Floristic and ecological patterns of toxic vascular plants in Morocco

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Research

Abstract

Background: Toxic vascular plants constitute a significant yet under-documented component of Morocco's floristic diversity. Despite their ecological importance and implications for public health, no recent nationwide synthesis has integrated floristic, ecological, and conservation data within a unified analytical framework.

Methods: This study presents an updated inventory and ecological analysis of toxic vascular plants reported in Morocco, based exclusively on critically evaluated bibliographic, taxonomic, and ecological sources. Species richness, taxonomic structure, biological spectrum, phenology, geographic distribution, habitat preferences, endemism, and conservation status were analyzed using a descriptive floristic–ecological approach.

Results: A total of 170 toxic species belonging to 124 genera and 51 families were documented, with a marked predominance of angiosperms (98.24%). Asteraceae, Fabaceae, Ranunculaceae, Apiaceae, Solanaceae, and Lamiaceae concentrate most taxa, while *Euphorbia* L. and *Artemisia* L. are the most species-rich genera. Therophytes (28.65%) and hemicryptophytes (21.05%) dominate the biological spectrum, reflecting adaptation to Mediterranean and semi-arid conditions. Flowering peaks occur mainly between March and June. Toxic taxa are widely distributed, with higher concentrations in semi-arid and sub-humid bioclimatic zones, particularly in the Rif, Middle Atlas, and Atlantic plains. Forests, matorrals, grasslands, rocky slopes, and ruderal habitats represent the principal ecological settings. Endemic taxa account for 15.8% of the recorded flora. Most species are classified as Least Concern, whereas a limited number fall within Threatened or Data Deficient categories.

Conclusions: This synthesis provides a comprehensive floristic–ecological baseline supporting biodiversity conservation planning, ecological monitoring, and the development of toxicovigilance strategies in Morocco.

Keywords: Toxic plants, vascular flora, plant ecology, floristic diversity, Morocco.

Background

Plants producing toxic or bioactive compounds constitute an integral component of vascular floras worldwide. These compounds, which include alkaloids, terpenoids, glycosides and phenolic derivatives, play essential ecological roles in plant defense, competition and adaptation, while simultaneously shaping long-standing interactions with human societies (Dewick 2009, Wink 2003). In Mediterranean regions, where floristic diversity intersects with a long history of traditional plant use, toxic plants occupy a particularly complex position at the interface between food, medicine and risk. These taxa are embedded in ethnobotanical knowledge systems, where their therapeutic, ritual, or alimentary uses coexist with documented poisoning risks, highlighting the dual dimension of cultural value and biological hazard.

Morocco is recognized as one of the major biodiversity hotspots of the Mediterranean Basin, characterized by strong biogeographical heterogeneity resulting from the interaction of Mediterranean, Atlantic, Saharan and montane influences. This diversity is reflected in a rich vascular flora structured along pronounced climatic, altitudinal and ecological gradients (Fennane *et al.* 2023). Within this context, numerous plant taxa traditionally used for medicinal, aromatic, or alimentary purposes are also known to exhibit toxic properties, especially when misused, confused, or consumed at inappropriate doses (Bellakhdar 2006, Hmamouchi 2001).

Over the last decades, toxic plants have been addressed in Morocco mainly through ethnobotanical and ethnopharmacological studies, often at local or regional scales, focusing on traditional uses and poisoning risks (Chaachouay *et al.* 2021, Elouardi *et al.* 2022, Kharchoufa *et al.* 2021, Najem *et al.* 2018a). While these studies provide valuable insights into local knowledge and practices, they are inherently heterogeneous in terms of objectives, spatial coverage, and taxonomic treatment. As a result, information on toxic plants remains fragmented, unevenly distributed across regions, and rarely integrated within a unified floristic–ecological framework.

Moreover, the concept of plant toxicity itself remains complex, often overlapping with medicinal use and dose-dependent pharmacological activity. The distinction between intrinsically toxic taxa and plants that may become harmful only under conditions of misuse or excessive dosage is not always clearly established in the literature. This conceptual ambiguity can generate inconsistencies in species selection and interpretation, particularly when ethnobotanical citations are not supported by explicit toxicological evidence. Addressing this issue requires a clearly defined toxicological framework, ensuring that plant toxicity is considered on the basis of documented adverse effects rather than solely on traditional use or perceived potency.

A first structured synthesis of toxic vascular plants reported across Morocco was recently proposed by Labrighli *et al.* (2024), providing a harmonized checklist based on critically reviewed bibliographic sources. This work constituted an essential baseline for understanding the taxonomic breadth of toxic plants and their documented uses. However, floristic inventories are dynamic by nature, and continued exploration of the literature, taxonomic updates and newly published regional studies progressively refine the knowledge of toxic taxa and their ecological attributes.

In this context, the present study represents a continuation and update of previously published work, to expand the documented pool of toxic vascular plants and, importantly, to provide a comprehensive floristic and ecological characterization of these taxa. Rather than relying on field surveys or ethnobotanical investigations, this study is based exclusively on cross-validated floristic, taxonomic, ecological, and toxicological sources, ensuring methodological consistency and reproducibility.

We hypothesize that toxic vascular plants in Morocco exhibit distinct taxonomic and ecological patterns structured by the country's biogeographical heterogeneity, and that these patterns partly reflect long-standing interactions between local communities and potentially hazardous plant resources. Specifically, this work seeks to: (i) update and consolidate the list of toxic vascular plants reported across Morocco, (ii) analyze their taxonomic structure and distribution across systematic groups, families and genera, (iii) characterize their ecological attributes, including life-form spectrum, geographical and bioclimatic distribution, habitat preferences and altitudinal ranges, (iv) assess patterns of endemism and conservation status based on available reference frameworks, and (v) situate toxic plants within the broader context of Moroccan vascular flora and biodiversity management.

By integrating floristic, ecological and conservation perspectives, this study aims to provide a robust reference framework for future research on toxic plants, contributing to a more nuanced understanding of their role within Mediterranean biodiversity and supporting interdisciplinary approaches linking botany, ecology, toxicology and public health.

Materials and Methods

The present study constitutes a continuation and update of the previously published checklist of toxic vascular plants of Morocco (Labrighli *et al.* 2024) and aims to provide a floristic and ecological reappraisal of the available data. The study area encompasses the entire territory of Morocco, characterized by marked biogeographical heterogeneity, including Mediterranean, Atlantic, Saharan and montane domains. Rather than claiming exhaustive national coverage, this work is based on an extensive compilation of toxic plant species reported in the published literature from different regions of the country. The previously published checklist was used as a validated baseline dataset and was enriched through the exploration of additional regional and thematic studies, which allowed an increase in the number of recorded species.

Despite this effort, the study remains constrained by the limited availability and uneven spatial distribution of published data on toxic plants in Morocco. References dealing explicitly with plant toxicity are scarce and often regionally restricted, leading to unavoidable gaps in coverage. Consequently, the dataset should be interpreted as a synthesis of documented information rather than as a comprehensive inventory. This limitation reflects the current state of knowledge in this field and highlights the need for further targeted studies on toxic flora in under-documented regions of the country.

Data sources and bibliographic basis

The dataset analyzed in this study was compiled exclusively from published, verifiable and citable sources to gather documented toxic plant species reported in the literature from different regions of Morocco. The work is conceived as an update and extension of a previously published checklist (Labrighli *et al.* 2024), which served as a validated baseline and was subsequently enriched through a broad bibliographic survey.

Classical and foundational references dealing with toxic, medicinal and harmful plants in Morocco were first examined, including early and widely cited works such as Charnot (1945), Hmamouchi (2001), and Bellakhdar (2006), which remain essential sources for historical records of plant toxicity and traditional uses. Major floristic syntheses and reference floras were also consulted, notably Fennane *et al.* (1999, 2007, 2014) and Fennane and Ibn Tattou (2012), to verify species occurrence, ecological information and distributional data. The dataset was further enriched through an extensive review of peer-reviewed scientific articles retrieved from international databases (Scopus, Web of Science, ScienceDirect, PubMed and Google Scholar). These included regional studies explicitly addressing toxic or poisonous plants, such as Najem *et al.* (2018a, 2018b) for the Central Middle Atlas and Zerhoun regions, Chaachouay *et al.* (2021) for the Rif, and Kharchoufa *et al.* (2018, 2021) for northeastern Morocco. Additional studies reporting toxicological risks associated with medicinal plants were also examined, including Traibi *et al.* (2013), Rachid *et al.* (2013), Mouaffak *et al.* (2013), Romo *et al.* (2017), OuLmaati *et al.* (2017), Nchinech *et al.* (2019), Hoummani *et al.* (2019), Hosni *et al.* (2019), Farzaei *et al.* (2020), Achour *et al.* (2021) and Elouardi *et al.* (2022). Ethnobotanical and ethnotoxicological studies were also consulted when they provided clearly identified taxa and explicit reference to toxic effects or poisoning risks. These included, among others, El Alami *et al.* (2016), Belhaj *et al.* (2021), Najem & Ibijbijen (2020), Najem *et al.* (2021), Eddouks *et al.* (2019), as well as broader syntheses such as Fakchich & Elachouri (2021). Additional regional ethnobotanical surveys (e.g., Benkhnigue *et al.* 2010, 2022, 2023, Fennane & Rejdali 2016, Imane *et al.* 2018, Loutfia et *al. 2013*, Saadi *et al.* 2017) were used as complementary sources when they reported confirmed or recurrent toxic uses. In addition, annual reports from the Moroccan Anti-Poison and Pharmacovigilance Centre were reviewed to identify plant species involved in documented poisoning cases over recent decades, providing an independent source of toxicological evidence that complements the bibliographic data.

Only taxa supported by clear taxonomic identification and explicit documentation of adverse toxic effects in independent sources were retained in the dataset. Studies reporting exclusively medicinal uses or referring to toxicity in a speculative or unsubstantiated manner were considered selectively and integrated only when supported by convergent evidence. The resulting dataset, therefore represents a critically assessed and cross-validated synthesis of the information currently available in the literature. While the distribution of published data on toxic plants varies among regions, this compilation provides a coherent and structured overview of documented occurrences, offering a reliable basis for floristic and ecological analyses and for identifying priorities for future research.

Taxonomic framework and databases used

The taxonomic framework adopted in this study is based on a critical harmonization of names and family circumscription using current and authoritative taxonomic databases. Scientific names, synonymy and accepted nomenclature were standardized primarily using Plants of the World Online (POWO, accessed 2026), which provides continuously updated taxonomic treatments for vascular plants. Nomenclatural authorship and publication details were verified using the International Plant Names Index (IPNI, accessed 2026). For taxa occurring in Morocco and the Mediterranean–North African region, additional verification was carried out using the African Plant Database (version 4.0.0) and Euro+Med PlantBase, in order to ensure regional taxonomic consistency. When required, taxonomic information was verified against the World Flora Online (WFO, accessed 2026) to ensure consistency with the current global taxonomic consensus. Family circumscription for angiosperms follows the Angiosperm Phylogeny Group IV (APG IV) system (APG IV 2016). In cases of discrepancies among sources, priority was given to the most recent and widely accepted taxonomic updates. All taxa were assigned to a single accepted name and family, and synonyms reported in the literature were critically reviewed and standardized before analysis. This approach ensured taxonomic stability and reproducibility across the compiled dataset.

Data processing and analytical approach

The floristic and ecological parameters attributed to each taxon were subsequently synthesized using a descriptive analytical approach. Taxa were selected based on two main criteria: (i) their confirmed presence in Morocco, and (ii) the documentation of their toxicity in more than one independent bibliographic source. In the present study, plant toxicity is defined as the documented ability of a taxon to induce adverse physiological or pathological effects in humans or animals under natural conditions of exposure (ingestion, contact, or inhalation). Toxicity was considered in a broad toxicological sense, encompassing intrinsic chemical toxicity associated with identified bioactive compounds (e.g., alkaloids, glycosides, terpenoids), clinically reported poisoning cases, or well-documented irritant or harmful effects under realistic exposure conditions. Species cited exclusively for medicinal use without explicit evidence of adverse effects were not retained, in order to distinguish pharmacologically active plants from taxa with confirmed toxic potential. Species reported as toxic exclusively to animals and lacking documented relevance to human exposure, as well as taxa occurring only under cultivation, were excluded from the analysis to ensure the coherence of the ecological and biogeographical parameters assessed. The life-form spectrum of the recorded poisonous flora was established according to Raunkiaer's (1934) classification, allowing the assessment of the relative contribution of the different life-form categories. Species were classified according to their status of occurrence (spontaneous, introduced or naturalized) based on information extracted from the consulted floristic and distributional sources. The analysis focused exclusively on toxic vascular plants occurring in natural or semi-natural environments within Morocco. Geographical distribution, bioclimatic stage, and ecological preferences were analyzed following the classifications and regional frameworks adopted in the *Flore pratique du Maroc* (Fennane 2021, Fennane *et al.* 1999, 2007, 2014). These references were used to assign each taxon to the corresponding phytogeographical regions and bioclimatic stages, ensuring consistency with the national floristic framework. Endemism and conservation status were assessed using the Moroccan Red List of vascular plants (Fennane 2021). The floristic structure was assessed by integrating the generic and specific richness of the inventoried families and systematic groups. Species richness, proportional representation of families, life-form categories and chorological elements were calculated using descriptive statistics, including absolute counts and percentage contributions. In this study, both floristic and ecological aspects were jointly considered, and a combination of quantitative and qualitative analyses was applied to improve the interpretation, evaluation, and comparative assessment of the results. A comparative assessment with previous regional studies was conducted to contextualize the results, contributing to a more comprehensive characterization of the toxic vascular flora documented in Morocco.

Results and Discussion

Botanical and floristical aspects

The floristic analysis of toxic vascular plants compiled in the present study resulted in a catalogue of 170 species, distributed among 124 genera and 51 botanical families (Table 1). These taxa are assigned to four major systematic groups, which are presented in alphabetical order within each group. For each species, information on the life-form spectrum, status of presence (spontaneous, naturalized, cultivated or imported), flowering period, bioclimatic stage, geographical distribution and habitat, as well as endemism and conservation status, was compiled and analyzed (Appendix 1).

The analysis of Table 1 reveals a pronounced dominance of angiosperms, which comprise 48 families, 121 genera, and 167 species, representing 94.12% of the families, 97.58% of the genera and 98.24% of the recorded species. This marked predominance underscores the central role of angiosperms in structuring the toxic flora of Morocco and reflects their overwheLming representation in the Moroccan vascular flora as a whole. This predominance aligns with global floristic patterns, where angiosperms represent the most diversified lineage and are known to accumulate a wide range of secondary metabolites involved in chemical defense mechanisms (Dewick 2009, Wink 2003). Within angiosperms, dicotyledons are clearly dominant, accounting for 42 families, 110 genera, and 155 species (91.18% of angiosperm species), whereas monocotyledons are weakly represented, with only 6 families, 11 genera, and 12 species (7.06%). The resulting monocotyledon/dicotyledon ratio (M/D × 100 = 7.74%) is particularly low, indicating a floristic structure strongly biased toward dicotyledonous lineages. This imbalance suggests that toxic traits within Moroccan angiosperms are preferentially associated with dicotyledonous taxa rather than being evenly distributed across angiosperm lineages. This pattern may be related to the higher diversification of secondary metabolite pathways within major dicot lineages, particularly in families known for producing alkaloids, glycosides and terpenoids. Such phylogenetically structured chemical defenses could partly explain the uneven taxonomic distribution of toxic taxa observed in Morocco. Similar taxonomic patterns have been reported in Mediterranean-type floras, where dicotyledonous families dominate toxic plant assemblages, suggesting convergent ecological and phytochemical processes across Mediterranean ecosystems (Quézel & Médail 2003).

Table 1. Synthesis of the floristical diversity of Moroccan poisonous plants (N: Number).

Systematic group	**Families (N)**	**%**	**Genera (N)**	**%**	**Species (N)**	**%**
Angiosperms	48	94.12	121	97.58	167	98.24
└ Dicotyledons	42	82.35	110	88.71	155	91.18
└ Monocotyledons	6	11.76	11	8.87	12	7.06
Gymnosperms	2	3.92	2	1.61	2	1.18
Chlamydosperms	1	1.96	1	0.81	1	0.59
Total	51	100	124	100	170	100

Gymnosperms occupy a secondary position, although they remain poorly represented, with 2 families (Cupressaceae and Taxaceae), 2 genera (*Juniperus* L. and *Taxus* L.) and 2 species (*Juniperus oxycedrus* L. and *Taxus baccata* L.). Despite their low species richness, these taxa belong to woody lineages well known for containing potent toxic or irritant compounds, highlighting their toxicological relevance disproportionate to their numerical contribution. Chlamydosperms are marginally represented, with a single family (Ephedraceae), one genus (*Ephedra* L.) and one species (*Ephedra alata* Decne.), reflecting their very limited contribution to the overall toxic flora.

Overall, the 51 botanical families recorded represent approximately 32.90% of the families of the Moroccan vascular flora (Fennane & Ibn Tattou 2012). This substantial proportion indicates that toxic taxa are distributed across a broad phylogenetic spectrum of the national flora, although their representation remains markedly uneven among systematic groups. Such a pattern underscores the non-random, phylogenetically structured distribution of toxic traits within the Moroccan vascular flora, suggesting that toxic potential constitutes a widespread ecological strategy rather than a marginal attribute.

Table 2 compares the floristic diversity of poisonous plants reported in the present study with that documented in previous works conducted in different regions of Morocco. The observed variations in the number of recorded species, genera and families reflect differences in geographical coverage, thematic focus and bibliographic depth among the studies.

At a comparable geographical scale, the present study can be directly contrasted with the checklist published by Labrighli et al. (2024). While that synthesis documented 138 species belonging to 99 genera and 46 families, the updated dataset presented here records 170 species distributed among 124 genera and 51 families. This increase is consistent with the integration of additional published records and more recent regional studies addressing poisonous plants, allowing a broader compilation of documented taxa. At the national level, Fakchich and Elachouri (2021) reported 162 species, a value close to that observed in the present study, although without detailed information on genera and families. The proximity of these values suggests a comparable scope in terms of geographical coverage, while differences in taxonomic resolution and data sources may account for the discrepancies observed.

At the regional scale, relatively high numbers of species are reported for the Northeastern region and the Rif, with 89 species (Kharchoufa et *al*. 2018) and 84 species (Chaachouay et *al.* 2021), respectively. These values likely reflect both the ecological heterogeneity of these regions and the intensity of ethnobotanical and toxicological investigations conducted there, resulting in a more detailed documentation of poisonous plants. The Central Middle Atlas stands out as one of the most consistently documented regions, with 83 species reported across several studies (Najem *et al.* 2018a, 2018b, 2021). However, these regional differences may also partly reflect variation in research effort and sampling intensity, indicating that apparent richness patterns are influenced not only by ecological factors but also by bibliographic coverage.

Although the number of species remains stable, variations in the number of genera and families among these studies (from 36 to 39 families) illustrate differences in taxonomic treatment, synonym handling and data aggregation rather than real changes in floristic composition. Intermediate values are observed for regions such as Fez–Meknes (59 species), Tafilalet (47 species) and the Central High Atlas (43 species). These figures are coherent with studies conducted over more restricted geographical areas or focused on specific ethnobotanical contexts, which tend to record a narrower spectrum of poisonous taxa. Lower species numbers reported for Mechraâ Bel Ksiri, and Zerhoun regions (ranging from 12 to 39 species) are consistent with the localized nature of these studies and their limited spatial extent.

Overall, the comparison indicates that the diversity of poisonous plants documented in Morocco varies widely across regions and studies. These variations primarily reflect differences in study scale, thematic orientation, and bibliographic coverage, underscoring the complementary role of regional studies and integrative syntheses in improving the overall documentation of toxic plant diversity. Consequently, the observed diversity gradients should be interpreted with caution, as differences in taxonomic standardization, synonym treatment and inclusion criteria among studies may influence reported diversity metrics.

Table 2. Comparison of the floristic diversity of poisonous plants inventoried in different regions of Morocco

Region	Number of			Authors
	Species	Genera	Families	
Our Study	170	124	51	
Whole Country	138	99	46	Labrighli et al. (2024)
Fez-Meknes Region	59	-	33	Ed-dahmani et al. (2024)
Whole Country	162	-	-	Fakchich and Elachouri (2021)
Rif	84	64	30	Chaachouay et al. (2021)
Central Middle Atlas	83	75	39	Najem et al. (2021)
High Atlas Central	43	-	-	Belhaj et al. (2021)
Central Middle Atlas	83	74	36	Najem et al. (2018a)
Tafilalet Region	47	-	38	Eddouks et al. (2019)
Zerhoun Region	17	17	13	Najem et al. (2018b)
Northeastern	89	81	45	Kharchoufa et al. (2018)
Mechraâ Bel Ksiri Region	39	-	-	Benkhnigue et al. (2010)

Spontaneity

The analysis of the status of occurrence of the toxic vascular plants recorded in the present study reveals a marked predominance of spontaneous taxa within the Moroccan flora (Table 3). Among the 170 toxic species compiled, 150 taxa (88.24%) are spontaneous, while 10 species (5.88%) are classified as introduced and another 10 species (5.88%) as naturalized.

Table 3. Types of poisonous plants recorded in Morocco and their contribution

Toxic plants type	Contribution %
Spontaneous	88.24
introduced	5.88
Naturalized	5.88

Although strictly comparable regional syntheses exclusively dedicated to toxic plants are lacking, this distribution pattern is consistent with the general floristic structure of Morocco, where spontaneous taxa constitute the dominant component of native and semi-natural vegetation types (Fennane et al. 1999, 2007, 2014). The limited contribution of introduced and naturalized species indicates that plant toxicity in Morocco is primarily associated with indigenous or long-established elements of the flora rather than with recent introductions.

The strong predominance of spontaneous toxic plants reflects their long-term ecological integration across diverse Moroccan ecosystems and suggests that toxic traits have developed within native evolutionary lineages. From a floristic and toxicological perspective, these findings indicate that toxic potential is deeply embedded within the native plant diversity, reinforcing the role of spontaneous flora as the principal reservoir of potentially hazardous species.

However, it should be noted that the relative proportion of introduced and naturalized taxa may partly reflect differential documentation effort, as non-native species are often more intensively studied in the context of invasion biology and ecological risk assessment. Consequently, the observed distribution pattern should be interpreted within the broader framework of floristic documentation and research intensity.

Generic and specific analysis of botanical families of taxa recorded in the study area

According to our results (Table 4), the toxic vascular flora considered in this study comprises 51 botanical families, showing a markedly uneven distribution among families. A limited number of families clearly dominate the floristic structure of the toxic flora. Asteraceae and Fabaceae rank first, each represented by 18 species distributed across 13 genera, followed by Ranunculaceae (13 species, 9 genera), Apiaceae and Solanaceae (12 species each), Lamiaceae (11 species), and Euphorbiaceae (10 species). Together, these seven families account for 95 species, representing 55.88% of the total number of toxic species recorded. A second group of families is moderately represented, notably Poaceae (6 species), Brassicaceae (5 species), and Plantaginaceae and Araceae (4 species each). These families contribute modestly to the overall species richness but remain recurrent components of the toxic flora.

In contrast, the majority of families are poorly represented. Indeed, 26 families are represented by a single species, each contributing only 0.59% to the total species richness, while most of the remaining families include no more than two to four species (Table 4). This pattern highlights a strong taxonomic imbalance, with toxic traits concentrated in a restricted group of floristically dominant families, whereas in many other families toxicity appears as an isolated lineage-specific feature.

From a generic perspective, Asteraceae and Fabaceae are the most diversified families, each comprising 13 genera, followed by Ranunculaceae and Lamiaceae (9 genera each) and Apiaceae (8 genera). The remaining families generally include a low number of genera, most often five or fewer, reflecting limited generic diversification among families with weak toxic representation.

When compared with the overall structure of the Moroccan vascular flora, this pattern is largely consistent with national floristic syntheses. According to Fennane & Ibn Tattou (2012) and broader Mediterranean floristic syntheses (Quézel & Médail 2003), families such as Asteraceae, Fabaceae, Lamiaceae and Apiaceae rank among the most species-rich plant families in Morocco and across Mediterranean-type floras. Their predominance within the toxic flora therefore, appears to reflect both their intrinsic floristic richness and their propensity to include taxa producing biologically active secondary metabolites.

The prominence of families such as Asteraceae, Fabaceae, Ranunculaceae and Solanaceae within the toxic flora likely reflects their high chemical diversity and their capacity to synthesize a wide range of secondary metabolites involved in plant defense mechanisms, including alkaloids, glycosides and terpenoids, many of which are responsible for toxic effects in humans and animals (Dewick 2009, Wink 2003). Conversely, families represented by a single toxic species illustrate the scattered and non-systematic occurrence of toxic traits within many lineages of the Moroccan flora.

Table 4. Genera and species richness of families recorded in Morocco (N: number).

Families	**N. of Genera**	**N. of Species**	**% of species**
Asteraceae	13	18	10.59
Fabaceae	13	18	10.59
Ranunculaceae	9	13	7.65
Apiaceae	8	12	7.06
Solanaceae	6	12	7.06
Lamiaceae	9	11	6.47
Euphorbiaceae	4	10	5.88
Poaceae	4	6	3.53
Brassicaceae	4	5	2.94
Plantaginaceae	2	4	2.35
Araceae	2	4	2.35
Boraginaceae	3	3	1.76
Cucurbitaceae	3	3	1.76
Caryophyllaceae	3	3	1.76
Amaranthaceae	3	3	1.76
Rutaceae	1	2	1.18
Buxaceae	1	2	1.18
Asparagaceae	2	2	1.18
Viburnaceae	1	2	1.18
Rosaceae	2	2	1.18
Apocynaceae	2	2	1.18
Santalaceae	1	2	1.18

Aristolochiaceae	1	2	1.18
Thymeleaceae	1	2	1.18
Paeoniaceae	1	2	1.18
Primulaceae	1	1	0.59
Cistaceae	1	1	0.59
Rubiaceae	1	1	0.59
Colchicaceae	1	1	0.59
Coriariaceae	1	1	0.59
Rhamnaceae	1	1	0.59
Araliaceae	1	1	0.59
Ericaceae	1	1	0.59
Myrtaceae	1	1	0.59
Cyperaceae	1	1	0.59
Nitrariaceae	1	1	0.59
Polygonaceae	1	1	0.59
Oleaceae	1	1	0.59
Asphodelaceae	1	1	0.59
Taxaceae	1	1	0.59
Dioscoreaceae	1	1	0.59
Cleomaceae	1	1	0.59
Ephedraceae	1	1	0.59
Papaveraceae	1	1	0.59
Scrophulariaceae	1	1	0.59
Cupressaceae	1	1	0.59
Berberidaceae	1	1	0.59
Plumbaginaceae	1	1	0.59
Onagraceae	1	1	0.59
Gentianaceae	1	1	0.59
Total: 51	124	170	100

The most represented families

Table 5 presents the ranking, in decreasing order of species richness, of the eight most represented botanical families within the toxic vascular flora documented in the present study, together with their relative positions in regional inventories and in the Moroccan vascular flora. The eight most represented families together account for 100 taxa (58.82%) of the recorded flora, indicating a marked concentration of toxic plants within a limited number of floristically dominant lineages. Overall, a good correspondence is observed between the ranking of these families at the scale of the present study and their position within the Moroccan vascular flora, although notable shifts occur. Asteraceae occupies the first position both locally and nationally, confirming its leading role in the Moroccan flora (Fennane & Ibn Tattou 2012). Fabaceae, which also ranks first in the present study, occupies the second position nationally. In contrast, Ranunculaceae, which ranks third locally, occupies only the sixth position nationally, highlighting a disproportionate representation of toxic taxa within this family. Apiaceae and Solanaceae, both ranked fourth locally, show moderate rank differences compared to the national flora, where they occupy the fifth and eighth positions, respectively. Lamiaceae ranks sixth locally but fourth nationally, whereas Poaceae, despite ranking eighth in the present study, occupies the third position at the national scale, reflecting its high floristic richness but comparatively low toxic potential. Euphorbiaceae shows a relatively stable ranking at both scales.

These families constitute some of the most structurally important components of the Moroccan vascular flora in terms of both species and genera richness (Fennane & Ibn Tattou 2012, Fennane *et al.* 2023). Their prominence within the toxic flora is closely linked to their long-standing integration into traditional food systems, medicinal practices and aromatic uses, which increases the probability of human exposure and consequently the documentation of toxic effects. This multifunctionality, combining alimentary, therapeutic, aromatic and toxic properties, has been extensively documented in classical ethnobotanical works (Bellakhdar 1997, Hmamouchi 2001) as well as in more recent regional and thematic studies (Chaachouay *et al*. 2021, Kharchoufa *et al.* 2021), and has been synthesized at the national level in recent integrative approaches (Labrighli *et al.* 2025, 2026).

Table 5. Comparison of the species richness of the prominent families of the poisonous flora of some regions of Morocco with the Moroccan vascular flora

Family	Rank and number of toxic plant species				
	Our study	**Morocco (Labrighli et al. 2024)**	**Rif region (Chaachouay et al. 2021)**	**Central Middle Atlas region (Najem et al. 2018a)**	**Moroccan vascular flora (Fennane & Ibn Tattou, 2012)**
Asteraceae	1 (18)	3 (12)	1 (9)	2 (12)	1 (540)
Fabaceae	1 (18)	1 (17)	1 (9)	5 (3)	2 (403)
Ranunculaceae	3 (13)	2 (13)	6 (2)	6 (2)	6 (60)
Apiaceae	4 (12)	5 (8)	3 (7)	3 (9)	5 (157)
Solanaceae	4 (12)	2 (13)	3 (7)	6 (2)	8 (29)
Lamiaceae	6 (11)	7 (3)	5 (4)	1 (13)	4 (195)
Euphorbiaceae	7 (10)	4 (11)	5 (3)	6 (2)	7 (45)
Poaceae	8 (6)	6 (6)	5 (3)	6 (2)	3 (330)

Within this framework, Asteraceae and Fabaceae jointly rank first, each represented by 18 toxic taxa. Asteraceae is also the most species-rich family of the Moroccan vascular flora, comprising approximately 128 genera and about 550 species (Fennane & Ibn Tattou 2012). Its predominance within the toxic flora reflects both its exceptional floristic richness and its broad ecological amplitude. In addition, numerous Asteraceae species are widely involved in food, medicinal, and aromatic practices, which may increase the risk of misuse or accidental poisoning (Bellakhdar 1997, Benkhnigue *et al.* 2023). Representative toxic taxa include *Artemisia herba-alba* Asso, *A. absinthium* L., *Chamaeleon gummifer* (L.) Cass., and *Atractylis cancellata* L., whose toxicity is mainly associated with sesquiterpene lactones and other bioactive secondary metabolites (Bellakhdar 1997, Chaachouay *et al.* 2021).

Fabaceae, which shares first rank with Asteraceae, represents another major family in which high floristic diversity overlaps with substantial socio-economic importance. Fabaceae species play a central role in Moroccan agri-food systems and traditional medicine, particularly through nutrient-rich seed crops such as *Cicer arietinum* L., *Lens culinaris* Medik, *Trigonella foenum-graecum* L., *Pisum sativum* L., *Arachis hypogaea* L., *Phaseolus vulgaris* L., and *Vicia faba* L. (Benkhnigue *et al.* 2022, Labrighli *et al.* 2025). Nevertheless, several taxa recorded in this study, namely *Anagyris foetida* L., *Lupinus angustifolius* L., *Retama monosperma* (L.) Boiss., and *Crotalaria saharae* Coss., are characterized by well-documented toxic effects, mainly linked to alkaloids and other nitrogen-containing secondary compounds.

Ranunculaceae, ranked third with 13 toxic taxa, displays a high toxicological relevance relative to its overall floristic size. The family is characterized by the production of potent bioactive compounds, including alkaloids, cardiac glycosides and protoanemonin derivatives (Al-Snafi *et al.* 2022). Species such as *Aconitum lycoctonum* L., *Helleborus foetidus* L., *Ranunculus sceleratus* L. and *Adonis aestivalis* L. are frequently cited among the most poisonous plants in traditional and medical literature (Bellakhdar 1997). Although of limited importance in food systems, Ranunculaceae occupy a prominent place in toxicological records, where severe poisoning cases due to misuse or misidentification are regularly reported (Labrighli *et al.* 2024).

Apiaceae and Solanaceae, both ranked fourth with 12 toxic taxa, exemplify the narrow boundary between food, medicinal use and toxicity. Apiaceae, which occupies the seventh rank in the Moroccan vascular flora (Fennane & Ibn Tattou 2012), includes widely consumed culinary and aromatic species such as *Foeniculum vulgare* Mill. and *Pimpinella anisum* L., alongside highly toxic taxa like *Conium maculatum* L. and *Oenanthe crocata* L., whose toxicity is linked to aromatic compounds and furanocoumarins (Amer & Aly 2019, Mnif & Aifa 2015). Similarly, Solanaceae comprise major food crops (*Solanum* spp.) as well as highly toxic medicinal and ritual plants (*Atropa belladonna* L., *Hyoscyamus niger* L., *Datura stramonium* L.), rich in tropane and steroidal alkaloids responsible for severe intoxications when misused (Labrighli *et al.* 2026, Pomilio *et al.* 2008).

Lamiaceae, ranked sixth with 11 toxic taxa, is traditionally regarded as one of the most important families of aromatic and medicinal plants in Morocco, owing to the abundance of glandular trichomes producing essential oils of high economic and pharmacological value (Cantino & Sanders 1986). Widely used genera such as *Mentha*, *Salvia*, *Lavandula*, *Thymus* and *Rosmarinus* (Bekut *et al.* 2018) include species that may become toxic when improperly used or overdosed, notably *Mentha pulegium* L., *Teucrium polium* L., *Ajuga iva* (L.) Schreb., *Salvia officinalis* L. and *Marrubium vulgare* L. Their toxicity is mainly associated with terpenoids, flavonoids and iridoids (Gibbs 1974, Rozman *et al.* 2007, Taskova *et al.* 1997). Overall, the dominance of these families within the toxic flora reflects the combined influence of high floristic richness, pronounced phytochemical diversity, and long-standing ethnobotanical interactions between humans and plants across Mediterranean ecosystems (Quézel & Médail 2003).

Genus richness of poisonous plants in Morocco

The analysis of Table 6 indicates that a limited number of genera concentrate the highest number of toxic species within the recorded flora. The genus *Euphorbia* ranks first with seven species, reflecting both its well-known toxic potential and its wide ecological distribution in Moroccan ecosystems. It is followed by *Artemisia*, represented by five species, a genus widely used in traditional medicine but also frequently associated with toxic effects when improperly used (Bellakhdar 1997, Chaachouay *et al.* 2021). *Lathyrus* and *Ranunculus* rank third, each with four species, while *Hyoscyamus*, *Digitalis* and *Solanum* occupy intermediate positions with three species each. Finally, *Paeonia*, *Lupinus* and *Salvia* are represented by two species each. Overall, this distribution highlights the predominance of a limited number of chemically and ethnobotanically significant genera in structuring the toxic flora of Morocco, whereas most genera are represented by only one or a few species.

Table 6. Genera ranked by the number of recorded poisonous species in Morocco.

Genera	N. of Species
Euphorbia L.	7
Artemisia L.	5
Lathyrus L.	4
Ranunculus L.	4
Hyoscyamus L.	3
Digitalis L.	3
Solanum L.	3
Paeonia L.	2
Lupinus L.	2
Salvia L.	2

Biological spectrum of the taxa recorded

The life-form types reflect the strategies adopted by plant species to survive unfavorable seasons, as defined by Raunkiaer (1905). This classification is based on the position of renewal buds, which ensures the persistence of species under climatic constraints. The relative proportions of species belonging to each biological type constitute the biological (or natural) spectrum of a flora. According to Raunkiaer (1934), life-form spectra are closely linked to climatic conditions and, more generally, to environmental and ecological settings. The life-form spectrum of the toxic vascular plants recorded in the present study is presented in Table 7 and compared with that reported in the only available national-scale checklist providing detailed biological-type data (Labrighli *et al.* 2024). The analysis of Table 7 indicates that both spectra exhibit a highly similar structure, with identical rankings and only slight variations in relative contributions.

Table 7. Life form spectra of the recorded species according to Raunkiaer's (1934) classification and their comparison with other studies.

Biological type	This study (N=170)		Labrighli *et al.* 2024 (N=138)	
	Ranking (N of species)	Ranking (contribution %)	Ranking (N of species)	Ranking (contribution %)
Therophytes	1 (49)	1 (28.82)	1 (37)	1 (26.81)
Hemicryptophytes	2 (35)	2 (20.59)	2 (27)	2 (19.57)
Nanophanerophytes	3 (28)	3 (16.47)	3 (25)	3 (18.12)
Chamaephytes	3 (28)	3 (16.47)	4 (23)	4 (16.67)
Geophytes	5 (24)	5 (14.12)	5 (21)	5 (15.22)
Phanerophytes	6 (6)	6 (3.53)	6 (5)	6 (3.62)
Total	170	100	138	100

In the present study, therophytes clearly dominate, occupying the first rank with 49 species (28.82%), a pattern fully consistent with that observed by Labrighli *et al.* (2024), where therophytes accounted for 37 species (26.81%). Hemicryptophytes rank second in both datasets, representing 35 species (20.59%) in this study and 27 species (19.57%) in the previous checklist. Nanophanerophytes and chamaephytes share the third rank, each contributing 16.47% of the recorded taxa in the present dataset, with comparable values reported by Labrighli *et al.* (2024). Geophytes rank fifth in both studies, whereas phanerophytes remain weakly represented, accounting for less than 4% of the total species richness.

The strong predominance of therophytes can be explained by the ecological characteristics of these annual species, which possess short life cycles and are particularly well adapted to environments subject to recurrent disturbance and seasonal drought (Bouhache et al. 2002, Maillet 1992). Therophytism is widely recognized as an effective adaptive strategy for coping with water stress and high temperatures in arid and semi-arid Mediterranean regions (Barbero et al. 1990, Daget 1980). The consistent dominance of therophytes observed in both datasets reflects the strong influence of climatic constraints and anthropogenic pressure on the structure of toxic vascular flora in Morocco. Overall, the close concordance between the biological spectra of the present study and that of Labrighli *et al.* (2024) supports the robustness of the observed life-form patterns and highlights the relative stability of ecological strategies among toxic plant taxa documented in the Moroccan context. These results confirm that the biological spectrum of the toxic flora largely reflects the ecological conditions and disturbance regimes that characterize Moroccan Mediterranean ecosystems.

Systematic notes

The nomenclature adopted for the recorded taxa was verified and updated using three internationally recognized taxonomic databases: the International Plant Names Index, Plants of the World Online, and World Flora Online. Taxonomic standardization is essential in floristic inventories to ensure consistency in species identification and to allow reliable comparisons with previous botanical studies and botanical databases. These resources reflect the most recent phylogenetic and nomenclatural revisions currently adopted in global plant taxonomy.

The verification process resulted in the update of 22 taxa, involving changes in generic placement, modifications of species circumscriptions, or adjustments at the infraspecific rank (Table 8). The accepted names retained in this study follow the taxonomic backbone provided by Plants of the World Online (POWO), which was used as the primary reference for nomenclatural standardization, while IPNI and World Flora Online were consulted for complementary verification of authorship and synonymy. Author abbreviations follow the standardized format provided by the International Plant Names Index.

Many of the nomenclatural changes identified in this study reflect recent advances in plant systematics, particularly those resulting from phylogenetic analyses based on molecular data, which have led to the reassessment of generic delimitations and species circumscription in several plant families. Such revisions are now widely incorporated into global taxonomic databases and constitute an essential component of modern floristic research, ensuring the accuracy and comparability of botanical inventories across regions and studies.

Table 8. Taxonomic updates and currently accepted names of selected taxa recorded in the present study

Families	Previous scientific names	Scientific names currently accepted
Amaranthaceae	*Hammada articulata* (Moq.) O. Bolòs & Vigo	*Haloxylon salicornicum* (Moq.) Bunge ex Boiss.
Apiaceae	*Anethum foeniculum* L.	*Foeniculum vulgare* Mill.
Apiaceae	*Ammi visnaga* (L.) Lam.	*Visnaga daucoides* Gaertn.
Asparagaceae	*Battandiera amoena* (Batt.) Maire	*Albuca amoen*a (Batt.) J.C.Manning & Goldblatt
Asteraceae	*Carlina gummifera* (L.) Less.	*Chamaeleon gummifer* (L.) Cass.
Asteraceae	*Chrysanthemum parthenium* (L.) Bernh.	*Tanacetum parthenium* (L.) Sch.Bip.
Asteraceae	*Echinops spinosus* L.	*Echinops spinosissimus* Turra
Asteraceae	*Anthemis nobilis* L.	*Chamaemelum nobile* (L.) All.
Brassicaceae	*Brassica nigra* (L.) W.D.J.Koch	*Mutarda nigra* (L.) Bernh.
Caryophyllaceae	*Saponaria vaccaria* L.	*Gypsophila vaccaria* (L.) Sm.
Colchicaceae	*Colchicum autumnale* subsp. *algeriense* Batt.	*Colchicum lusitanum* Brot.
Cucurbitaceae	*Bryonia dioica* Jacq.	*Bryonia cretica* subsp. *dioica* (Jacq.) Tutin
Fabaceae	*Astragalus vogelii* (Webb) Bornm	*Podlechiella vogelii* (Webb) Maassoumi & Kaz.Osaloo
Fabaceae	*Lupinus micranthus* Guss.	*Lupinus gussoneanus* J.Agardh
Fabaceae	*Astragalus lusitanicus* Lam	*Erophaca baetica* (L.) Boiss.
Lamiaceae	*Hyssopus officinalis* L.	*Dracocephalum officinale* (L.) Y.P.Chen & B.T.Drew
Lamiaceae	*Rosmarinus officinalis* L.	*Salvia rosmarinus* Spenn.

Lamiaceae	*Calamintha officinalis* Moench	*Clinopodium nepeta* subsp. *spruneri* (Boiss.) Bartolucci & F.Conti
Paeoniaceae	*Paeonia corallina subsp. coriacea* (Boiss.) Maire	*Paeonia coriacea* Boiss.
Ranunculaceae	*Ficaria verna* Huds.	*Ranunculus ficaria* L.
Ranunculaceae	*Myosurus minimus* L.	*Ranunculus minimus* (L.) E.H.L.Krause
Ranunculaceae	*Delphinium staphisagria* L.	*Staphisagria macrosperma* Spach

Geographical distribution of the recorded taxa

The geographical distribution of the recorded toxic taxa highlights their broad spatial occurrence across Morocco's principal phytogeographical regions (Figure 1). The highest numbers of taxa are recorded in the Rif (R) with 91 taxa, followed by the High Atlas (HA; 89 taxa) and the Middle Atlas (MA; 88 taxa). Because taxa can occur in more than one phytogeographical region, values shown in Figure 1 represent the frequency of regional occurrence (presence by region) rather than mutually exclusive richness, and therefore cannot be summed across regions. North Atlantic Morocco (Man) and Middle Atlantic Morocco (Mam) also show high values, with 82 and 77 taxa respectively.

Intermediate values are observed along the Mediterranean coast (Lm) and in the Anti-Atlas (AA), each comprising 73 taxa. In contrast, lower numbers are recorded in the Oriental Mountains (Om; 65 taxa) and the Eastern Plateaux (Op; 61 taxa). The lowest values occur in Saharan Morocco (Ms; 42 taxa) and the Saharan Atlas (As; 34 taxa), reflecting the more arid environmental conditions prevailing in these southern regions.

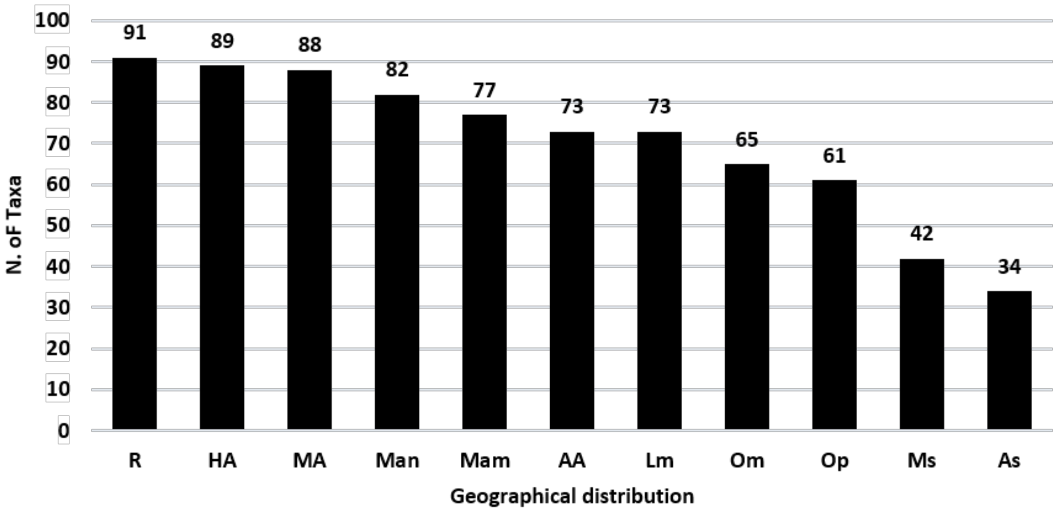

Figure 1. Geographical distribution of toxic vascular plant taxa across the main phytogeographical regions of Morocco. (R: Rif, MA: Middle Atlas, HA: High Atlas, Man: North Atlantic Morocco, Mam: Middle Atlantic Morocco, Lm: Mediterranean coast, AA: Anti Atlas, Om: Eastern Moroccan Mountains, Op: Eastern Moroccan plains and plateaus, Ms: Saharan Morocco, As: Saharan Atlas).

Overall, this distribution pattern indicates a clear concentration of toxic plant taxa in the Mediterranean and montane regions of Morocco, which are characterized by high floristic richness, marked ecological heterogeneity, and favorable climatic conditions for plant diversification. The predominance of toxic taxa in these regions may also reflect the ecological and evolutionary importance of secondary metabolites in Mediterranean environments, where plants are exposed to strong biotic pressures such as herbivory and competition, as well as to abiotic stresses including drought and high solar radiation. The observed pattern also reflects the well-known north–south bioclimatic gradient of vegetation in Morocco, with species richness progressively decreasing from the Mediterranean and montane regions of northern Morocco towards the more arid Saharan territories.

Bioclimatic stages

The toxic taxa recorded in the present study are distributed across six bioclimatic stages: semi-arid, subhumid, humid, arid, Saharan, and high-mountain (Figure 2). The analysis shows a clear dominance of the semi-arid stage, which concentrates the highest number of taxa (131 species), followed by the subhumid stage (94 taxa). The humid and arid stages are moderately represented, with 64 and 58 taxa, respectively, whereas the Saharan (25 taxa) and high-mountain (7 taxa) stages contribute only marginally to the toxic flora.

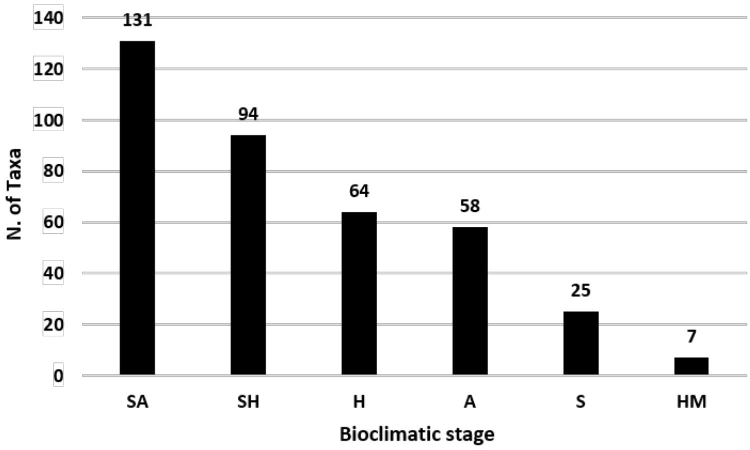

Figure 2. The bioclimatic stage of the toxic vascular plants recorded in Morocco (A: Arid; SA: Semi-arid; H: Humid; SH: Subhumid; S: Saharan; HM: High Mountain)

This bioclimatic pattern is consistent with the geographical distribution previously observed for the recorded taxa, which highlights the predominance of Mediterranean and montane regions such as the Rif, the Middle Atlas and the High Atlas. These regions are largely characterized by semi-arid to subhumid climatic conditions that favor high floristic diversity and the development of numerous spontaneous taxa. In contrast, the limited representation of Saharan and high-mountain stages reflects the more restrictive ecological conditions prevailing in these environments, which constrain both species richness and the occurrence of toxic taxa.

Overall, this distribution reflects the strong influence of Morocco's Mediterranean-type bioclimatic gradient, where the transition from humid and subhumid northern regions to increasingly arid southern environments lead to a progressive decline in floristic richness and associated toxic taxa (Fennane & Ibn Tattou 2012, Quézel & Médail 2003).

Taken together, the geographical distribution, the predominance of semi-arid to subhumid bioclimatic stages, and the dominance of therophytic life forms reveal a coherent ecological pattern. These results suggest that the toxic vascular flora of Morocco is largely structured by Mediterranean climatic conditions and disturbance regimes, which favor annual species and chemically defended taxa adapted to seasonal drought and heterogeneous habitats.

Habitat types and altitudinal distribution of the recorded taxa

The diversity of habitats occupied by the recorded toxic taxa reflects the strong environmental heterogeneity of Morocco, shaped by the coexistence of plains, low and middle mountain ranges, and contrasted bioclimatic conditions ranging from arid to subhumid stages. This environmental mosaic strongly influences the distribution of species across different habitat types (Table 9). Forests constitute the habitat hosting the highest number of toxic species (48 taxa), followed by matorrals (42 taxa) and fields and uncultivated habitats (each with 37 taxa). Lawn and meadow habitats (25 taxa) and stream margins (24 taxa) also contribute substantially to the overall richness. In contrast, rocky habitats, debris sites, hedges, clearings, and sand and gravel habitats host comparatively fewer species, each supporting fewer than 15 taxa. This pattern highlights the importance of structurally complex and moderately disturbed habitats, which combine ecological stability with frequent human–plant interactions, in shaping the distribution of toxic flora. The association of many toxic taxa with moderately disturbed habitats may also reflect the ecological role of chemical defense in plants growing under strong biotic pressure, where the production of secondary metabolites contributes to protection against herbivory and environmental stress.

Altitudinal distribution further reinforces this pattern (Table 10). A clear dominance of species is observed in low mountain belts (96 taxa), followed by plains (82 taxa) and middle mountain belts (68 taxa). In contrast, high mountain environments harbor only a limited number of species (7 taxa). This altitudinal gradient is consistent with the predominance of semi-arid and subhumid climatic conditions and with the geographical concentration of toxic taxa in Mediterranean and montane regions previously highlighted. Low and middle altitudes offer favorable climatic conditions, diversified habitats, and greater accessibility, which together promote higher species richness and increase the likelihood of toxic plant occurrence.

Table 9. Habitat types of toxic plants in Morocco.

Habitat types	Number of taxa
Forest	48
Matorral	42
Fields	37
Uncultivated place	37
Lawn and meadow	25
Stream margins	24
Pasture	21
Rocky habitats	12
Debris sites	11
Hedges	11
Clearing	8
Sand and gravel	8

Table 10. Different types of altitude for toxic plants collected in Morocco.

Altitude	Number of taxa
Low mountain	96
Plain	82
Middle mountain	68
High mountain	7

Taken together, the predominance of toxic taxa in forests, matorrals and moderately disturbed habitats at low and middle elevations is consistent with the bioclimatic distribution and life-form spectrum observed in this study, suggesting that the structure of the toxic vascular flora of Morocco is strongly influenced by Mediterranean climatic conditions and landscape heterogeneity.

Flowering phenology

Flowering is a key biological process associated with reproductive success and is strongly influenced by environmental factors such as temperature, photoperiod, and water availability. The analysis of the flowering periods of the recorded toxic taxa (Table 11) shows a clear predominance of spring-flowering species, with 130 taxa flowering during this season. Summer-flowering species are also well represented (89 taxa), whereas autumn (20 taxa) and winter (16 taxa) flowering species remain comparatively limited. This pattern reflects the strong influence of Mediterranean climatic conditions, where favorable temperature and moisture conditions during spring promote flowering activity in a wide range of plant species. In contrast, the reduced number of species flowering in autumn and winter is likely related to less favorable environmental conditions during these seasons, particularly in semi-arid and arid regions.

Table 11. Seasonal flowering distribution of the toxic plant taxa recorded in Morocco.

Flowering period	Number of taxa
Spring	130
Summer	89
Autumn	20
Winter	16

The predominance of spring flowering among the recorded taxa may also be associated with the ecological dynamics of secondary metabolite production in plants. Several studies have shown that the synthesis and accumulation of many bioactive compounds involved in plant defense tend to increase during periods of active growth and reproductive development, particularly during flowering. This physiological phase is often characterized by enhanced metabolic activity, which may favor the accumulation of toxic secondary metabolites in many plant taxa (Agrawal 2011, Mithöfer & Boland 2012, Pichersky & Lewinsohn 2011). This relationship between flowering phenology and secondary metabolite production highlights the functional link between plant reproductive cycles and chemical defense strategies in Mediterranean ecosystems.

Endemism

Among the 170 toxic taxa recorded in the present study, a total of 27 taxa exhibit some degree of endemism, representing 15.88% of the flora considered (Figure 3). Strictly Moroccan endemic species account for 16 taxa, corresponding to 9.41% of the recorded taxa, whereas the remaining taxa elements are shared with neighboring regions, mainly North Africa and the western Mediterranean basin.

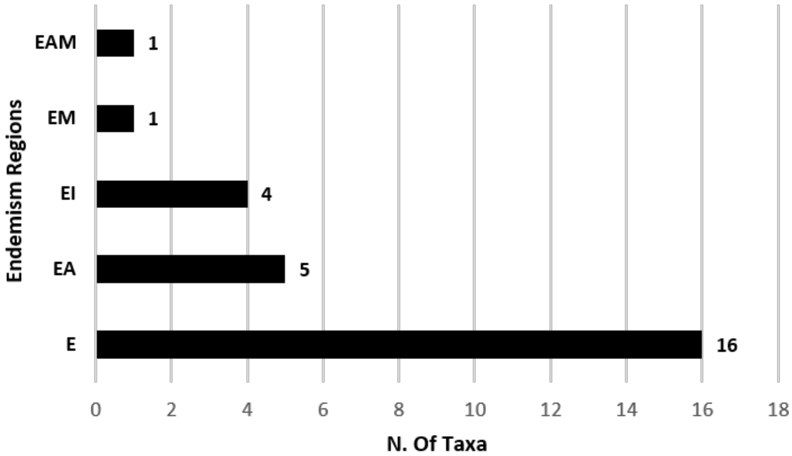

Figure 3. Endemism patterns of the toxic vascular plant taxa recorded in Morocco (E: endemic to Morocco; EI: endemic to Morocco and the Iberian Peninsula; EA: endemic to Morocco and Algeria; EAM: endemic to Morocco, Algeria and Mauritania; EM: endemic to Morocco and Mauritania).

Overall, endemic taxa thus constitute a relatively limited but noteworthy component of the toxic flora. This pattern highlights the biogeographical singularity of Morocco while indicating that the majority of toxic plant species occurring in the country have relatively wide geographical distributions. The occurrence of endemic toxic taxa also reflects the important role of Moroccan mountain systems in the diversification and persistence of endemic elements within the regional flora.

These results are consistent with the recognized status of Morocco as one of the major centers of plant diversity and endemism in the Mediterranean Basin, particularly within the Rif and Atlas Mountain ranges, which host a large proportion of the country's endemic vascular flora (Fennane & Ibn Tattou 2012, Fennane 2021).

Conservation status

The conservation status of the toxic vascular plants inventoried in this study was assessed based on the Moroccan Red Book of Vascular Plants (Fennane 2021). Two taxa included in the present inventory have not yet been evaluated in the Moroccan Red Book of Vascular Plants. The distribution of taxa across IUCN threat categories is presented in Figure 4.

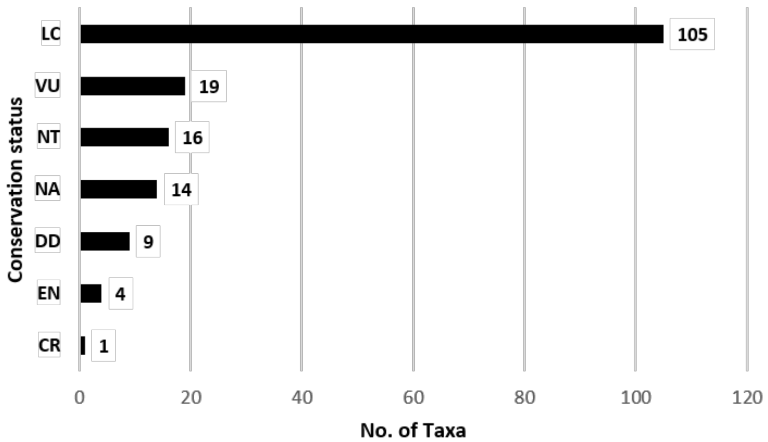

Figure 4. Conservation status of the toxic vascular plant taxa recorded in Morocco according to the Moroccan Red Book of Vascular Plants (Fennane 2021) (LC: Least Concern; NT: Near Threatened; VU: Vulnerable; EN: Endangered; CR: Critically Endangered; DD: Data Deficient; NA: Not Applicable).

The analysis reveals a clear predominance of species classified as Least Concern (LC), with 105 taxa, accounting for the largest proportion of the recorded flora. This pattern suggests that most toxic plant species occurring in Morocco remain relatively widespread and stable at the national scale. Nevertheless, a non-negligible proportion of taxa falls within categories reflecting different levels of conservation concern. Vulnerable (VU) species are represented by 19 taxa, while 16 taxa are classified as Near Threatened (NT), indicating potential risks of future population decline if current ecological pressures persist. In addition, four species are categorized as Endangered (EN) and one species as Critically Endangered (CR), highlighting the presence of highly threatened toxic taxa that require particular conservation attention.

The occurrence of Data Deficient (DD) taxa (9 species) and taxa classified as Not Applicable (NA) (14 species) reflects important gaps in available ecological, demographic, and distributional information. These categories emphasize the need for additional field surveys, ecological monitoring, and updated conservation assessments to improve knowledge on the status of several toxic plant species in Morocco.

Overall, these results indicate that, despite the predominance of LC taxa, a substantial fraction of the toxic vascular flora is associated with varying degrees of conservation concern. The presence of threatened taxa within the toxic flora highlights the importance of integrating these species into national biodiversity conservation strategies. Toxic plants constitute not only potential sources of poisoning but also important reservoirs of bioactive secondary metabolites with significant pharmacological potential, which reinforces their ecological, toxicological, and ethnobotanical significance.

When compared with the Moroccan vascular flora as a whole, the proportion of threatened taxa observed in the present study remains relatively moderate. According to the Moroccan Red Book of Vascular Plants, a significant fraction of the national flora is affected by different levels of conservation concern, particularly among endemic and geographically restricted species (Fennane 2021). The presence of threatened species within the toxic flora therefore reflects broader conservation patterns affecting Moroccan plant diversity, particularly in Mediterranean and mountain ecosystems where anthropogenic pressures and habitat transformations remain significant.

Overall, the patterns observed in taxonomy, ecology, phenology, and conservation status indicate that the toxic vascular flora of Morocco represents a structurally integrated component of Mediterranean biodiversity, shaped by climatic gradients, ecological heterogeneity, and evolutionary processes linked to plant chemical defense strategies.

Conclusion

The toxic vascular flora documented in this study represents a noteworthy component of plant diversity reported across Morocco. It comprises 170 species distributed among 124 genera and 51 botanical families, reflecting a broad taxonomic spectrum of toxic taxa within the Moroccan flora. These species are grouped into four main systematic groups, with a clear dominance of angiosperms, particularly dicotyledons, which account for the vast majority of recorded families, genera, and species.

Among the families represented, a limited number concentrate most of the toxic taxa, notably Asteraceae, Fabaceae, Ranunculaceae, Apiaceae, Solanaceae, Lamiaceae, Euphorbiaceae and Poaceae, which are also among the most species-rich families of the Moroccan vascular flora. At the generic level, Euphorbia and Artemisia emerge as the most species-rich genera, reflecting both their floristic diversification and their well-documented toxic potential.

From an ecological perspective, the life-form spectrum is characterized by a marked predominance of therophytes, followed by hemicryptophytes and low woody forms, a pattern typical of Mediterranean and semi-arid environments. The recorded taxa are mainly associated with semi-arid and sub-humid bioclimatic stages and occur preferentially in forests, matorrals, uncultivated lands, and agricultural habitats, indicating a close relationship between toxic flora, environmental heterogeneity, and human-modified landscapes.

Although most recorded species are classified as Least Concern, the occurrence of endemic taxa as well as species belonging to threatened or data-deficient categories highlights the dual dimension of toxic plants as both elements of biodiversity and potential risk factors. This observation underlines the importance of documenting toxic taxa within broader floristic and conservation frameworks, rather than addressing them solely from a toxicological perspective.

Overall, this study provides a structured floristic and ecological baseline that contributes to a better understanding of toxic plants within Moroccan biodiversity. It offers a reference framework for future research in floristics, ecology, conservation biology and toxicovigilance, and may facilitate the integration of toxic plants into multidisciplinary approaches combining botanical knowledge, public health awareness and biodiversity management.

Declarations

Ethics approval: This study did not involve human participants, animals, or experimental procedures requiring ethical approval. The research was based on floristic data, bibliographic sources, and botanical inventories.

Consent to participate: Not applicable

Consent for publication: Not applicable

Availability of data and materials: The data supporting the findings of this study are included within the article and its tables. Additional information may be obtained from the corresponding author upon reasonable request.

Competing interests: The authors declare that they have no competing interests.

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Author contributions: Conceptualization, K.L.; Methodology K.L. and C.M.; Experimentation, K.L. and C.M.; Formal analysis, K.L. C.M. and B.O; Writing Original Draft, K.L.; Supervision, C.M., B.O and J.E; Review & editing, C.M., B.O and J.E.

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Appendix 1. Checklist of the toxic plants in Morocco and their plant type, life form spectrum, flowering period, bioclimatic stage, geographical distribution, conservation status, endemism, habitat and ecology

Flowering: **Sm**: Summer; **Sp**: Spring; **W:** Winter; **A**: Autumn; **Life form**: **Ph:** Phanerophyte; **Nan**: Nanophanerophyte; **Ch**: Chamaephytes; **Hem**: Hemicryptophyte; **Th**: Therophyte; **G:** Geophyte. **Conservation status**: **LC**: Least Concern (low risk of extinction); **NA**: Not Applicable; **VU**: Vulnerable; **NT**: Near Threatened; **DD**: Data Deficient; **CR**: Critically Endangered; **EN**: Endangered. **Geographical Distribution**: **Ms**: Morocco Saharan; **As**: Saharan Atlas; **AA**: Anti Atlas; **HA**: High Atlas; **MA**: Middle Atlas; **Mam**: Middle Atlantic Morocco; **Man**: North Atlantic Morocco; **Op**: Eastern Morocco plateaus; **Om**: Mountains of eastern Morocco; **LM**: Mediterranean coastline; **R**: Rif; **All Div**: All Divisions. **Endemism**: *__E:__ endemic to Morocco; ***EI**: endemic to Morocco and the Iberian Peninsula; ***EA**: Endemic to Morocco and Algeria; ***EAM**: Endemic to Morocco, Algeria and Mauritania, ***EM:** Endemic to Morocco and Mauritania; **-**: Not Available

PHYLUM (no. of family), families (no. of species) and species accepted name	Plant type	Life form	Flowering period	Bioclimatic stage	Geographical Distribution	Conservation Status	Habitat & Ecology
I. GYMNOSPERMS (2)							
Cupressaceae (1)							
Juniperus oxycedrus L.	Spo	Nph	Sp, W	SA; SH; H	As, AA, HA, MA, Man, OM, LM, R	LC	Forests and matorral; plains and mountains
Taxaceae (1)							
Taxus baccata L.	Spo	Ph	Sp	H; HM	MA, R	VU	Shaded ravines and mid-elevation mountain forests
II. CHLAMYDOSPERMES (1)							
Ephedraceae (1)							
Ephedra alata Decne.	Spo	Nph	Sp	S	Ms	LC	Sandy habitats; oases
III. ANGIOSPERMAE							
<u>MONOCOTYLEDONAE (12)</u>							
Asparagaceae (2)							
Albuca amoena (Batt.) J.C.Manning & Goldblatt	Spo	G	Sp, W	S; A	Ms, Mam	LC	Saharan and arid rangelands
Drimia maritima (L.) Stearn	Spo	G	Sm, A	A; S; SA; SH; H	All Div	NT	Clearings; wastelands; ruderal habitats; rocky outcrops; screes; plains; low- and mid-elevation mountains
Asphodelaceae (1)							
Asphodelus macrocarpus Parl.	Spo	G	Sp		MA, Man,Om, LM, R		Matorral vegetation; wastelands; low- and mid-elevation mountains
Colchicaceae (1)							
***E** *Colchicum lusitanum* Brot.	Spo	G	A	SA; SH; H	HA;MA;Man;Mam;Om; LM;R		Pastures; clearings; plains and mountains
Cyperaceae (1)							

Cyperus longus L.	Spo	G	Sm	A; SA; SH; H	All Div	LC	Water margins and wet habitats; plains, low- and mid-elevation mountains
Dioscoreaceae (1)							
Dioscorea communis (L.) Caddick & Wilkin	Spo	G	Sp	SA; SH; H	AA; HA; MA; Mam; Man; Op; Om; LM; R	LC	Matorral vegetation, forests, and cool habitats; plains, low- (and mid-) elevation mountains
Poaceae (6)							
Anthoxanthum odoratum L.	Spo	Hem	Sp	SA; SH	HA; MA; Man; Om; R	LC	Forests; matorral vegetation; wastelands; margins of *dayas* (temporary ponds); plains; low- and mid-elevation mountains
Arundo donax L.	Nat	G	Sm; A	A; SA; SH	Ms ; As ; AA ; HA ; MA ; Mam; Man; Op; Om; LM; R	LC	Hedgerows, water margins, muddy grounds; plains and low mountains
Lolium perenne L.	Spo	Hem	Sp; Sm	SA; SH; H	AA; HA; MA; Mam; Man; Op; Om; LM; R	LC	Matorral vegetation; wastelands; plains, low- and mid-elevation mountains
Lolium temulentum L.	Spo	Th	Sp; Sm	SA; SH; H	AA; HA; MA; Mam; Man; Op; Om; LM; R	LC	Primarily in cultivated fields
Molinia caerulea (L.) Moench	Spo	Hem	Sp; Sm	SH	HA; R	DD	Marshes and wet habitats, predominantly on siliceous substrates
Phalaris minor Retz.	Spo	Th	Sp	A; S; SA; SH	Ms; As; AA; HA; MA; Mam; Man; Op; Om; LM; R	LC	Wastelands, harvested fields, sandy croplands; plains, low- (and mid-) elevation mountains
DICOTYLEDONAE (156)							
Amaranthaceae (3)							
Chenopodium vulvaria L.	Spo	Th	Sp; Sm	A;SA;SH;H	HA ; MA ; Mam; Man; Op; LM; R	LC	Fields, rubble, and roadsides
Haloxylon scoparium Pomel	Spo	Ch	A	S; A	Ms;As; AA; HA; Mam	LC	Steppes; plains and low mountains
Dysphania ambrosioides (L.) Mosyakin & Clemants	Nat	Th	Sp; Sm; A	A;SA;SH	Ms; HA; Mam; Man; Op; LM; R	LC	Naturalized in cool uncultivated habitats, ditches, hedgerows, and sandy alluvial substrates
Apiaceae (12)							
Ammi majus L.	Spo	Th	Sp	A;SA;SH;H	AA; HA; MA; Mam; Man; Op; Om; LM; R	LC	Matorral vegetation, wastelands, and fields; plains and low mountains
***E** *Bupleurum canescens* Schousb.	Spo	Nan	Sp	A	Ms; AA; Mam	VU	Plains and low mountains
****E*** *Bupleurum dumosum* Coss. & Balansa	Spo	Ch	Sp	A; SA	Ms; AA; HA; Mam;	DD	Plains and low limestone mountains
Conium maculatum L.	Spo	Th	Sp	A;SA;SH;H	HA; MA; Mam; Man; Op; Om; LM; R	LC	Moist grasslands, hedgerows, rubble; plains and low mountains

Ferula communis L.	Spo	G	Sp; Sm	A;SA;SH;H	Ms; As; AA; HA; MA; Mam; Man; Op; Om; LM; R	LC	Plains, low- and mid-elevation mountains
***E** *Foeniculum vulgare* Mill.	Nat	Ch	Sp; Sm	A;SA;SH;H	As; AA; HA; MA; Mam; Man; Op; Om; LM; R	LC	Uncultivated fields, arid slopes, ravines, rocky habitats; plains and low mountains
Oenanthe crocata L.	Spo	Hem	Sp	SH;H	HA; Man; LM; R	LC	Small streams and shaded marshy habitats; low siliceous mountains
Oenanthe fistulosa L.	Spo	G	Sp	SA;SH;H	Man; R	VU	Marshes and water margins
Pimpinella anisum L.	Int	Th	Sp; Sm	SA;H			
Thapsia villosa L.	Spo	G	Sp	SA;SH;H	HA; MA; Mam; Man; Om; LM; R	LC	Low- and mid-elevation mountains
Visnaga daucoides Gaertn.	Spo	Th	Sp; Sm	SA;SH;H	All Div	LC	Fallow land and cultivated fields on clayey soils
Apocynaceae (2)							
Calotropis procera (Aiton) W.T. Aiton	Nat	Nan	Sm	S;A	Ms; AA	NT	Beds of desert wadis
Nerium oleander L.	Spo	Nan	Sp; Sm	S;A;SA;SH;H	Ms; As; AA; HA; MA; Mam; Man; Op; Om; LM; R	LC	Banks of wadis up to c. 2000 m a.s.l.
Araceae (4)							
Arisarum simorrhinum Durieu	Spo	G	W; Sp	A;SA;SH;H	AA; HA; MA; Mam; Man; Om; LM; R	LC	Plains and low mountains; nitrophilous
Arisarum vulgare O. Targ. Tozz.	Spo	G	W; Sp	A;SA	AA; HA; MA; Mam; Man; Om; LM; R	LC	Circum-Mediterranean; plains and low mountains
Arum hygrophilum Boiss.	Spo	G	Sp	A;SA	MA; Mam; Man; Op	VU	Shrublands; hedgerows; shaded moist habitats; plains and low mountains
Arum italicum Mill.	Spo	G	Sp	A;SA	HA; MA; Mam; Man; Op; Om; LM; R	LC	Shrublands; hedgerows; shaded moist habitats; plains and low mountains
Araliaceae (1)							
Hedera helix L.		Ph	A		AA; HA; MA; Mam	LC	Shaded rocky habitats within forests and matorral vegetation of plains, low- and mid-elevation mountains
Aristolochiaceae (2)							
***E** *Aristolochia baetica* L.	Spo	Ph	W; Sp	SA;SH;H	AA; HA; Mam; Man; Om; LM; R	LC	Rocky habitats; hedgerows; shrublands and forests; plains and low mountains

***E** *Aristolochia paucinervis* Pomel	Spo	G	Sp	SA;SH;H	AA; HA; MA; Mam; Man; Om; LM; R	LC	Rocky habitats; hedgerows; shrublands and forests; plains and low mountains
Asteraceae (18)							
***EI** *Anacyclus pyrethrum* (L.) Lag.	Spo	Hem	Sp; Sm	SH;H; HM	As, AA; HA; MA; Man; Op; Om; R	VU	Forest clearings, matorral vegetation, wastelands, and pastures; (plains), low-, mid-, and high-elevation mountains
Artemisia absinthium L.	Spo	Nan	Sm; A	SA;SH	MA; Op	EN	Open forests and matorral vegetation on sparsely stony soils; mid-elevation mountains
Artemisia arborescens L.	Spo	Nan	W; Sp	SA;SH	Man; Om;LM; R	NA	Matorral vegetation of coastal and subcoastal hills
***E** *Artemisia herba-alba* Asso	Spo	Ch	Sm; A	S;A;SA	Ms; AA; HA; MA; Op; Om; LM; R	DD	Steppes and rocky pastures
***E** *Artemisia ifranensis* Didier	Spo	Ch	Sm; A	SH;H	HA; MA	VU	Forest clearings, depressions, and earthy slopes; mid-elevation mountains
***E** *Artemisia mesatlantica* Maire	Spo	Ch	Sm; A		AA; HA; MA	LC	Clayey steppes and rocky pastures of low- and mid-elevation mountains
Atractylis cancellata L.	Spo	Th	Sp; Sm	S;A;SA;SH;H	All Div	LC	Degraded forests, wastelands, and uncultivated fields; plains, low- (and mid-) elevation mountains
Chamaemelum nobile (L.) All.	Spo	Hem	Sm	SH	MA; Man; LM; R	LC	Wastelands and grasslands, nitrophilous; low- and mid-elevation mountains
Chamaeleon gummifer (L.) Cass.	Spo	Hem	Sp; Sm	A;SA;SH	HA; MA; Mam; Man; Om; LM; R	LC	Open matorral vegetation, wastelands, and uncultivated land; mainly on loose and deep soils; plains and low mountains
Echinops spinosissimus Tura	Spo	Hem	Sm		All Div	LC	Degraded matorral vegetation, steppes, and uncultivated habitats; plains, low- and mid-elevation mountains
Jacobaea vulgaris Gaertn.	Spo	Hem	Sp	SH	Man	NT	
***E** *Kleinia anteuphorbium* (L.) Haw.	Spo	Nan	Sp	A; SA	Ms; AA; HA; Mam; Op; Om	NT	Matorral vegetation, steppes, regs, and superficial sandy substrates; plains and low mountains
***E** *Lactuca virosa* L.	Spo	Th	Sm; A	SH; H	AA;MA; HA;Man; R	LC	Matorral vegetation, wastelands, cultivated fields, and cool habitats; low- and mid-elevation mountains

Launaea arborescens (Batt.) Murb.	Spo	Nan	Sm; A; Sp	S;A;SA	All Div	LC	Steppes, arid rocky habitats, and overgrazed areas; plains, low- (and mid-) elevation mountains
***EAM** *Perralderia coronopifolia* Coss.	Spo	Ch	Sp	S;A;SA	Ms; As; AA; HA; Mam; LM; R	LC	Open forests of arid regions, and desert rocky habitats and screes
Senecio leucanthemifolius Poir.	Spo	Th	W; Sp	S;A;SA;SH;H	HA; MA; Mam; Man; Op; Om; LM; R	LC	Maritime sandy and rocky habitats, matorral vegetation, wastelands, and cultivated fields; plains (and low) mountains
Senecio vulgaris L.		Th	A; W; Sp; Sm	A;SA;SH;H	AA; HA; MA; Mam; Man; Op; Om; LM; R	LC	Open forests, stony pastures, and cultivated fields; plains and mountains
Tanacetum parthenium (L.) Sch.Bip.	Int	Hem	Sm	-	-	NA	Fields, rubble, and hedgerows
Berberidaceae (1)							
Berberis vulgaris L.	Spo	Ph	Sp	-	-	LC	-
Boraginaceae (3)							
Borago officinalis L.	Spo	Th	Sp; Sm	SA;SH;H	AA; HA; MA; Mam; Man; Op; Om; LM; R	LC	Uncultivated habitats and areas surrounding dwellings; plains and low mountains
Cynoglossum maghrebicum Sutorý	Spo	Th	Sm	SA;SH;H; HM	A ; HA ; MA ; Op ; Om ; LM ; R	LC	Montane forests
Heliotropium europaeum L.	Spo	Th	Sp; Sm	A;SA;SH;H	AA; HA; MA; Mam; Man; Op; Om; LM; R	LC	Cultivated fields and fallow land; plains, low- and mid-elevation mountains
Brassicaceae (5)							
Brassica napus L.	Int	Th	Sp			NA	
***EA** *Diplotaxis tenuisiliqua* Delile	Spo	Th	W; Sp	A;SA;SH	AA; HA; Mam; Man	LC	Nitrophilous; plains and low mountains
Isatis tinctoria L.	Int	Hem	Sp; Sm	SA;SH;H; HM	AA; HA; MA	LC	Low-, mid-, and high-elevation mountains
Lepidium sativum L.	Int	Th	Sp	-	-	NA	
Mutarda nigra (L.) Bernh.	Spo	Th	Sp	S;A	Ms;Man;R	LC	Gravelly wadi beds, cultivated fields, and rubble
Buxaceae (2)							
Buxus sempervirens L.	Spo	Nan	Sm	SA;HM	HA	Vu	Matorral vegetation of calcareous mountains (1500–3000 m a.s.l.)
Buxus balearica Lam	Spo	Nan	Sp	SA;SH	AA ; HA ; MA ; Op ; Om ; Lm ; R	LC	Matorral vegetation of low- and mid-elevation calcareous mountains up to 2200 m a.s.l.
Caryophyllaceae (3)							
Agrostemma githago L.	Nat	Th	Sp; Sm	SA;SH	HA; MA; Mam; Man; Om; LM; R	LC	Matorral vegetation of low- and mid-elevation calcareous mountains up to 2200 m a.s.l.

Corrigiola telephiifolia Pour.	Spo	Hem	Sp	SA;SH;H	AA; HA; MA;Mam; Man;R	NT	Stony and sandy terrains of plains and mountains
Gypsophila vaccaria (L.) Sm.	Spo	Th	Sp			LC	
Cistaceae (1)							
***EI** *Cistus ladanifer* L.	Spo	Nan	Sp	SH;H	MA ; Mam ; Op LM ; R	LC	Low mountains
Cleomaceae (1)							
Cleome amblyocarpa Barratte & Murb.	Spo	Th	Sp; Sm	S;A	Ms; As; AA; HA	LC	Sands, gravels, and rocky habitats of desert regions and arid steppes
Coriariaceae (1)							
Coriaria myrtifolia L.	Spo	Nan	Sp	SH	R	NT	Forests, matorral vegetation, and water margins; plains and low mountains
Cucurbitaceae (3)							
Bryonia cretica subsp. dioica (Jacq.) Tutin	Spo	G	Sp	A;SA;SH;H	AA; HA; MA; Mam; Man; Op; Om; LM; R	LC	Forests, shrublands, hedgerows, and shaded habitats; plains, low- and mid-elevation mountains
Citrullus colocynthis (L.) Schrad.	Spo	G	Sm	S;A;SA	Ms; As; AA; MA; Mam; Man; Op; LM; R	LC	Coastal sands; steppes and arid stony terrains; regs and silty or sandy wadi beds
Ecballium elaterium (L.) A. Rich.	Spo	G	Sp; Sm	SA;SH;H	Mam; Man; Op; R	LC	Rubble and uncultivated habitats; plains and low mountains
Ericaceae (1)							
Arbutus unedo L.	Spo	Nan	A	SA;SH;H	AA; HA; MA; Mam; Man; Op; Om; LM; R	LC	Forests and matorral vegetation, generally on siliceous substrates; plains, low- and mid-elevation mountains
Euphorbiaceae (10)							
Chrozophora tinctoria (L.) A. Juss.	Spo	Th	Sp; Sm	A;SA;SH;H	HA;MA;Mam; Man; LM; R	LC	Primarily cultivated fields and disturbed clayey soils; plains and low mountains
Euphorbia balsamifera Aiton	Spo	Nan	Sp	S;A	Ms;AA	NT	
Euphorbia falcata L.	Spo	Th	Sp; Sm	A;SA;SH;H	As;AA; HA; MA; Mam; Man; Op; Om; LM; R	LC	Wastelands, cultivated fields, and fallow land; plains, low- (and mid-) elevation mountains
Euphorbia helioscopia L.	Spo	Th	W; Sp; Sm; A	S;A;SA;SH;H	Ms;AA; As; HA; MA; Mam; Man; Op; Om; LM; R	LC	Open habitats; plains and low mountains; nitrophilous
Euphorbia lathyris L.	Int	Th	Sp; Sm	SA;SH	Mam; Man	NA	Gardens, hedgerows, and uncultivated habitats
Euphorbia nicaeensis All.		Hem	Sm	SA;SH;H; HM	Ms; HA; MA; LM	LC	Rocky fields, rock surfaces, and screes; low-, mid-, and high-elevation mountains

***EM** *Euphorbia officinarum* subsp. *echinus* (Hook. f. & Coss.) Vindt	Spo	Nan	Sm	S;A;SA	Ms; AA; MA	NT	Thermophilous and xerophilous; plains, low- and mid-elevation mountains
***E** *Euphorbia resinifera* O. Berg	Spo	Nan	Sm	A;SA	AA; HA; MA; Mam	NT	Calcareous rocky substrates; low- and mid-elevation mountains
Mercurialis annua L.		Th	W; Sp; Sm	S;A;SA;SH;H	Ms; As; AA; HA; MA; Mam; Man; Op; Om; LM; R	LC	Cultivated fields, roadsides, rubble, and rocky habitats; plains, low- and mid-elevation mountains
Ricinus communis L.	Nat	Ph	Sm;A	A;SA;SH	Ms; As; AA; HA; MA; Mam; Man; Op; Om; LM; R	NA	Roadsides, hedgerows, and rubble; plains and low mountains
Fabaceae (18)							
Anagyris foetida L.	Spo	Nan	Sp;W	A;SA;SH;H	AA; HA; MA; Mam; Man; LM; R	LC	Clayey soils below 1300 m a.s.l.; open forests; lentisk scrublands
Calicotome villosa (Poir.) Link	Spo	Nan	Sp	SA;SH	MA ; Man ; R	LC	Plains and low mountains
Coronilla scorpioides (L.) W.D.J. Koch	Spo	Th	Sp;Sm	S;A;SA;SH;H	Ms ; As ; AA ; HA ; MA ; Mam; Man; Op; Om; LM; R	LC	Cultivated fields, harvested fields, fallow land, and rocky habitats; plains and low mountains
***EA** *Crotalaria saharae* Coss.	Spo	Ch	Sp;Sm;A	S	Ms	LC	Dayas (temporary ponds), torrent beds, and rocky steppes
Erophaca baetica (L.) Boiss.	Spo	Ch	Sp	SA;SH		LC	Forests and matorral vegetation on siliceous substrates; plains and low mountains
***E** *Erinacea anthyllis* Link.	Spo	Ch	Sp	SA;SH	As ; AA ; HA ; MA ; Op ; R	LC	Cold steppes and low matorral vegetation; mid- and high-elevation mountains
***EA** *Genista quadriflora* Munby	Spo	Nan	Sp	SA;SH;H	HA; MA; Man; Op; LM; R	LC	Non-calcareous mountains
Lathyrus aphaca L.	Spo	Th	Sp	SA;SH;H	HA ; MA ; Mam ; Op ; LM ; R	LC	Open forests, cultivated fields, and moist habitats; plains and low mountains
Lathyrus cicera L.	Spo	Th	Sp	A;SA;SH;H	AA; HA; MA; Mam; Man; Op; Om; LM; R	LC	Cultivated fields, matorral vegetation, and wastelands; plains and low mountains
Lathyrus clymenum L.	Spo	Th	Sp	A;SA;SH	AA; HA; MA; Mam; Man; Op; Om; LM; R	LC	Plains, low- and mid-elevation mountains
Lathyrus ochrus (L.) DC.	Spo	Th	Sp	A;SA;SH	Mam; Man; Op; Om; LM; R	LC	Forest clearings, wastelands, and fallow land of plains
Lupinus angustifolius L.	Spo	Th	Sp	SA;SH	AA; HA; MA; Mam; Man; R	LC	Sandy terrains; plains and low mountains

Lupinus gussoneanus J.Agardh	Spo	Th	Sp	SA;SH;H	AA; MA; Mam; Man; Op; Om; R	LC	Open forests and matorral vegetation; plains and low mountains
***E** *Ononis pseudoserotina* Batt. & Pit.	Spo	Ch	Sm	SH;H	HA; MA; Man	VU	Forests and rocky matorral vegetation; plains, low- (and mid-) elevation mountains
Podlechiella vogelii (Webb) Maassoumi & Kaz.Osaloo	Spo	Th	Sp;W	S	Ms	DD	Wadi beds, sandy soils, and desert savannas
***EI** *Retama monosperma* (L.) Boiss.	Spo	Nan	Sp;W	S;A;SA	Ms; AA; HA; Mam; Man; R	LC	Coastal dunes, matorral vegetation, and stony wastelands; plains and low mountains
Retama raetam (Forsk.)	Spo	Nan	Sp;W	S;A;SA;SH	Ms; AA; HA; Mam; Man; R	NT	Coastal dunes, matorral vegetation, and stony wastelands; plains and low mountains
Trigonella foenum-graecum L.	Int	Th	Sp	-	-	NA	-
Gentianaceae (1)							
***EA** *Centaurium erythraea* Rafn.	Spo	Th	Sp;Sm	SA;SH;H	AA; HA; MA; Mam; Man; Om; LM; R	DD	Open forests, matorral vegetation, wastelands, and cultivated fields; plains, low- and mid-elevation mountains
Lamiaceae (11)							
Ajuga iva (L.) Schreb.	Spo	Hem	Sp	-	All Div	LC	Degraded forests and matorral vegetation, wastelands, uncultivated fields, and rocky habitats; plains and mountains up to c. 2700 m a.s.l.
Clinopodium nepeta subsp. *spruneri* (Boiss.) Bartolucci & F.Conti	Spo	Hem	Sm	-	-	LC	-
Dracocephalum officinalis (L.) Y.P.Chen & B.T.Drew	Spo	Ch	Sp;Sm	SA;SH;HM	As;HA	NT	Open forests, rocky habitats, and stony soils; mid- and high-elevation mountains
Mentha pulegium L.	Spo	Hem	Sp;Sm	-	AA; HA; MA; Mam; Man; Om; LM; R	DD	Wet habitats of plains, low- and mid-elevation mountains
Marrubium vulgare L.	Spo	Ch	Sm	-	All Div	LC	Primarily ruderal; plains, low- and mid-elevation mountains
Origanum majorana L.	Int	Ch	Sm	-		NA	
Origanum vulgare L.	Spo	Ch	Sm	-	HA;MA	DD	Open forests and matorral vegetation of low (and mid-) elevation mountains
Salvia officinalis L.	Int	Ch	Sm	-		NA	
Salvia verbenaca L.	Spo	Hem	Sp	-	All Div	LC	Forest clearings, matorral vegetation, wastelands, and steppes; plains, low- and mid-elevation mountains

Salvia rosmarinus Spenn.	Spo	Nan	Sp;Sm	-	As;HA;MA; Op;Om;R	NT	Open forests and matorral vegetation of low- and mid-elevation mountains
Teucrium polium L.	Spo	Ch	Sm	-	HA; MA; Mam; Man; Op; Om; LM; R	LC	Forest clearings, matorral vegetation, pastures, rocky habitats, steppes, and maritime cliffs; plains and mountains
Myrtaceae (1)							
Myrtus communis L.	Spo	Nan	Sp	SA;SH	Man ; Om ; LM ; R	NT	Plains and low siliceous mountains
Nitrariaceae (1)							
Peganum harmala L.	Spo	Ch	Sp;Sm	S;A;SA	All Div.	LC	Steppes, uncultivated fields, and rubble; plains and low mountains
Oleaceae (1)							
Ligustrum vulgare L.	Spo	Nan	Sp;Sm	H	MA	EN	Stream margins and cool gorges of mid-elevation calcareous mountains
Onagraceae (1)							
Epilobium hirsutum L.	Spo	Hem	Sp;Sm	S;A;SA;SH;H	Ms ; AA ; HA ; MA ; Mam ;Man	LC	Marshes and water margins; plains, low- and mid-elevation mountains
Paeoniaceae (2)							
Paeonia coriacea Boiss.	Spo	G	Sp	SH;H	HA;MA;R	NT	Mid-elevation mountain forests
Paeonia mascula (L.) Mill.	Spo	G	Sm	SH;H	HA;MA;R	VU	Mid-elevation mountain forests
Papaveraceae (1)							
Papaver rhoeas L.	Spo	Th	Sp;Sm	A;SA;SH;H	All Div.	LC	Cultivated fields, harvested fields, and uncultivated habitats; plains, low- and mid-elevation mountains
Plantaginaceae (4)							
***E** *Digitalis lutea* L.	Spo	Hem	Sp;Sm	SA;SH	HA;MA;Op;Om	NT	Open forests and rocky habitats of mid-elevation mountains
***EI** *Digitalis obscura* L.	Spo	Ch	Sm	SH	Lm;R	VU	Open forests and rocky habitats of low- and mid-elevation mountains
*E *Digitalis purpurea* L.	Spo	Hem	Sp;Sm	H	AA;MA;R	VU	Forests and matorral vegetation of low- and mid-elevation siliceous mountains
Globularia alypum L.	Spo	Ch	Sp	A;SA;SH;H	All Div.	LC	Forests and matorral vegetation; plains and low mountains
Plumbaginaceae (1)							

Plumbago europaea L.	Spo	Ch	Sm;A	A;SA;SH;H	AA; HA; MA; Mam; Man; Om; LM; R	LC	Plains, low- and mid-elevation mountains
Poeoniaceae (1)							
Polygonaceae (1)							
***E** *Rumex acetosa* L.	Spo	Hem	Sm	SA;SH;H; HM	AA;HA;MA	LC	Streams and moist meadows; mid-elevation mountains
Primulaceae (1)							
***EA** *Cyclamen africanum* Boiss. & Reut.	Spo	G	W	H	R	LC	Matorrals
Ranunculaceae (13)							
Aconitum lycoctonum L.	Spo	Hem	Sm	SA;SH	AA;MA	NT	Stream margins and irrigated meadows; mid-elevation mountains
***E** *Adonis aestivalis* L.	Spo	Th	Sp	SA;SH	Op; Om	LC	Eurasia; uncultivated fields and pastures
***E** *Aquilegia vulgaris* L.	Spo	Hem	Sp	SA;SH;H; HM	HA; MA; R	VU	Stream margins and moist rocky habitats of mountains (1800–3000 m a.s.l.)
Helleborus foetidus L.	Spo	G	Sp;W	H	R	VU	Forests and calcareous rocky habitats of mid-elevation mountains
Nigella damascena L.	Spo	Th	Sp	A;SA;SH	HA; MA; Mam; Man; LM; R	LC	Cultivated fields and pastures of plains and low mountains
Nigella sativa L.	Int	Th	Sp	SH;H	LM ; R	NA	Cultivated fields and gardens; subspontaneous and cultivated as a condiment (black seeds)
Ranunculus bulbosus L.	Spo	Hem	Sp;Sm	SA;SH;H	HA; Man	LC	Moist forest clearings, marshes, and stream margins; plains and mountains up to 2900 m a.s.l.
Ranunculus flammula L.	Spo	Hem	Sp	H	R	CR	Water margins and marshes
Ranunculus repens L.	Spo	Hem	Sp;Sm	SH;H	HA; MA; Op; R	VU	Stream margins; marshy habitats of mountains
Ranunculus sceleratus L.	Spo	Th	Sp	SA;SH;H	MA; Man; R	DD	Marshes and stream margins
Ranunculus ficaria L.	Spo	Hem	Sp; A	SA;SH;H	HA; MA; Man	LC	Moist meadows and cool forests of plains and mountains up to c. 2000 m a.s.l.
Ranunculus minimus (L.) E.H.L.Krause	Spo	Th	Sp	SH	HA; MA	VU	Small temporary ponds and margins of dayas
Staphisagria macrosperma Spach	Spo	Hem	Sp	SH;H	LM ; R	VU	Cool forests and matorral vegetation; plains and low mountains
Rhamnaceae (1)							
Frangula alnus Mill.	Spo	Ph	Sp;Sm	SH;H	Man;R	VU	Marshes
Rosaceae (2)							

Agrimonia eupatoria L.	Spo	Hem	Sm	A;SA;SH;H	HA;MA;Mam;Man;R	LC	Cool grassy valleys and matorral vegetation; plains and mountains up to c. 1700 m a.s.l.
Crataegus monogyna Jacq.	Spo	Nan	Sp	SA;SH;H	AA;HA;MA;Mam;Man; Op;Om;Lm;R		Low- and mid-elevation mountains
Rubiaceae (1)							
Rubia peregrina L.	Spo	Ch	Sm	A;SA;SH;H	MA;Mam;Man;Op;Om; Lm;R	LC	Forests and matorral vegetation; plains, low- and mid-elevation mountains
Rutaceae (2)							
Ruta chalepensis L.	Spo	Ch	Sp;Sm	A;SA;SH	HA; Mam; Man; Om; R	LC	Open forests, dry uncultivated slopes, and rocky habitats; plains, low- and mid-elevation mountains
Ruta montana L.	Spo	Ch	Sp;Sm	A;SA;SH	AA; HA; MA; Mam; Man; Op; Om; LM; R	LC	Open forests and rocky matorral vegetation; low- and mid-elevation mountains
Santalaceae (2)							
Viscum album L.	Spo	Ch	Sp;Sm	H	R	EN	Moist forests
Viscum cruciatum Sieber ex Boiss.	Spo	Ch	Sp	A;SA;SH;H	As; AA; HA;MA; Man; Op; R	LC	Forests and matorral vegetation; low- and mid-elevation mountains
Scrophulariaceae (1)							
Verbascum sinuatum L.	Spo	Hem	Sm			LC	
Solanaceae (12)							
***EI** *Atropa baetica* Willk	Spo	Hem	Sm	SH; H	HA; MA; R	DD	Forest clearings and stony slopes; mid-elevation calcareous mountains
Atropa bella-donna L.	Spo	Hem	Sm	SH; H	MA; R	EN	Cool forests of mid-elevation mountains
Datura innoxia Mill.	Nat	Th	Sp;W	SH	Mam	NA	Forests and matorral vegetation; plains and mountains
Datura stramonium L.	Nat	Th	Sp;Sm;A	S; A; SA; SH	Ms;As;AA; HA; MA; Mam; Man;Op; Om; LM; R	NA	Cultivated fields, rubble, and open habitats; nitrophilous
Hyoscyamus albus L.	Spo	Th	Sp;Sm	A; SA; SH; H	AA; HA; MA; Mam; Man; Op; Om; LM; R	LC	Rubble, cultivated fields, and old walls; nitrophilous
***EAM** *Hyoscyamus muticus* subsp. *falezlez* (Coss.) Maire	Spo	Hem	Sp	S	Ms	VU	Silty beds of desert torrents and Saharan sands
Hyoscyamus niger L.	Spo	Th	Sp;Sm	SA;SH;H	HA ; MA, Mam ; LM ; R	LC	Cultivated fields and rubble; plains, low- and mid-elevation mountains

Mandragora officinarum L.	Spo	G	Sp;Sm	SA;SH	Mam; Man	LC	Matorral vegetation, wastelands, uncultivated habitats, and cultivated fields, mainly on clayey soils
Solanum dulcamara L.	Spo	Hem	Sp;Sm	SA;SH;H	HA; MA; Mam; Man;LM; R	LC	Marshes, hedgerows, and moist ditches
Solanum elaeagnifolium Cav.	Nat	Hem	Sp	A;SA	Mam; Man	NA	Plains and low mountains
Solanum nigrum L.	Spo	Th	Sp; Sm	S;A;SA;SH;H	AA; HA; MA; Mam; Man; Op; Om; LM; R	LC	Rubble, rocky habitats, and cultivated fields; nitrophilous; plains, low- and mid-elevation mountains
Withania somnifera (L) Dunal.	Spo	Ch	Sp;Sm	S;A;SA;SH	Ms; Mam;Man; Om;LM; R	LC	Rubble, hedgerows, and cultivated fields; plains and low mountains
Thymeleaceae (2)							
***EA** *Daphne gnidium* L.	Spo	Ch	Sp	SA; SH	As ; AA ; HA ;MA ; Mam ; Man; Op; Om; LM; R	LC	Forests, matorral vegetation, wastelands, and cultivated fields; plains, low- and mid-elevation mountains
Daphne laureola L.	Spo	Nan	Sp	H	HA; MA; LM ; R	LC	Forests and moist rocky habitats of mountains (800–3000 m a.s.l.)
Viburnaceae							
Sambucus ebulus L.	Spo	G	Sp;Sm	SA; SH	HA;MA;Man;R	LC	Plains and low mountains
Sambucus nigra L.	Nat	Nan	Sp	SA; SH	HA;MA;Man;R	NA	Low mountains