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SYSTEMATICS, TAXONOMY, AND NOMENCLATURE

An overview of georeferenced chromosomes numbers of Moroccan Asteraceae

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Abstract. In Moroccan vascular flora, the Asteraceae family ranks first in terms of specific richness. However, there is no up-to-date account of the geographic distribution of its species with established chromosome numbers.

In this contribution, we inspected the chromosome number of Moroccan Asteraceae published in former studies; a synonym glossary is given, the names were verified and updated to the recent and accepted ones, by using Moroccan flora Volume 3 and online botany databases: IPNI, The plant list and African plants database.

As a result, we present for the first time the georeferencing of chromosome number for 276 Asteraceae species and subspecies from 866 localities across Morocco, with their voucher specimen, addresses and authors. We identified the spots of endemism for Asteraceae species with known chromosome numbers in Morocco as Middle Atlas, High Atlas, Anti-Atlas and the Rif. Concerning the ploidy level, our findings indicate that most Asteraceae species in Moroccan flora are diploid, with the chromosome number of 2*n* = 18 and B-chromosomes occur in arid and semi-arid areas. We also provide species distribution models and presence-only predictions, along with an analysis of how each climatic variable and elevation affect the probability of presence for Asteraceae species. This study significantly contributes to enhancing conservation efforts and assisting researchers in plant cytogenetics.

Keywords: Morocco, Botany, Asteraceae, karyology, Cytotaxonomy, Chromosome numbers, Georeferencing.

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Introduction

Morocco is located at a strategic floristic intersection, shaped by its extensive coastlines that extend approximately 3500 km along both the Atlantic Ocean and the Mediterranean Sea (Snoussi *et al.*, 2008). This geographical positioning contributes to a remarkable diversity of habitats and ecosystems, influenced by a range of Mediterranean-type climates along the coastal zones, as well as a gradient from arid Saharan conditions in the south to humid oceanic climates in the north (Rankou *et al*., 2012; Gharnit *et al*., 2024). Furthermore, the country features significant elevational variation, with montane climates occurring in the summits of major mountain ranges such as the Middle Atlas, High Atlas, Anti-Atlas, and Rif, where several peaks rise above 2,000 to 4,000 meters (Rankou *et al*., 2012; Outourakhte *et al*., 2025).

This geographic and ecological diversity makes Morocco a key region for studying patterns of plant evolution, distribution, and conservation, particularly within highly speciose families such as the Asteraceae (Fennane *et al*., 2014). The high level of endemism and habitat specialization in Moroccan Asteraceae species (Rankou *et al*., 2012; Fennane *et al*., 2014), suggests that understanding their cytogenetic and spatial characteristics may yield insights into broader ecological and evolutionary processes (Siljak-Yakovlev & Peruzzi, 2012).

In the Moroccan flora, Asteraceae is the largest family of flowering plants, comprising 141 genera, and 594 species (including 170 subspecies), *Centaurea* is the richest species-rich genus, with 54 species and 23 subspecies (Rankou *et al*., 2012; Fennane *et al*., 2014). The family also ranks among those with the highest number of endemic taxa, totaling 333 species and subspecies (Fennane *et al*., 2014).

Cytogenetic research on Asteraceae in Morocco began in 1957 with the pioneering chromosome counts published by (Quézel, 1957) and (Reese, 1957), on populations from Toubkal (The High Atlas) and Figuig (Eastern Morocco), respectively. Since then several studies followed, the most recent one was published by Gounssa et al. (2018).

However, despite the growing volume of cytogenetic data, these records remain scattered across various sources, making it difficult to analyze trends or extract regional patterns. To date, no comprehensive georeferenced cytogenetic database exists for Moroccan Asteraceae, limiting the researchers' ability to assess spatial trends in chromosomal diversity or to identify areas of cytogenetic endemism.

Addressing this gap is crucial for the advancement of both plant taxonomy and conservation science. Compiling and organizing cytogenetic data into a digitized, spatially explicit format enhances its accessibility and reusability within the scientific community, while enabling more detailed cytogeographic analyses, this effort aligns with the principles of integrative taxonomy, which is defined as combining multiple data types and methodologies to resolve taxonomic questions more effectively (Dayrat, 2005; Pedial *et al*., 2010). Such approaches are essential for identifying hotspots of endemism, examining ploidy-level variation, and evaluating the conservation importance of various phytogeographic regions in Morocco. Furthermore, integrating chromosomal data with spatial distribution models provides a foundational cytogenetic and geographic dataset that may support the future identification and delimitation of evolutionarily significant units (ESUs) (Pedial *et al*., 2010; Frajman *et al*., 2019).

In this context, knowing the number and precise location of endemic species within each biogeographic region represents a fundamental step in assessing their conservation status (Treurnicht *et al*., 2017). Moreover, documenting endemic richness in biodiversity hotspots is not only vital for guiding targeted conservation strategies (Marshall *et al*., 2016), but also for enhancing our understanding of the ecological and evolutionary processes that have shaped these hotspots, centers of endemism, and national floras more broadly (Harold & Mooi, 1994; Morrone, 2008).

In this study, we compile and georeference all available chromosome number records for Moroccan Asteraceae species. Our objectives are to: (1) provide an updated and verified list of cytogenetically studied taxa; (2) develop a geodatabase for these records, enriched with metadata and information on endemism, phytogeographic regions, threat status, chromosome formula, and other relevant attributes; (3) employ spatial analysis tools to map the distribution of endemic, identify hotspots of endemism, and assess ploidy-level variation across Morocco's phytogeographic regions. We also provide species distribution models and presence-only predictions under current and future climate conditions.

Material and Methods

In order to know what have been achieved until now and provide georeferenced chromosome numbers of Asteraceae species, former studies were inspected by collecting the species given name, chromosome counts, textual description of the address (most of the time in earliest studies) or Global Positioning System coordinates GPS (available in the recent ones), ploidy level, publications details (authors, study title and year). Textual descriptions of the address were converted into GPS coordinates: latitude and longitude. All these coordinates were verified on the geoplaner website "www.geoplaner.com/" for more species positioning accuracy. Some addresses were corrected when inconsistency between the given textual address and GPS coordinates was found.

Latitude and longitude of species were compiled in Microsoft Excel in order to be exported to ArcGis 10.3 (Database.1).

A synonymic index is provided, the old names were updated according to Moroccan flora and online database such as: Euro+Med Plantbase, IPNI, the plant list and African plants database. Our data was organized as follow: updated name, given name, 2n count, n count, locality, herbarium information accession, voucher specimens, and reference in different columns, each single record in rows (Database. 2).

Results and Discussion

Georeferenced chromosome numbers of Moroccan Asteraceae

The database.2 integrated in ArcGIS allowed us to georeference 276 (35.99 %) of Moroccan Asteraceae species, including 54 subspecies out of 764 species and subspecies, belonging to 141 genera, of which 179 (53.75 %) out of 333 species are endemic. The georeferenced species are distributed in 866 localities across Morocco

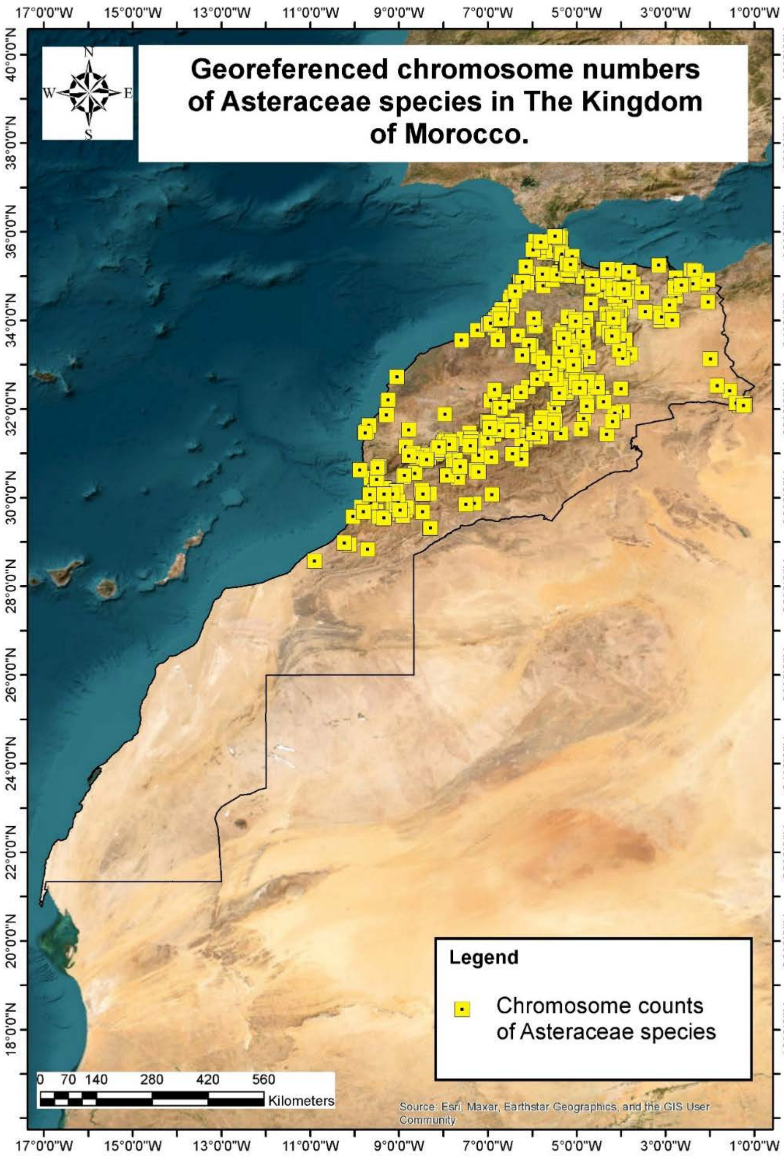

Figure 1. Georeferenced chromosome numbers of Asteraceae species in The Kingdom of Morocco.

Table 1. Chromosome counts with their percentage in the 12 regions of The Kingdom of Morocco. Abbreviations are: N. spe, number of species counted by region; % chrom., percentage of species counted by region; N. chrom., number of chromosome counts reported by region; %, percentage of chromosome counts reported by region.

Regions	N. spe.	% spe.	N. chrom.	% chrom.
Fez-Meknes	81	16.14	157	18.1
Tanger -Tetouan-Al Hoceïma	81	16.14	144	16.6
Drâa-Tafilalet	79	15.74	136	15.7
L'Oriental	57	11.35	101	11.7
Marrakech-Safi	55	10.96	97	11.2
Souss-Massa	53	10.56	89	10.3
Rabat-Salé-Kenitra	48	9.56	70	8.1
Béni Mellal-Khenifra	41	8.17	64	7.4
Guelmim-Oued Noun	5	1.00	5	0.6
Dakhla-Oued Ed-Dahab	0	0.00	0	0.0
Laâyoune-Sakia El Hamra	0	0.00	0	0.0
Casablanca-Settat	2	0.40	3	0.3
Total	502	100.0	866	100.0

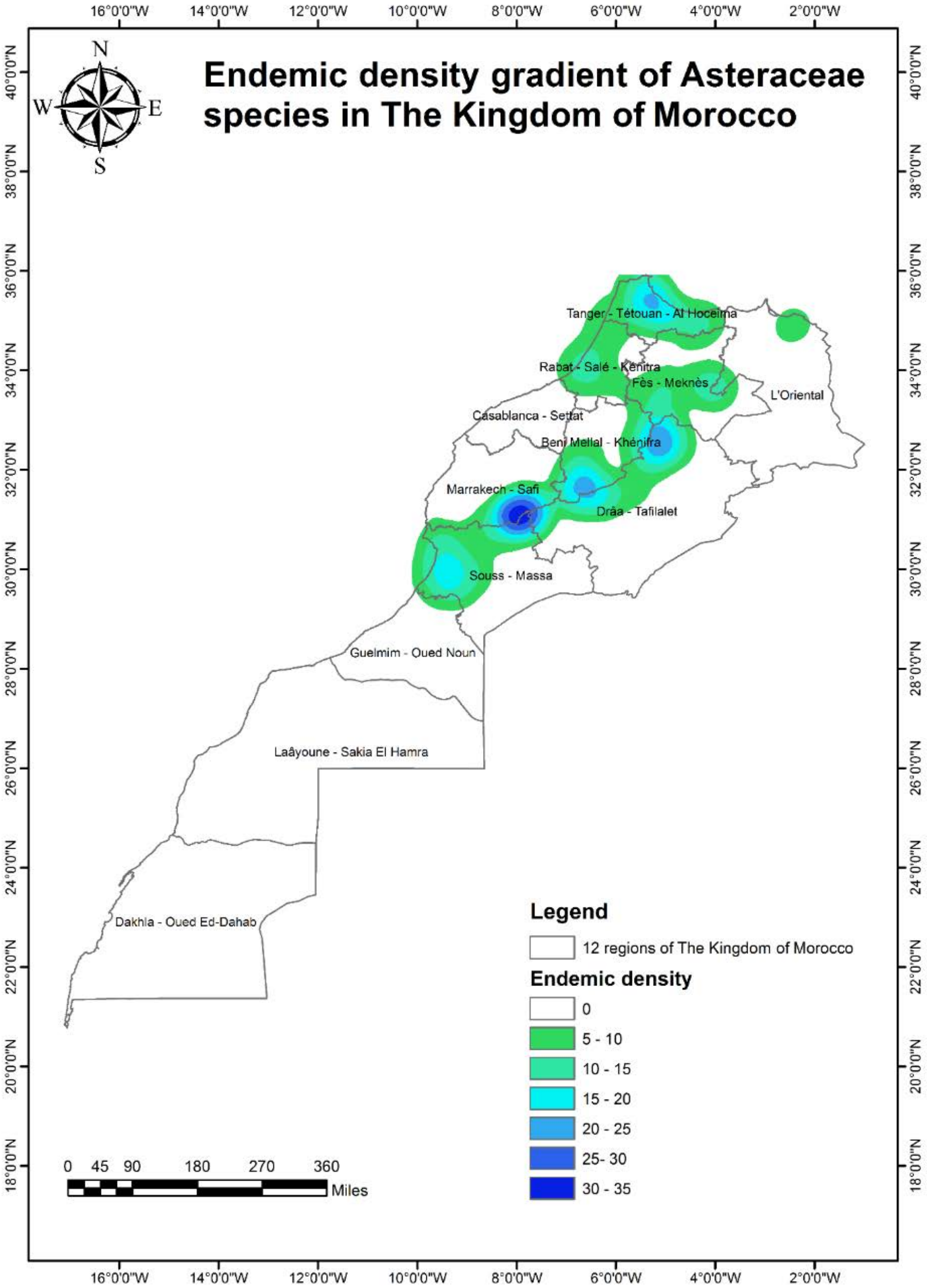

Figure 2. Endemic density gradient of Asteraceae species in The Kingdom of Morocco.

(Figure 1), which constitutes a great step toward the computerization of all the counts published on Moroccan flora generally and Moroccan Asteraceae particularly.

Chromosome counts by region

Based on database.2, we were able to calculate the number of chromosome numbers reports in each region of Morocco (Table 1), the region of Fez-Meknes was found to have the highest chromosome number reports with 157 reports, followed by the regions of Tanger-Tetouan-Al Hoceïma and Drâa-Tafilalet with 144 and 136 reports respectively. Moreover, certain regions have not yet been subjected to any karyological studies, namely Dakhla-Oued Dahab, Laâyoune-Sakia El Hamra, and Casablanca-Settat. Consequently, further karyological studies will be conducted in these regions.

Density gradient of endemic Asteraceae

The analysis of the distribution of endemic Asteraceae species with known chromosomes numbers using density gradient tool (Figure 2), shows that the most significant number of endemics are in the Middle Atlas with 25 species: 16 endemic species near the rural commune of Itzer (32.87912 °N, -5.05410 °E), in the region of Drâa-Tafilalet. In addition to 9 species around the National Park of Tazekka (34.02146 °N, -4.22832°E) in the Middle Hight Atlas, in the region of Fez-Meknes.

The second floristic area that has a notable quantity of species is the High Atlas with 24 endemic species: 9 species surrounding the rural commune

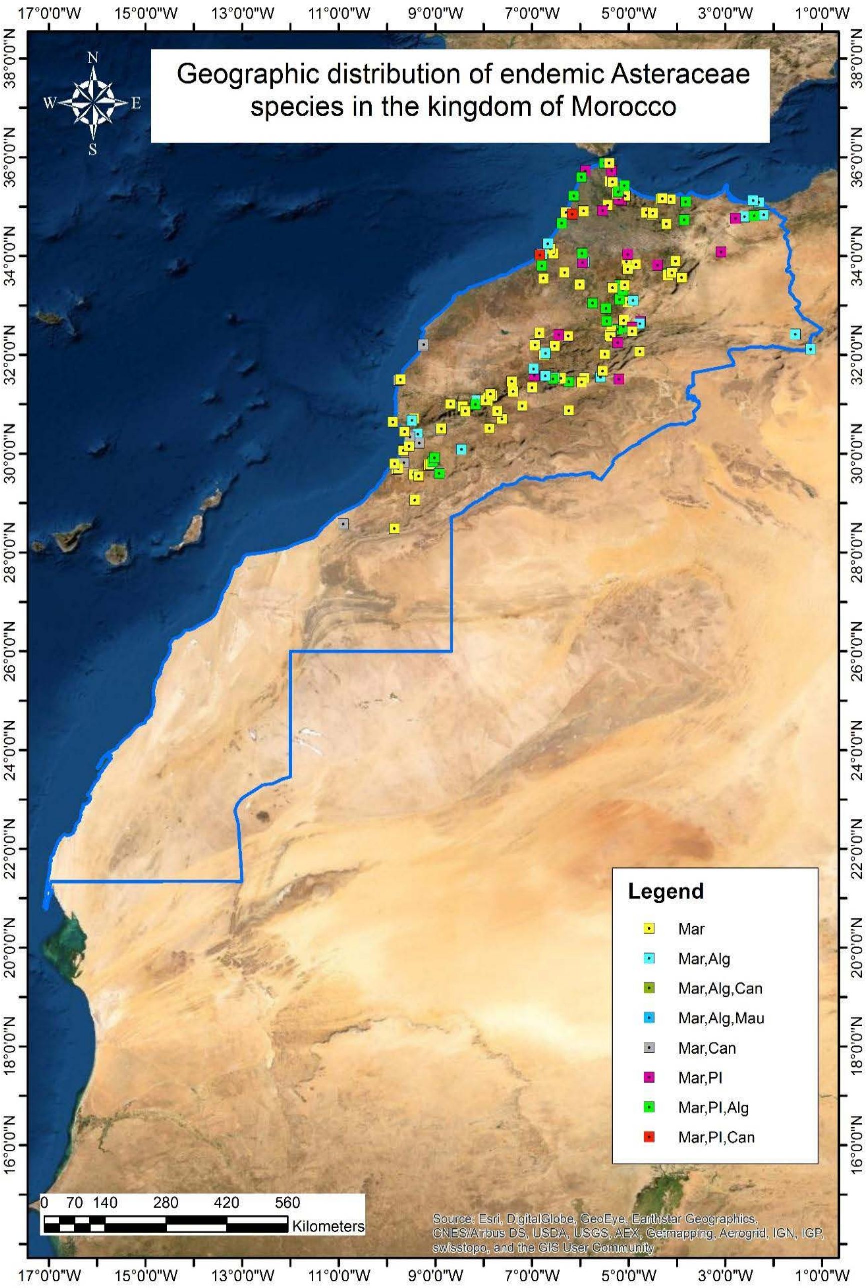

Figure 3. Geographic distribution of endemic Asteraceae species restricted to Morocco and shared with other countries: Mar, Morocco; Alg, Algeria; Can, Spain (Canary Islands); Mau, Mauritania; PI, Iberian Peninsula.

Table 2. Number of endemic Asteraceae species restricted to Morocco and those shared with neighbouring countries, without repetition of localities records

Number of endemics (*)	Countries	Percentage
65	Morocco (strict endemics)	36.31
35	Morocco - Algeria	19.55
28	Morocco - Iberian Peninsula	15.64
33	Morocco - Iberian Peninsula - Algeria	18.44
9	Morocco – Spain (Canary Islands)	5.03
7	Morocco - Iberian Peninsula – Spain (Canary Islands)	3.91
1	Morocco - Algeria - Mauritania	0.56
1	Morocco - Algeria – Spain (Canary Islands)	0.56
Total 179		100.00

of Aït Bou Oulli (31.60421° N, -6.59850 °E) in the Central High Atlas, in the region of Béni Mellal-Khenifra and 15 species near Jbel Toubkal (31.06012 °N, -7.91470 °E) in the Western Hight Atlas, in the region of Marrakech-Safi.

The third floristic division is the Anti Atlas with 14 endemic species around the rural commune of Tanalt (29.77492 °N, -9.16848 °E), in the region of Souss-Massa.

The Rif is the fourth important floristic division with 13 endemic species in and around the National Park of Talassemtane (Chefchaouen) (35.22276 °N, -5.12960 °E), in the region of Tanger-Tetouan-Al Hoceïma.

Mountain ranges are generally rich in endemics (Spehn *et al*., 2011; Hobohm *et al*., 2019; Noroozi *et al*., 2019). The geographical distribution of Moroccan endemic species (Figure S1) highlights the great originality and importance of the High Atlas as the main hotspot of endemism and confirm biogeographers idea about the high altitudes of North Africa; it states that the mountain ranges, notably the High, Middle and Anti-Atlas Atlas, and the Rif mountains in north Morocco played a very important role during the Quaternary glaciations by offering refugia to the Holarctic taxa which evolved afterwards in isolated areas (Fennane & Ibn Tattou, 1999; Fennane, 2004; Médail & Diadema, 2009). This can be explained by diverse micro-climates and topographic complexity in mountains that promote high biodiversity and endemism (Irl *et al*., 2015; Steinbauer *et al*., 2016; Noroozi *et al*., 2019).

The results of georeferenced endemic Asteraceae species in Morocco align with these findings, showing that they are primarily distributed across the Anti-Atlas, High Atlas, Middle Atlas, and Rif mountains (Table S1).

Endemics shared with neighboring countries

The number of endemics in the Asteraceae family in Morocco is 333 species and subspecies (Fennane *et al*., 2014), through this study we were able to georeferenced 179 species, making 53.75 % (Figure 3 and Figure S2).

Morocco and Algeria shared the highest percentage of endemic Asteraceae species with 35 species in 11 genera (Table 2), these species are: *Anthemis mauritiana* subsp. *faurei* (Maire) Oberpr. *Bellis rotundifolia* (Desf.) Boiss. & Reuter, *Carduus leptocladus* Dur, *Carthamus atractyloides* (Pomel) Greuter, *C. duvauxii* (Batt, & Trab, *C. rhaponticoides* (Pomel) Greuter, *Centaurea fragilis* Dur, *C. nana* Desf, *C. pubescens* subsp. *amourensis* (Pomel) Batt, *Pallenis cuspidata* subsp. *canescens* (Maire) Greuter, *Pallenis spinosa* subsp. *maroccana* (Aurich & Podlech) Greuter, *Rhodanthemum gayanum* subsp. *gayanum* (Coss. & Durieu) B, H, Wilcox, K, Bremer & Humphries, *Scorzonera caespitosa* Pomel, *Warionia saharae* Benth, & Coss.

Threatened species

The analysis of threatened species in the three categories of threat—CRe, ENe, and VUe (e: estimated)—in fascicule number 3, Red List of Asteraceae Species in Morocco (Fennane, 2016-2017), as part of the Red Book of Vascular Flora of Morocco project, shows that we were able to georeference 9 CRe, 10 ENe, and 5 VUe species (Table S2).

Chromosome counts on Moroccan Asteraceae species

The compilation of all reports shows that they are not regularly distributed over time (Figure S3). The first reports began in the mid-twentieth century, with a rapid growth in chromosome number data observed from 1978 to 1994, and later in 2008 and 2012. The slow start can be explained by the use of laborious, error-prone techniques (e.g., manual section techniques). In contrast, the increase in chromosome reports between the 1960s and 1970s can be attributed to the successful implementation of squash and smear methods, as well as the growing recognition of the scientific relevance of chromosomal evolution. A similar observation was made by Semple & Watanabe (2009) for the period between 1960 and 1980, when major efforts were dedicated to determining chromosome numbers in a large number of composites. However, despite the extensive use of flow cytometry in the late 1990s and after 2000 (Paule *et al*., 2017), we have not identified any combined studies focusing on both karyology and genome size/flow cytometry in Moroccan Asteraceae species.

The same remark is applicable to karyomorphological studies, only one study (Oberprieler, 1994) gave karyomorphological characters of the counted chromosomes, *Anthemis gharbensis* Oberpr., an endemic to Morocco and *Sonchus boulosii* Chamboul., Mejías & J.F.Léger, spec. nov were the only species with a known chromosome formula: $2n$ = 18 = 12m + 2sm + 4 st-sat and 2M-m+8m+ 2m sat+4sm+2sm sat, respectively. This could possibly be explained by the size of some the chromosome of some Asteraceae species or some issue while using the squash technique.

Here, we present all 54 published reports on chromosome numbers in Moroccan Asteraceae, organized by author (in alphabetical order), along with the year of publication and the number of reports (Table S3), which served as the basis for our two databases. We found that in some studies, particularly older ones, precise location details were not always included or clearly stated. For example, some authors provided only the names of Moroccan cities or simply referred to Morocco as the origin of the studied species. Additionally, this list is based on chromosome counts from a single individual per taxon; multiple counts for a single taxon were not included in the published records (Table S3).

In addition, the comparison of all 54 published reports with the species and subspecies of Asteraceae in the Moroccan flora allowed us to extract and estimate the number of established chromosome numbers for each genus. This, in turn, enabled us to identify the genera that have been fully studied karyologically and those that remain unstudied (Table S4).

Table 3. Different ploidy level of Asteraceae species with the number of records.

Basic number / Ploidy level	Numbers of records	Percentage
2x	668	77,14
3x	2	0,23
4x	88	10,16
5x	1	0,12
6x	4	0,46
7x	1	0,12
8x	1	0,12
2x / 3x	70	8,08
2x / 3x / 6x	13	1,50
5x / Polyploid	1	0,12
Poly / Aneuploid	13	1,50
7x/ Polyploid	1	0,12
4x / 8x	3	0,35
	866	100,00

Table 4. Asteraceae species with B chromosomes and their bioclimatic stages.

Species	2n / n	Bioclimatic stage
Anthemis maroccana Batt. & Pitard subsp. *maroccana*	*n* = 9 + 0-1B	Semi-Arid
Callendula tripterocarpa Rupr.	2 *n* = 30 + 0-2B	Saharan / Arid
Hedypnois rhagadioloides (L.) F. W. Schmidt	2 *n* = 10/10 + 1B	Arid
Carduus pynocephalus L.	2 *n* = c. 60 + 2B	Semi-Arid
Launaea nudicaulis (L.) Hook. f.	2 *n* = 18+1B	Saharan
Picris asplenioides subsp. *saharae* (Coss, & Kralik) Dobignard	2 *n* = 10 + 1B	Arid
Scorzonera caespitosa Pomel	2 *n* = 12+1B	Arid

Chromosome numbers, Ploidy level, B chromosomes and polyploid species

Chromosome numbers

A very large range in chromosome numbers and chromosomal base numbers occurs in Asteraceae. More than 750 different mitotic counts have been reported: 2 *n* = 6, 8, 10, 10 + 1B, 12, 12+1B, 13, 14, 16, 18, 18+1B, 20, 22, 24, 26, 27, 28, 30, 32, 34, 36, 37, 38, 40, 42, 44, 48, 54, 60, 63, 64.

Ploidy level

The examination of the ploidy level of all the Asteraceae species in the database revealed that the majority of the species, 668 records out of 866 are diploid with the chromosome number of 2 *n* = 18 as the most frequent number (Table 3). In a review of chromosome numbers in Asteraceae (Semple and Watanabe, 2009) found also that 2 *n* = 2 *x* = 18 as the most frequent number in there database. *Hedypnois arenaria* (Schousb,) DC, an endemic to Morocco, Iberian Peninsula and Canary Islands has the low sporophytic number with 2 *n* = 6; the highest number reported is 2 *n* = 64 (x = 8) for *Volutaria tubuliflora* (Murb,) Sennen.

B chromosomes

Although *Asteraceae* is one of the families with the greatest prevalence of B chromosomes (Camacho, 2005), a careful review of all the published chromosome reports used in this study revealed the presence of B chromosomes in 7 species: *Anthemis maroccana* Batt. & Pitard subsp. *maroccana, n* = 9 + 0-1B, *Callendula tripterocarpa* Rupr.*, 2 n = 30 + 0-2B, Hedypnois rhagadioloides* (L.) F. W. Schmidt*, 2 n* = 10/10 + 1B, *Carduus pynocephalus* L., 2 *n* = c. 60 + 2B, *Launaea nudicaulis* (L.) Hook. f., *2 n* = 18+1B, *Picris asplenioides* subsp. *saharae* (Coss, & Kralik) Dobignard*,* 2 *n* = 10 + 1B, *Scorzonera caespitosa* Pomel, 2 *n* = 12+1B, (Table 4).

The maximum number of B chromosome in Asteraceae is shown by *Centaurea scabiosa* L. with 22 B chromosomes, their presence is linked to arid and dry habitats (Fröst, 1957). The distribution of these three species, according to the pluviometric diagram and the bioclimatic stages of Emberger, indicates that they are localized in the arid and semi-arid belt, which aligns with these findings.

Polyploid species

Concerning polyploid species Tereza *et al*. (2006); El Alaoui-Faris *et al*. (2010) suggested that the chromosome variations in *Bidens pilosa* L. 2 *n* = 24, 36, 48, 72 may or not be linked to morphological differences especially discoid and radiated flower. Ouyahya and Viano (1981) in their study of *Artemisia atlantica* var. *maroccana* (Coss.) Maire found diploid and polyploid chromosome numbers and suggested that the geographic distribution might be the source of differences in chromosome numbers.

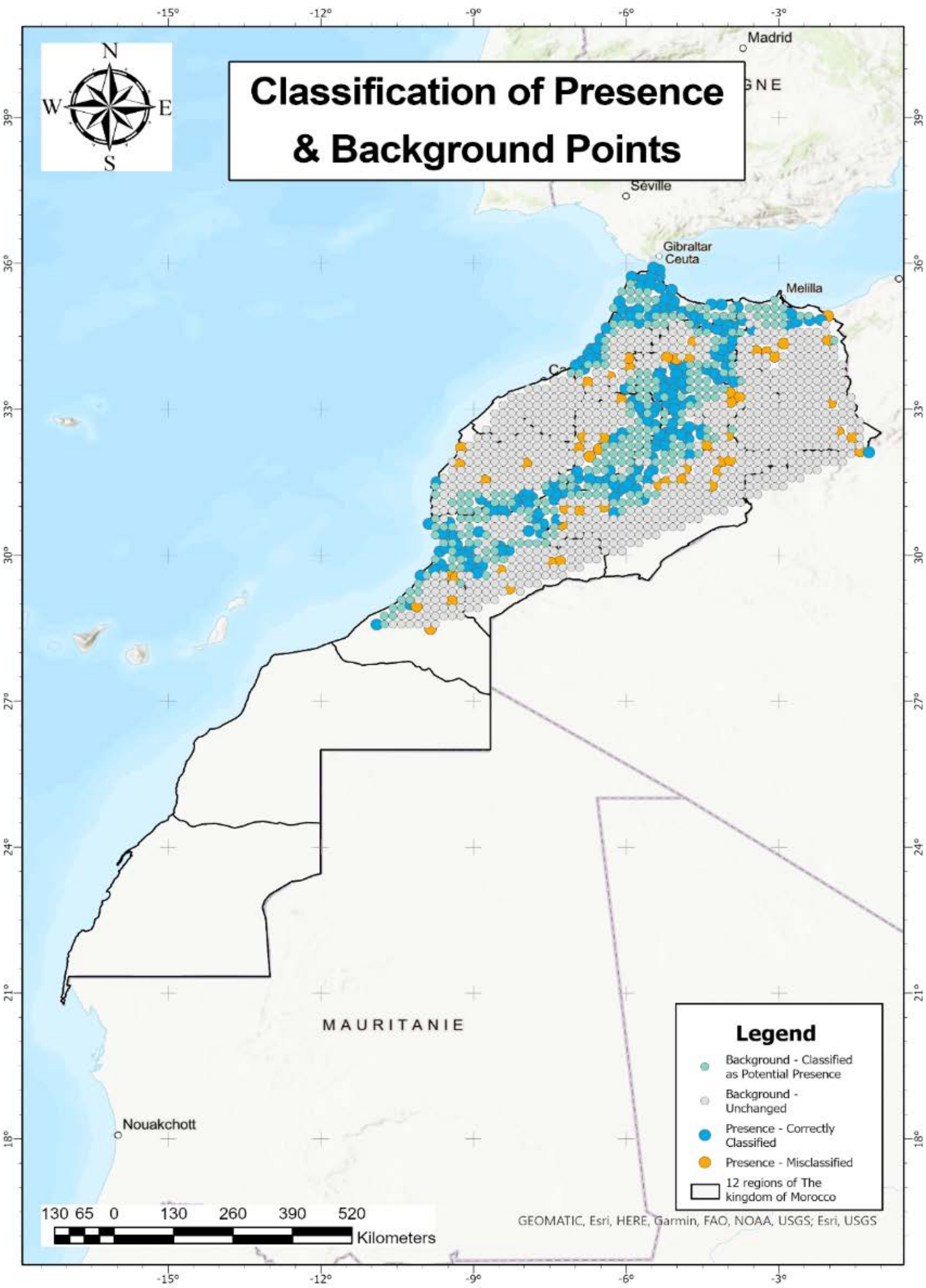

Figure 4. Classification of Presence of Asteraceae species with known chromosome numbers in Morocco.

Several studies have hypothesized that polyploidy occurs more frequently in high mountain plants. It is believed that extreme environments, such as high altitudes and latitudes, are more likely to harbor polyploid species than their diploid relatives (Levin, 2002; Weiss-Schneeweiss *et al*., 2013).

However, the correlation between the prevalence of polyploid taxa in alpine environments is still controversial. Mas de Xaxars *et al*. (2016), while examining the polyploidy high mountain species of *Artemisia* L. found a low incidence of polyploid taxa in the high mountain, with 73.08 % are diploid, 19.23 % are exclusively polyploid and 7.69 % are known both at diploid and polyploid levels, Nie *et al*. (2005) detected only 22 % of polyploid taxa across the flora of the Hengduan Mountains (Qing-Hai Tibet Plateau) and Loureiro *et al*. (2013) found only 23 % of polyploids across two Spanish high mountain ranges, showing that polyploidisation is probably not linked to species adaptation to such environments.

In this study, we observed that the mountain ranges of the Atlas and the Rif hosted a higher number of polyploid species compared to other non-mountainous areas (Figure S4).

Tkach *et al*. (2008) have noted a higher frequency of polyploids in arctic *Artemisia* species, in the light of this finding, Mas de Xaxars *et al*. (2016) suggest that the range of polyploidy, and its increase with latitude, may be more closely associated with the ability to colonize new habitats, such as recently deglaciated environments, rather than a greater cold-hardiness or higher altitudes.

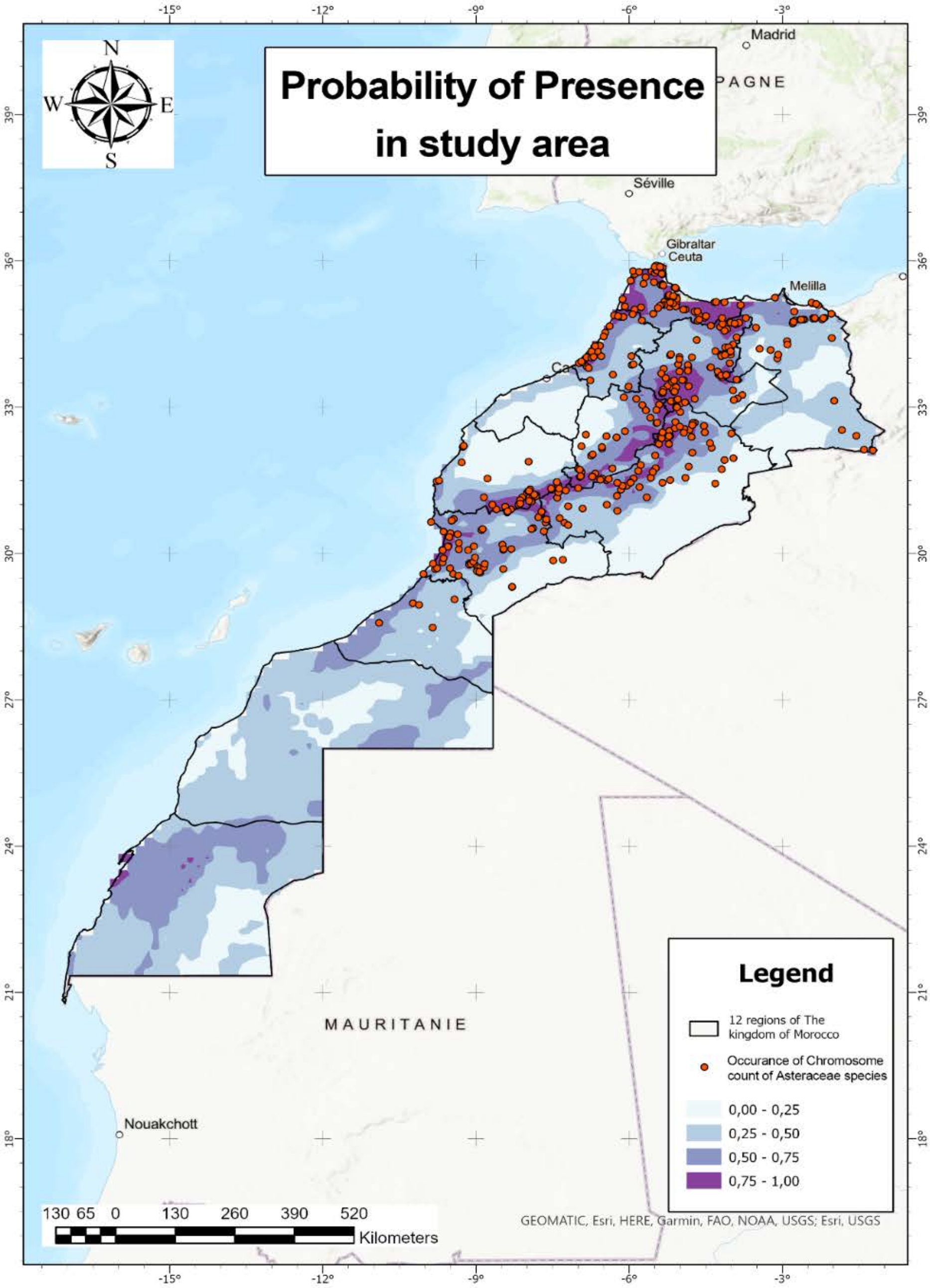

Figure 5. Possibility of presence of Asteraceae species with known chromosome numbers across Morocco (current climate conditions).

The basic ancestral chromosome number that occurs in many genera of Asteraceae family is $x = 9$ (plesiomorphies) (Semple & Watanabe 2009; Mota *et al*., 2016). Other basic chromosome numbers can arise through dysploidy, which is the most common mutation observed in this family. Dysploidy alters the chromosome number while preserving the total amount of chromatin in the karyotype. Allopolyploidy contributes to the emergence of another derived basic number, by combinations of x numbers, for example, the $x_2 = 9$ base number in *Chrysopsis* $2n = 18$ is derived from hybridizing $x = 4$ and $x = 5$ parental taxa (Semple & Watanabe, 2009), or *Santolina chamaecyparissus* $2n = 5x = 45$ (Giacò *et al*., 2022).

All these suggestions need further detailed karyomorphological and molecular cytogenetics studies in order to better understand the mechanisms involved in the evolution of these species in general and in Moroccan Flora in particular.

Presence-only prediction (MaxEnt) for Asteraceae species with a known chromosome number

The use of Presence-only prediction (MaxEnt) geoprocessing tool (provided by Esri on: www.esri.com/), which based on a well-established algorithm in modeling species distribution estimates the presence of a phenomenon in a study area using previously known presence locations, (Figure 4).

The key factors used to explain the probability of Asteraceae species' presence is the Köppen-Geiger climate classification zones from World Bank, which provides a typology of climate zones based on categorical data. Additionally, a comprehensive set of 19 bioclimatic variables from WorldClim is utilized to capture various aspects of annual patterns, seasonal fluctuations, and some extreme temperature and precipitation conditions (Table S5). Data from both the World Bank and WorldClim include current conditions and future projections (Esri, www.esri.com/).

The model enabled us to identify suitable habitats in Morocco for Asteraceae species with known chromosome numbers (Figure 5). The output trained features, or model results, are illustrated using different symbols: large blue dots represent correctly classified presence points, large yellow dots indicate misclassified presence points, small green dots denote background points classified as potential presence locations, and small gray dots represent background points with a low probability of species presence.

Interpretation

Mountain Regions: The Atlas mountain ranges appear to be key refuges for the species, with higher elevations likely providing microclimates that buffer against broader climate changes (Irl *et al*., 2015; Steinbauer *et al*., 2016; Noroozi *et al*., 2019).

Coastal areas with moderate to high probability might benefit from maritime influences that moderate temperature and precipitation extremes by maintaining high levels of air humidity and bringing moisture through fog (Vasey *et al*., 2014; Vanderplank & Ezcurra 2016).

Detailed partial responses of each continuous variable are presented in the supplementary material (Figures S5, S6).

Conservation implications

The map highlights areas where conservation efforts could be focused to protect habitats that are likely to remain suitable for the species in the future. These areas include the Middle Atlas, High Atlas, and certain coastal regions. Additionally, it identifies areas where conservation efforts could be prioritized to support the species' persistence in Morocco.

Conclusion

To our knowledge, this is the first integrated effort combining chromosome number data, spatial distribution, and ecological modelling for the Asteraceae in Morocco, made accessible through two databases. Through this approach, we characterized the family in terms of geographic distribution, endemism, ploidy level, basic chromosome numbers, and the localization and classification of various categories of threatened taxa. We also developed species distribution models under current and projected climate conditions, providing insights into the ecological and elevational factors shaping the distribution of cytogenetically studied species. Our work aims to support conservation planning and guide future cytogenetic research by offering precise locality data and highlighting underexplored taxa. In particular, this dataset can assist researchers in identifying new areas, genera, and species in Morocco that have not yet been karyologically investigated, thereby helping to fill critical gaps in our understanding of chromosomal evolution and diversity. These results lay the groundwork for more integrative studies, including the potential identification of evolutionarily significant units (ESUs) and the incorporation of molecular data to refine phylogeographic and conservation assessments. As a continuation of this work, we are currently developing an online database (geoportal), accessible via a dedicated website, to facilitate broader access to the data generated in this study and to support further research and conservation initiatives.

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Authorship contribution

A.G.: Conceptualization, Data curation, Formal analysis, Research, Methodology, Project management, Supervision, Writing - first draft, Writing - review and editing; Z.O.: Conceptualization, Data curation, Formal analysis, Software, Visualization; B.S.: Conceptualization, Writing - first draft, Writing - review and editing; O.E.G.: Conceptualization, Data curation, Formal analysis, Software, Visualization; A.E.A.: Conceptualization, Fundraising, Project management, Resources, Supervision, Writing - first draft; N.G.: Conceptualization, Resources, Supervision; H.T.: Conceptualization, Resources, Supervision.

Conflict of interest

None.

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Supplementary material

Supplementary material 1.
Database1 (Excel file).

Supplementary material 2.
Database2 (Excel file).

Supplementary material 3.
Table S1. Numbers of Asteraceae species strictly endemic to Morocco by regions and floristic division.
Table S2. Georeferenced threatened species following 3 categories: CRe, ENe and Vue*, with their endemic status: (•) Endemic to Morocco; (•A) Endemic to Morocco and Algeria; (•C) Endemic to Morocco and Spain (Canary Islands); (•I) Endemic to Morocco and The Iberian Peninsula (Spain and Portugal). (*) The suffix "e" indicates categories were assessed through expert judgment (Fennane, 2016-2017).
Table S3. List of all the 54 published chromosomes number counts on Moroccan Asteraceae by authors. (*) One count for a single taxon.
Table S4. The number of species and subspecies subject to karyological studies for each genus of the Asteraceae family in Morocco, with their respective percentage and the total numbers of genera,

species and subspecies of the Asteraceae family in Morocco.

Table S5. The 19 WorldClim bioclimatic variables (Esri, www.esri.com/).

Figure S1. Number of endemics in Morocco by floristic divisions (Fennane and Ibn Tattou 1999; Fennane 2004). HA: High Atlas, MA: Middle Atlas, R: Rif, AA: Anti Atlas; Mam: Middle Atlantic of Morocco, Man: North Atlantic of Morocco, Ms: Moroccan Sahara, Op: Plateaus of the Eastern Morocco, LM: Mediterranean Coast, Om: Eastern Mountains, As: Atlas Sahara.

Figure S2. Comparison between the number of georeferenced endemic (strict and shared) Asteraceae species in this study and the number of endemics in the Asteraceae family in the Moroccan flora. (*) numbers without repetition of localities records. Morocco (strict endemics). **M-A**: Morocco – Algeria; **M-I P:** Morocco - Iberian Peninsula (Spain and Portugal); **M-I P-A:** Morocco - Iberian Peninsula (Spain and Portugal) – Algeria; **M-C I:** Morocco – Spain (Canary Islands); **M-I P-C I:** Morocco - Iberian Peninsula (Spain and Portugal) and Spain (Canary Islands); **M-A-Mauri:** Morocco - Algeria – Mauritania; **M-A-C I:** Morocco - Algeria – Spain (Canary Islands); **M-Mauri:** Morocco – Mauritania; **M-I P-A-C I:** Morocco - Iberian Peninsula - Algeria – Spain (Canary Islands); **M-Mauri-C I**: Morocco - Mauritania – Spain (Canary Islands).

Figure S3. Summary of the number of chromosome counts published since 1957 to 2018.

Figure S4. Georeferenced polyploid species of Asteraceae in Morocco.

Figure S5: Partial response of continuous variables chart for Asteraceae species with known chromosome numbers across Morocco.

Figure S6: Possibility of presence of Asteraceae species with known chromosome numbers across Morocco (under future climate conditions: 2081-2100).