crassulaceae	
24	<i>Sedum cyrenaicum</i> Brullo & Furnari	<i>Sedum creticum</i> subsp. <i>cyrenaicum</i> (Brullo & Furnari) Afferni	Crassulaceae	
25	<i>Sedum bracteatum</i> Viv.		Crassulaceae	
26	<i>Limonium cyrenaicum</i> (Rouy) Brullo.		Plumbaginaceae	
27	<i>Limonium subrotundifolium</i>		Plumbaginaceae	
28	<i>Limonium teuchirae</i> Brullo		Plumbaginaceae	
29	<i>Pachyctenium mirabile</i> Maire & Pamp.	<i>Daucus mirabilis</i> (Maire & Pamp.) Reduron, Banasiak & Spalik	Umbiliferae	Apiaceae
30	<i>Athamanta della-cellae</i> Asch. & Barbey ex E.A.Durand & Barratte	<i>Daucus della-cellae</i> (Asch. & Barbey ex E.A.Durand & Barratte) Spalik, Banasiak & Reduron	Apiaceae	
31	<i>Libyella cyrenaica</i> (E.A.Durand & Barratte) Pamp.	<i>Poa cyrenaica</i> E.A.Durand & Barratte	Gramineae	Poaceae
32	<i>Poa pentapolitana</i> H.Scholz		Poaceae	
33	<i>Silene cyrenaica</i> Maire & Weiler		Caryophyllaceae	
34	<i>Petrohagia rupestris</i> Brullo & Furnari		Caryophyllaceae	
35	<i>Petrohagia cyrenaica</i> (E.A.Durand & Barratte) Ball.		Caryophyllaceae	

36	<i>Bellevia cyrenaica</i> Maire & Weiller		Liliaceae	Asparagaceae
37	<i>Scilla cyrenaica</i> (Pamp.) Bartolo, Brullo, Pavone & Terrasi	<i>Prospero cyrenaica</i> (Pamp.) Speta	Liliaceae	Asparagaceae
38	<i>Gagea trinervia</i> (Viv.) Greuter		Liliaceae	
39	<i>Crocus boulosii</i> Greuter		Iridaceae	
40	<i>Romulea cyrenaica</i> Bég.		Iridaceae	
41	<i>Orchis cyrenaica</i> Barratte & E.A.Durand	<i>Anacamptis cyrenaica</i> (E.A.Durand & Barratte) H.Kretzschmar, Eccarius & H.Dietr	Orchidaceae	
42	<i>Euphorbia pseudoapios</i> Maire & Weiller		Euphorbiaceae	
43	<i>Hypericum decaisneanum</i> Coss. & Daveau		Guttiferae	Hypericaceae
44	<i>Orobanche cyrenaica</i> Beck ex E.A.Durand & Barratte		Orobanchaceae	
45	<i>Plantago lagopus</i> subsp. <i>ptolemaidis</i> Brullo & Furnari		Plantaginaceae	
46	<i>Plantago cyrenaica</i> E.A.Durand & Barratte		Plantaginaceae	
47	<i>Allium ruhmerianum</i> Asch. ex E.A.Durand & Barratte		Alliaceae	Amaryllidaceae
48	<i>Arum cyrenaicum</i> Hruby		Araceae	
49	<i>Convolvulus maireanus</i> Pamp.		Convolvulaceae	
50	<i>Erodium tocranum</i> Guitt. & Le Houér.	<i>Erodium salzmanni</i> subsp. <i>tocranum</i> (Guitt. & Le Houér.) Guitt.	Geraniaceae	
51	<i>Erodium hirtum</i> var. <i>cyrenaicum</i> Pamp.	<i>Erodium cyrenaicum</i> (Pamp.) Guitt.	Geraniaceae	
52	<i>Lonicera nummulariifolia</i> subsp. <i>occidentalis</i> (Pamp.) Brullo & Furnari		Caprifoliaceae	
53	<i>Scabiosa libyca</i> Alavi		Dipsacaceae	Caprifoliaceae

54	<i>Arbutus pavarii</i> Pamp.		Ericaceae	
55	<i>Polygala aschersoniana</i> Chodat.		Polygalaceae	
56	<i>Cyclamen rohlfsianum</i> Asch.		Primulaceae	
57	<i>Ranunculus cyclocarpus</i> Pamp.		Ranunculaceae	
58	<i>Asperula hirsuta</i> var. <i>cyrenaica</i> (E.A.Durand & Barrate)	<i>Hexaphylla cyrenaica</i> (E.A.Durand & Barrate) P. Caputo & Del Guacchio	Rubiaceae	
59	<i>Rhamnus pendula</i> Pamp.	<i>Rhamnus alaternus</i> subsp. <i>pendula</i> (Pamp.) Jafri	Rhamnaceae	
60	<i>Thesium erythronicum</i> Pamp.		Santalaceae	
61	<i>Fumaria macrocarpa</i> Parlatore	<i>Fumaria macrocarpa</i> subsp. <i>cyrenaica</i> Liden	Fumariaceae	Papaveraceae

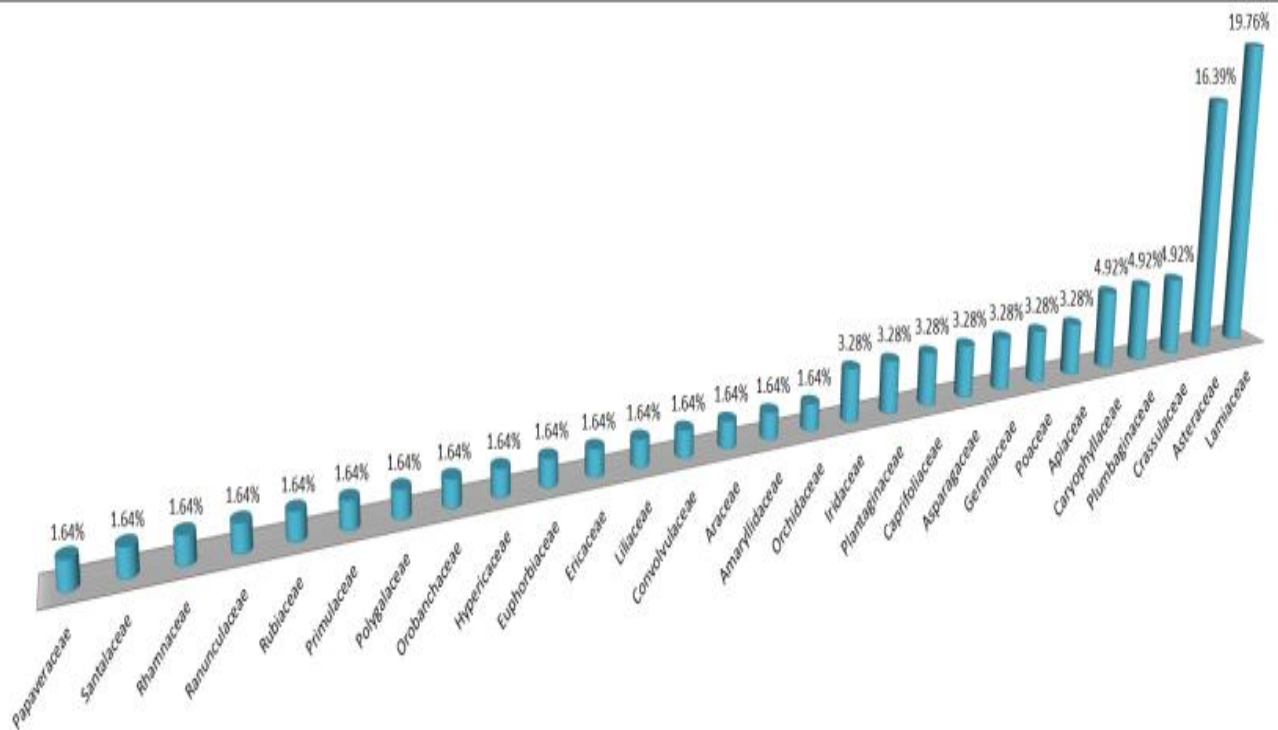


Figure 2. Taxonomic distribution of endemic plant taxa in the study area across plant families.



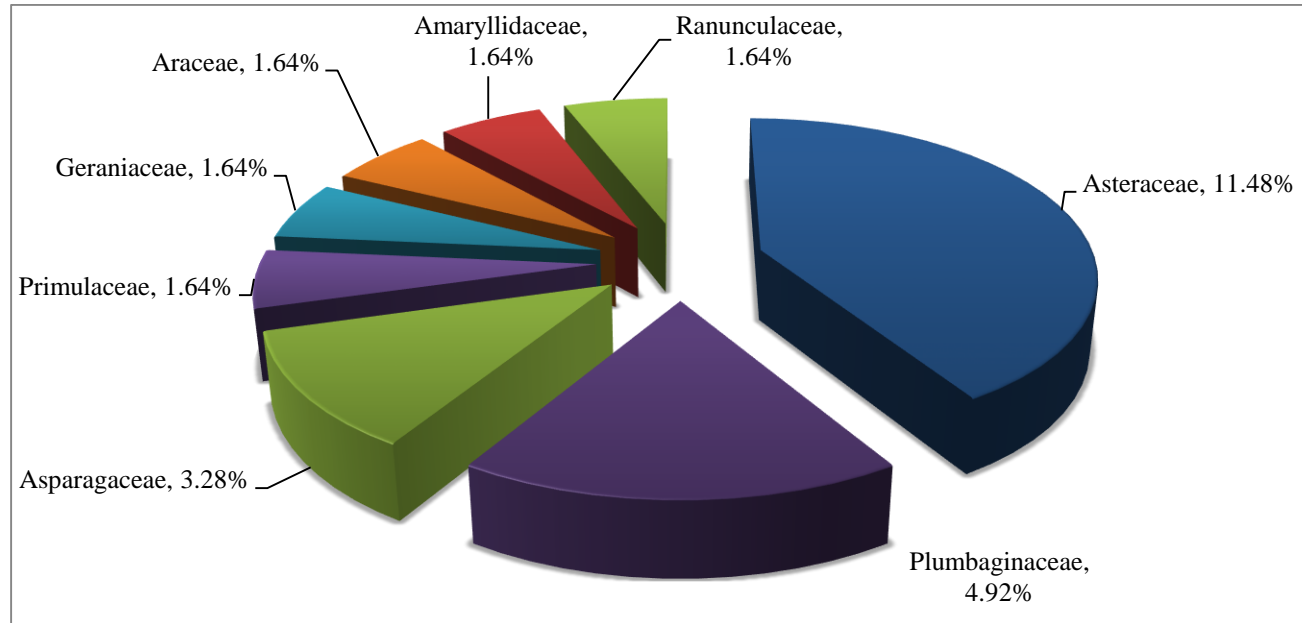
**Figure 3.** Photographs of selected endemic plants in their natural habitats: A. *Teucrium davaeanum*, B. *Scabiosa libyca*, C. *Anthemis cyrenaica*, D. *Sedum bracteatum*, E. *Cyclamen rohlfsianum*, F. *Arbutus pavarii*.

### 3. Chromosomal Variation, Ploidy Levels, and Karyotype Patterns of Endemic Plant Species in El-Jabal El-Akhdar

Karyotype data and ploidy levels obtained from the Index to Plant Chromosome Numbers (IPCN, 2024) indicate significant chromosomal diversity in the El-Jabal El-Akhdar region (Table 2). However, information regarding chromosome numbers and karyotypes for endemic plant species in this region remains limited, with only 27.87% of endemic species having published chromosome number records.

The endemic plants that have been previously studied karyologically belong to a variety of families.

The most studied families in the region include: Asteraceae (7 endemic species, 11.48%), Plumbaginaceae (3 endemic species, 4.92%), Asparagaceae (2 endemic species, 3.28%), and Primulaceae (1 endemic species, 1.64%), as well as Geraniaceae (1 endemic species, 1.64%), Araceae (1 endemic species, 1.64%), Amaryllidaceae (1 endemic species, 1.64%), and Ranunculaceae (1 endemic species, 1.64%) (Fig. 4).



**Figure 4.** Proportion of endemic plant species with available chromosome number and karyotype data in the study region.

For each species, the symbol  $x$  refers to the basic chromosome number,  $n$  represents the gametic chromosome number, and  $2n$  corresponds to the somatic (zygotic) chromosome complement (Mirzaghaderi & Marzangi, 2015). Chromosome numbers observed in this region range from  $2n = 8$  to 96, with a mean chromosome number of  $2n = 28.65 \pm 26.53$ . *Cyclamen rohlfsainum* has the highest chromosome number ( $2n = 96$ ), and *Bellevalia cyrenaica* the lowest ( $2n = 8$ ) among previously studied endemic species.

The frequency of ploidy levels among the studied taxa was as follows: diploid (14.75%), triploid (3.28%), tetraploid (4.92%), and hexaploid (4.92%). The combined proportion of polyploidy levels therefore reached 13.12%, indicating that diploids are only slightly more common in the regional flora. Observed basic chromosome numbers include ( $x$ ) = 4, 5, 7, 9, 11, and 14 (Legro, 1959; Guittonneau & Le Hou rou, 1968; Marchant, 1973; Boyce, 1989; Bartolo *et al.*, 1984; Brullo *et al.*, 1990).

Karyotype characters are valuable for resolving taxonomic problems and assessing relationships between species (Sun *et al.*, 2019). Maire (1958) classified the Libyan-endemic *Allium ruhmerianum* alongside *Allium chamaemoly* within the section *Molium*. The chromosome complement of *A. chamaemoly* is  $2n = 2x = 16$ , consisting of seven metacentric pairs and one telocentric satellite pair (Mossa & Scrugli, 1970; Garbari, 1975). In contrast, Bartolo *et al.* (1984) reported that *A. ruhmerianum* has a chromosome complement of  $2n = 3x = 33$ , with all chromosomes metacentric, three of which bear satellites (SATs). Therefore, its karyotype is distinct from the derived karyotype of *A. chamaemoly*. Consequently, Bartolo *et al.* (1984) reclassified the Libyan endemic *A. ruhmerianum* into the section *Rhynchocarpum*.

Species within the same genus can be differentiated by their chromosome numbers and ploidy levels even without additional karyological data (Rivero *et al.*, 2019). Brullo *et al.* (1990) reported chromosomal

diversity (polyploidy) in three Libyan endemic species from the genus *Limonium*: *L. teuchirae* ( $2n = 3x = 27$ , triploid), *L. subrotundifolium* ( $2n = 4x = 32$ , tetraploid), and *L. cyrenaicum* ( $2n = 6x = 54$ , hexaploid). These chromosomal variations are useful for differentiating these species and indicate that polyploidy plays a minor role in the speciation of this genus. The occurrence of triploid, tetraploid, and hexaploid taxa, particularly within genera such as *Limonium*, indicates that polyploidization has also contributed to diversification in the region. Polyploidy is widely recognized as a major evolutionary mechanism in angiosperms, facilitating ecological adaptation, reproductive isolation, and lineage divergence (Wendel, 2015). However, diploid taxa (14.75%) are only slightly more frequent than the combined proportion of polyploidy levels (triploid, tetraploid, and hexaploid; 13.12%), indicating that although polyploidy is not the dominant pattern, it has contributed significantly to diversification among the endemic flora of El-Jabal El-Akhdar. Brullo *et al.* (1990) also observed that, despite sharing the same chromosome number ( $2n = 18$ ), the karyotype formulas of *Anthemis taubertii* and *Anthemis cyrenaica* differ.

Additionally, Bartolo *et al.* (1984) found that the karyotype of *Allium ruhmerianum* is symmetrical, composed exclusively of metacentric chromosomes, whereas asymmetrical karyotypes characterize *Bellevalia cyrenaica*, *Prospero cyrenaicum*, *Anthemis taubertii*, *Anthemis cyrenaica*, and *Picris mauginiana* (Bartolo *et al.*, 1984; Brullo *et al.*, 1990).

Satellite chromosome patterns also vary significantly among species: *Cyclamen rohlfsianum* possesses four satellites (Legro, 1959), *Allium ruhmerianum* has satellites on three metacentric chromosomes; *Scilla cyrenaica* (*Prospero cyrenaicum*) shows a macrosatellite on one acrocentric chromosome; and *Bellevalia cyrenaica* has satellites on two metacentric and two submetacentric chromosomes (Bartolo *et al.*, 1984). Despite these findings, comprehensive karyotypic data remain limited for most regional endemics.

The analysis of chromosomes in cytological preparations involves estimating karyotype parameters and constructing ideograms (Mirzaghaderi & Marzangi, 2015). Published literature includes only chromosome measurements (1-2  $\mu\text{m}$ ) for *Cyclamen rohlfsianum* (Legro, 1959) and ideograms for three endemic species: *Allium ruhmerianum*, *Scilla cyrenaica*, and *Bellevalia cyrenaica* (Bartolo *et al.*, 1984).

Variations in chromosome morphology, symmetry, and satellite organization may reflect structural rearrangements associated with evolutionary divergence (Peruzzi *et al.*, 2009). However, despite these insights, cytogenetic data for El-Jabal El-Akhdar remain sparse and unevenly distributed. Karyological

data are currently available for only a limited portion of the endemic flora, indicating the necessity for further investigation. Strengthening cytogenetic knowledge will not only improve understanding of evolutionary patterns and taxonomic relationships but will also lay the foundation for targeted research addressing the significant gaps in our current understanding of this biodiversity-rich hotspot.

#### 4. Cytogenetic Research Gap in El-Jabal El-Akhdar

El-Jabal El-Akhdar, the primary center of plant endemism in Libya, remains markedly underexplored from a cytogenetic perspective. Of the 61 endemic taxa recorded in the region, chromosome numbers have been documented for only 17 species, representing less than one-third of the endemic flora ( $17/61 \approx 27.87\%$ ). Most available chromosome data were generated by European researchers during the mid-to-late twentieth century (Legro, 1959; Guittonneau & Le Houérou, 1968; Marchant, 1973; Boyce, 1989; Bartolo *et al.*, 1984; Brullo *et al.*, 1990), and no systematic studies have been conducted by local researchers. This imbalance between floristic richness and cytogenetic knowledge highlights a significant research gap.

In biodiversity hotspots, chromosomal studies are considered fundamental tools for understanding speciation processes, polyploid evolution, and patterns of endemism (Siljak-Yakovlev & Peruzzi, 2012). However, systematic chromosomal surveys have not been proportionally conducted for Libyan endemic taxa. Moreover, modern molecular cytogenetic techniques—such as genome size estimation, DNA barcoding, fluorescent in situ hybridization (FISH), and the localization of rDNA—have proven highly effective in elucidating chromosomal evolution and diversification in endemic plants. Applying these approaches in El-Jabal El-Akhdar could significantly advance understanding of the cytogenetic basis of endemism, species differentiation, and evolutionary processes in this biodiversity-rich region.

#### 5. Conclusion

This review highlights the chromosomal diversity present within the endemic flora of El-Jabal El-Akhdar, one of the main centers of plant endemism in Libya. Among the 61 endemic taxa recorded in the region, chromosome numbers are available for only 17 species ( $17/61 \approx 27.87\%$ ), revealing variation in chromosome numbers, ploidy levels, and karyotype characteristics. These cytogenetic differences provide valuable insights into species differentiation and evolutionary relationships. However, the limited availability of chromosomal data indicates that most endemic taxa remain cytologically unexplored. Expanding cytogenetic studies will be essential for improving taxonomic knowledge and understanding the evolutionary diversity of this Mediterranean biodiversity hotspot.

**Table 2.** karyotype analysis of some endemic plant taxa in the El-Jabal El-Akhdar region according to IPCN.

Endemic Plant Taxa	Basic chromosome number (x)	Chromosome numbers (2n) and ploidy levels	Karyotype Formula (KF)	Satellites	Karyograms, Chromosome measurements, and Karyotype indices	Karyotype Symmetry/Asymmetry	References
<i>Cyclamen rohlfsianum</i>	x= NR	2n = 96	NR	4	1-2 µm	NR	(Legro,1959)
<i>Erodium salzmannii</i> subsp. <i>tocranum</i>	x= NR	2n = 6x = 60	NR	NR	NR	NR	(Guittonneau & Le Hou��rou,1968)
<i>Arum cyrenaicum</i>	x= 7	2n = 28	NR	NR	NR	NR	(Marchant,1973)
<i>Arum cyrenaicum</i>	x= 14	2n = 4x = 56	NR	NR	NR	NR	(Boyce,1989)
<i>Allium ruhmerianum</i>	x= 11	2n = 3x = 33	33m	3	Ideogram	Symmetrical	(Bartolo <i>et al.</i> ,1984)
<i>Bellevalia cyrenaica</i>	x= 4	2n = 2x = 8	2m+4sm+2st	4	Ideogram	Asymmetrical	(Bartolo <i>et al.</i> ,1984)
<i>Prospero cyrenaicum</i>	x= 7	2n = 2x = 14	6m+4sm+2st+2t	1	Ideogram	Asymmetrical	(Bartolo <i>et al.</i> ,1984)
<i>Lactuca haimanniana</i>	x= ?	2n = 2x = 16	NR	NR	NR	NR	(Brullo <i>et al.</i> ,1990)
<i>Anthemis taubertii</i>	x= 9	2n = 2x = 18	6m+2sm+6st+4t	NR	NR	Asymmetrical	(Brullo <i>et al.</i> ,1990)
<i>Anthemis cyrenaica</i>	x= 9	2n = 2x = 18	8m+4sm+4st+2t	NR	NR	Asymmetrical	(Brullo <i>et al.</i> ,1990)
<i>Limonium teuchirae</i>	x= 9	2n = 3x = 27	NR	NR	NR	NR	(Brullo <i>et al.</i> ,1990)
<i>Limonium subrotundifolium</i>	x= 9	2n = 4x = 32	NR	NR	NR	NR	(Brullo <i>et al.</i> ,1990)

<i>Limonium cyrenaicum</i>	$x = 9$	$2n = 6x = 54$	NR	NR	NR	NR	(Brullo <i>et al.</i> ,1990)
<i>Centaurea cyrenaica</i>	$x = \text{NR}$	$2n = 2x = 18$	NR	NR	NR	NR	(Brullo <i>et al.</i> ,1990)
<i>Picris mauginiana</i>	$x = 5$	$2n = 2x = 10$	$2m+4sm+4st$	NR	NR	Asymmetrical	(Brullo <i>et al.</i> ,1990)
<i>Tolpis virgata</i> subsp. <i>apolloniae</i>	$x = \text{NR}$	$2n = 6x = 54$	NR	NR	NR	NR	(Brullo <i>et al.</i> ,1990)
<i>Senecio trilobus</i>	$x = \text{NR}$	$2n = 20$	NR	NR	NR	NR	(Brullo <i>et al.</i> ,1990)
<i>Ranunculus cyclocarpus</i>	$x = \text{NR}$	$2n = 16$	NR	NR	NR	NR	(Brullo <i>et al.</i> ,1990)

\*NR= Not Reported

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