Article

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Raising awareness of toxic spontaneous plants in Morocco: a comprehensive checklists

Abstract

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The Morocco's geographical position makes it an ecologically and climatically diverse country, home to various plant species of ecological, cultural and medicinal importance. Some of these plants are widely used in traditional Moroccan medicine, although their toxicity has been reported in previous studies. This could pose a threat to human health. This investigation seeks to catalog the spontaneous poisonous plants found in Morocco. Although these plants have an important heritage in traditional medicine, unintentional poisoning, particularly in the case of poor and financially sensitive populations, remains a major obstacle. In this work, we have compiled a comprehensive database of toxic plants found in Morocco, describing in detail the equipment and methods used on the one hand, and enriching our study with a detailed discussion on the other.

As part of this study, we have identified 189 toxic species in Morocco. However, we will focus on the 138 spontaneous Moroccan species that are toxic to humans. These species are belonging to 99 genera and 46 botanical families, of which five are the most representative and total 66 species (47.82%), namely: *Fabaceae*, *Ranunculaceae*, *Solanaceae*, *Asteraceae*, and *Euphorbiaceae*. Among the cataloged taxa, 21 are strictly endemic to Morocco and 20 occur also in other sourrounding countries. In addition, the classification by life forms showed that the Therophytes (34 species) and Hemicryptophytes (27 species) are the most represented.

Our data collection not only enriches current scientific knowledge, but also reinforces effective mitigation policies. This research strives to promote awareness, avoid incidents of inadvertent poisoning and take early action, while preserving the country's botanical heritage. Research prospects in this field are also considered in the concluding section.

Key words: toxic plants; native species; traditional knowledge; North Africa.

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Introduction

Morocco boasts impressive ecological diversity, encompassing different ecosystems from coastal areas to the Atlas Mountains and the immense Sahara Desert. Morocco’s geo-

graphic and climatic diversity favors rich biodiversity, which in turn favors a very high floristic diversity estimated at 5211 species and subspecies (Fennane & Ibn Tattou 2012). The country's diverse landscapes and rich biodiversity are home to an exceptional range of plant species, which have played an important role in the daily lives of the indigenous population for many generations. As part of our research project, we have developed a comprehensive database containing information on all the toxic plant species found in the regions of Morocco. However, this article focuses solely on spontaneous toxic species and our discussion and conclusions are limited to this part of the flora.

Poisonous plants hold significant importance in the social context of Morocco, particularly concerning traditional medicine and folk practices. Indigenous communities in the country have historically utilized the healing potential of specific toxic plants, administering them in precisely measured quantities to treat specific ailments. Nevertheless, the boundary between medicinal usage and inadvertent poisoning is often unclear, resulting in unintended outcomes for those searching for relief. Moreover, accidental ingestions do occur, particularly among vulnerable populations, posing a major public health problem (Najem & al. 2019).

The article's primary goal is to compile a comprehensive list and categorization of spontaneous toxic species in Morocco. By identifying and categorizing the most dangerous species based on their level of toxicity, we hope to offer crucial insights into the distribution and properties of these toxic plants. This information will make a valuable contribution to the current academic literature and assist in designing efficient strategies to reduce the dangers related to contact with harmful plants.

Through careful examination of Morocco's toxic flora, this article aims to increase awareness among the public on the subject. Its focus is on prevention and early intervention to reduce the risk of accidental poisoning. Furthermore, it establishes the groundwork for future research and enables the development of targeted management strategies that will secure the continued preservation of the country's botanical heritage.

The following sections detail the materials and methods and present a comprehensive database of the spontaneous toxic plants of Morocco, together with detailed results and discussion. The paper concludes with a perspective and points of view.

Materials and Methods

Study Area

Our study is dealing with the whole area of Morocco. The country encompasses a wide range of ecosystems, including coastal areas, fertile plains, the Atlas Mountains and vast desert areas of the Sahara. These diversified geographical conditions provide a favorable habitat for growing and reproducing various plant species, some of which are poisonous to humans.

Data Collection on Toxic Plants in Morocco

Data on poisonous plants in Morocco were collected from several credible scientific sources. The main sources used were the following:

Reference Books: Charnot (1945); Bellakhdar (1997); Fennane (1997); Hmamouchi (1999).

Reports from the Anti Poison and Pharmacovigilance Centre of Morocco: we thoroughly reviewed the annual reports of the Anti-Poison and Pharmacovigilance Centre of Morocco to identify plants involved in reported poisoning cases in Morocco between 2008 and 2021.

Scientific research: extensive searches were conducted in reputable scientific databases, including Scopus, ScienceDirect, PubMed, Web of Science, and Google Scholar, to access various types of literature. Articles such as: Traibi & al. (2013), Rachid & al. (2013), Mouaffak & al. (2013), Romo & al. (2017), Oulmaati & al. (2017), Nchinech & al. (2019), Najem & al. (2019), Hoummani & al. (2019), Hosni & al. (2019), Farzaei & al. (2020), Achour & al. (2021), Ghizlane & al. (2021), Elouardi & al. (2022) were reviewed. Monographs such as Benzeid & al. (2018) provided additional context, and ethnobotanical studies including:Yassir & al. (2012), El Alami & al. (2016), Najem & al. (2019), Kharchoufa & al. (2021), Belhaj & al. (2021), Chaachouay & al. (2021) offered insights into local knowledge. Surveys conducted by other researchers on toxic plants in Morocco, such as Loutfia & al. (2013), Fennane & Rejdali (2016), Eddouks & al. (2017), Saadi & al. (2017), Kharchoufa & al. (2018), Najem & Ibijbijen (2018) and Imane & al. (2018), further enriched our database.

These bibliographic sources allowed us to compile comprehensive, updated, and reliable data on toxic plants in Morocco, thus contributing to the robustness and validity of our study.

List of Toxic Plants

Using the data collected, a preliminary list of toxic plants was compiled by identifying plant species reported to be potentially hazardous to human health. To further validate this list, we adopted an approach based on using *ProTox 3.0 server*. This software predicts the potential toxicity of molecules using an algorithm based on their chemical structure.

To catalog the active principles and known chemical compounds present in each toxic plant, the information obtained from bibliographic sources was thoroughly analyzed. The toxicity of these molecules was then predicted using the *ProTox 3.0 server* (https://tox.charite.de/protox3/#). The final list included plants with molecules identified as toxic by the software.

Database construction

A total of 189 toxic plants were identified, including invasive species, cultivated plants, and some species toxic exclusively to animals, for which no evidence was found in the literature to confirm their toxicity to humans. However, in this paper, we have chosen to present only spontaneous toxic plants, totaling 138 species out of the 189 identified, while excluding those not relevant to human toxicity. A comprehensive database was created for these 189 plants, containing the following fields:

Scientific name:

We consulted the African Plant Database (version 4.0.0) (http://www.ville- ge.ch/musinfo/bd/cjb/africa) to check the accepted scientific name and synonym(s) for each plant. The three volumes of the “Flore pratique du Maroc” (Fennane & al. 1999, 2007, 2014) were used as sources of information for the botanical family, life form and flowering season.

Common and vernacular names

Common names (in French and English) and vernacular ones (in arabic or amazigh) come from Fennane & al. (1999, 2007, 2014), Skalli et al. (2006): Najem & al. (2020).

Red List conservation status

Assessment of the conservation status of each species according to the Red List criteria. We used the "Livre Rouge de la flore vasculaire du Maroc" (Fennane & al. 2021) as a reference. Additionally, we consulted the IUCN Red List online to verify the global conservation status of our species.

Endemism status

Indicates whether the plant is endemic to Morocco or whether it is also found in other regions of the world. We used the Checklist of Endemics and Type Specimens of the Vascular Flora of North Africa (El Oualidi & al. 2012) and "Livre Rouge de la flore vasculaire du Maroc" (Fennane & al. 2021) as references.

Geographical and regional distribution

Specific distribution according to the geographical regions of the country, following the information and the map presented in the "Flore pratique du Maroc" (Fennane &al. 1999, 2007, 2014). See the Electronic Supplementary File 1 (ESF1, Fig. S1).

Bioclimatic zone distribution

Classification of toxic plants according to their distribution in Morocco's bioclimatic zones, following the classification in Fennane & al. (1999).

Ecology and habitat

Description of the environment and preferred habitat of each poisonous plant (arid environments, forests, mountainous areas, etc.) following the information presented in the "Flore pratique du Maroc " (Fennane & al. 1999, 2007, 2014).

Uses of the plants

Indicate some primary uses of the recorded plants (Food, Medicinal…)

Toxic parts

Indicate the specific plant parts (roots, leaves, flowers, etc.) responsible for its toxicity.

Lethality

Specifies whether the plant is potentially lethal if ingested or contacted.

Toxic Dose

Provide information on the toxic dose for humans, if available.

Intoxication symptoms

Detailed description of the symptoms caused by ingesting or exposing to each toxic plant, allowing quick identification of signs of intoxication.

Toxicity producing molecules

If identified, list the active ingredients/molecules responsible for each plant's toxicity.

LD50 of molecules

Indication of the median lethal dose of the molecules responsible, if available, which provides information on the toxic potency of these compounds.

Molecules categorization

To evaluate the toxic potential of the molecules collected from the studied species, we used the *ProTox* 3.0 web server. *ProTox* 3.0 is a widely recognized web-based tool for predicting the toxicity of chemical compounds. The server integrates molecular similarity models and machine learning algorithms to make predictions based on a database of

molecular structures and their known biological activities.(Banerjee & al. 2024) We submitted the molecular structures of our samples to Protox 3.0 to estimate their toxicity levels. The results obtained were classified into three categories: highly toxic, moderately toxic, and low toxic, based on the toxicity scores generated by the server. This method enabled us to establish detailed toxicity profiles for each sample, thus facilitating the comparison and analysis of toxic substances present in the collected species.

Toxicity-inducing uses:

Information on specific circumstances or uses that may cause poisoning.

Information validation

The data collected from the various bibliographic sources were rigorously validated by comparing them with recent scientific articles and specific studies on certain toxic plants. This cross-validation approach has enabled us to guarantee the accuracy and reliability of the information gathered, as well as the quality of our database.

Results and Discussion

As part of this study, we have identified 189 toxic species in Morocco. However, we will focus on the 138 spontaneous Moroccan species that are toxic to humans. It is worth noting that some of the remaining species are toxic exclusively to animals (37 species), while others (14 species) are introduced and cultivated species (ESF1, Table S1).

This section aims to enhance our comprehension of the toxicity of spontaneous plants in the Moroccan ecosystem. The presented results will provide a detailed analysis of the toxicity of these plants, highlighting significant trends and characteristics.

Plants that are both toxic and strictly endemic to Morocco are marked with a * in the table in ESF1.

Classification by degree of toxicity

The plants were classified according to their toxicity levels (highly toxic, moderately toxic, slightly toxic) using the Protox 3.0 server to forecast the toxicity levels of the poisonous molecules in the plants collected. Among the 138 species examined, 7 species have unidentified toxic molecules. Fig. 1a shows that a significant percentage of the plants were classified as ‘highly toxic’ and ‘moderately toxic’ highlighting the need for increased vigilance, especially in regions where these plants are prevalent. These results make it possible to rank toxic plants according to their potential danger, which is essential for risk management.

Life form and family

Life form

Another aspect of the analysis was the life forms and botanical family affiliation of spontaneous toxic species.

Examining the distribution of toxic plants based on their biology reveals the range of “tactics” used by these species to adapt to different environments.

Fig. 1b displays the variety of life forms categories, which demonstrates how spontaneous toxic plants can thrive in diverse environments and adapt to shifting environmental

conditions. The distribution is mainly dominated by the therophytes, which comprise 34 species. They exhibit exceptional adaptability to harsh environmental conditions such as arid soil and bush fires. This suggests that many toxic plants are well-suited to seasonal or periodically stressed environments. Furthermore, there are high numbers of taxa of hemicryptophytes (27), chamaephytes (21), and nanophanerophytes (24), which may be attributed to the prevalent dry conditions in many areas of Morocco.

This analysis highlights the importance of understanding the biological distribution of poisonous plants endemic to Morocco, which provides important insights into their ecology and special adaptations.

Family

An examination of the distribution of poisonous plants by the botanical family unveils compelling patterns. As depicted in Fig. 1c, the family with the highest representation is *Fabaceae*, which exhibits 17 toxic species, followed by *Ranunculaceae* and *Solanaceae* each with 13 species. Additionally, *Asteraceae* and *Euphorbiaceae* have substantial representation, each with more than 10 toxic species. Diversity in habitats and ecological conditions to which the toxic plants are adapted is shown by several other families, each represented by either one or two plants.

Distribution of spontaneous toxic species in Morocco

Our study examined the geographical repartition of toxic plants in Morocco, specifically regarding geography and bioclimatic zones. It is worth mentioning that some of the taxa recorded in our listcan be found in multiple bioclimatic zones and geographical areas.

Geographical divisions

According to our analysis (Fig. 1d), the top regions with the highest occurrence of toxic species are the coastal and mountainous areas, notably the Rif, followed by the High and Middle Atlas Mountains, which possess a significant concentration of these plants. The North and Middle Atlantic coastal regions, as well as the Mediterranean coast, exhibit a substantial number of toxic plants, while the diversity is comparatively lower in Saharan Morocco and the Saharan Atlas.

This geographic distribution can be affected by several environmental and climatic factors that are region-specific.

One significant factor is altitude, which affects temperature, precipitation patterns, and soil types, all of which can create microenvironments conducive to the growth of some toxic species (Elouardi & al. 2022). For example, higher altitudes in the Rif and Atlas Mountains experience cooler temperatures and increased rainfall compared to the arid regions of Saharan Morocco, promoting the proliferation of diverse plant species, including toxic ones (Maimouni & al. 2021)

Water availability is another critical factor. Coastal regions and areas with higher rainfall tend to support a richer biodiversity, including toxic plants. The North Atlantic and Mediterranean coastal areas receive more consistent precipitation, contributing to a higher prevalence of these species (Zerkani & al. 2022). In contrast, the arid conditions of the

Saharan regions limit the diversity and abundance of plant species in general, including toxic ones (Souahi & al. 2022); (Kawada & al. 2020).

The distance from human habitats is also a significant factor. Remote mountainous regions, with minimal human interference, can serve as refuges for plants biodiversity, including toxic species. In contrast, these plants may be eradicated or diminished in more populated areas due to agricultural activities, urbanization, and land use changes (Muller & al. 2015).

These factors do not exclusively affect toxic plants but influence plant biodiversity as a whole. However, plant species have adaptations that allow them to thrive in specific environmental conditions, making their presence more pronounced in particular regions. Therefore, the observed distribution pattern is a result of these complex interactions between the plants' ecological preferences and the regional environmental conditions.

Bioclimatic zones distribution

The analysis of poisonous plant distribution by bioclimatic zones indicates that the sub-humid bioclimate has the highest representation, followed closely by the warm semi-arid and humid ones. These findings are illustrated in Fig. 1e and reflect the ecological preferences of poisonous plants and their adaptation to specific environmental conditions.

Toxic plants in the sub-humid zone likely adapt to the more humid environment of this area due to their ecological preferences for higher moisture levels. This adaptation may involve physiological mechanisms such as enhanced water uptake and storage capacities, as well as morphological traits like larger leaf surface areas that facilitate transpiration and cooling (Lambers & al. 2008; Chaves & al. 2003).

Conversely, plants in the warm semi-arid zone likely exhibit specific adaptations to survive high temperatures and drought conditions. These adaptations may include the development of deep root systems to access groundwater, reduced leaf surface area to minimize water loss, and the production of secondary metabolites that deter herbivory and contribute to their toxicity (Chaves & al. 2003; Larcher 2003). These survival mechanisms enable these plants to thrive in harsh environments where other species may not persist.

Overall, the observed distribution patterns of toxic plants reflect their ability to adapt to distinct bioclimatic zones, highlighting the importance of specific ecological and physiological traits that enable their survival under varying environmental conditions (Lambers & al. 2008).

Endemism and conservation status of spontaneous toxic plants in Morocco

Endemism

Regarding endemism, 39 out of the 138 spontaneous toxic plants are specific to Morocco. This is a vital component of Moroccan biodiversity (Rankou & al. 2013).

According to Fig. 2a, 21 out of the 39 species are exclusive to Morocco, representing 54% of all endemic species in our database and 15% of all spontaneous species collected in our database. The remaining endemic species are distributed across other regions, including Algeria, the Iberian Peninsula, Mauritania, the Canary Islands, and the Macaronesian islands.

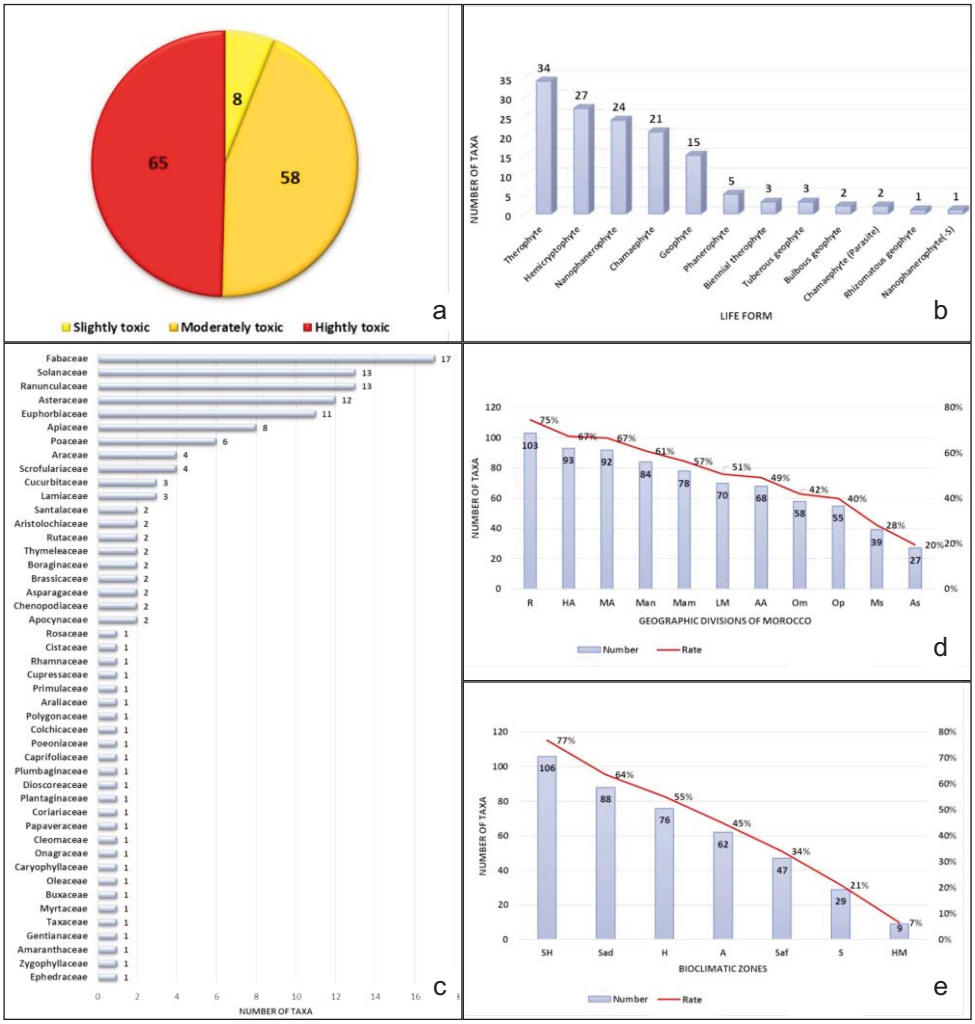

Fig. 1. Spontaneous toxic plants in Morocco: a) toxicity level; b) life forms; c) families; d) geographical divisions (R: Rif, MA: Middle Atlas, HA: High Atlas, Man: North Atlantic Morocco, Mam: Middle Atlantic Morocco, LM: Mediterranean coast, AA: Anti Atlas, Om: Eastern Moroccan mountains, Op: Eastern Moroccan plains and plateaus, Ms: Saharan Morocco, As: Saharan Atlas); e) bioclimatic zones (SH: Subhumid, Sad: Semi-arid warm, H: Humid, A: Arid; Saf: Semi-arid cold, S: Saharan, HM: High Mountain);

This report presents valuable data on the endemism status of toxic plants in Morocco. The presence of 21 species exclusively found in Morocco highlights the country's rich biodiversity and emphasizes the need for preservation. The fact that 18 other species are also found in Morocco and other neighboring countries underscores the importance of international collaboration in their conservation efforts.

These findings have important implications for biodiversity management and conservation in Morocco. Endemic species are often vulnerable to environmental disturbances, climate change and other threats. Therefore, targeted conservation efforts are needed to preserve these unique species.

Conservation status

An assessment of the conservation status of poisonous plants in Morocco using Red List valuations, According to Fennane & al. (2021), highlights the vulnerability of certain species. As shown in Fig. 2b, most species are currently considered to be at low risk of extinction (LC), while 24 species are classified as threatened (Critically Endangered, Vulnerable and Endangered). This underlines the importance of continued monitoring of these species and the implementation of appropriate conservation strategies.

It is also important to note that the presence of species classified as "Data Deficient" highlights the uncertainty surrounding their status. This uncertainty requires further research to properly assess their status and importance. In addition, the fact that several species are classified as "Near Threatened: close to the threshold of the threatened categories" suggests that precautionary conservation measures may be needed to prevent them from falling into the higher threat categories.

In comparison with the global IUCN Red List assessment, for which the status of only 28 species was available, the majority (26 species) are also categorized as "Least Concern" (LC), indicating a low risk of extinction on a global scale. However, one species is classified as "Vulnerable" and another as "Near Threatened," aligning with the findings at the national level where several species are also approaching a threatened status. While these global assessments corroborate the local evaluation for many species, the presence of globally vulnerable species highlights the necessity for specific conservation actions beyond the national context. Additionally, the identification of species as "Near Threatened" at both levels stresses the need for precautionary conservation measures to prevent further deterioration of their status.

These results underscore the importance of preserving Moroccan flora, especially endemic threatened species. Targeted conservation efforts, ongoing research and biodiversity awareness are key to ensuring the long-term survival of these "unique" toxic plants.

Symptoms of poisoning, lethality, toxic parts and uses

Symptoms of poisoning

Exposure to toxic plants can lead to a variety of symptoms. An analysis of the 138 spontaneous toxic plants indicates several common symptom combinations. The symptoms may vary depending on the specific toxic plant involved, highlighting the necessity for prompt and accurate identification of intoxication indicators. Moreover, some plants can induce multiple types of symptoms, complicating the assessment and management of intoxication

Fig. 2c provides an overview of the main symptom categories observed.

Digestive and nervous disorders: The results of our study reveal that 38% of the toxic plants identified in our list i.e. 54 plants cause digestive and nervous system disturbances, with symptoms such as nausea, vomiting, diarrhea, and alterations to the nerv-

ous system, including convulsions and dizziness. These observations are consistent with the data from the Anti-Poison and Pharmacovigilance Centre of Morocco (CAPM), which, in its report covering the period from 2009 to 2019, identified the digestive and nervous systems as the most frequently affected by plant poisonings in Morocco (Rhalem & al. 2022).

Digestive and cardiac disorders: symptoms combining digestive and cardiac disorders highlight the diversity of possible reactions to toxic plant poisoning, including cardiac problems such as palpitations and arrhythmias in addition to gastrointestinal symptoms. They are linked with 44 plants representing 32% of toxic plants in our list.

Digestive and respiratory disorders: gastrointestinal symptoms coupled with respiratory problems such as dyspnea or coughing are associated with 22 plants representing 16% of toxic plants in our list.

Skin irritation and photosensitization: skin irritation and photosensitization indicate that some toxic plants can cause skin damage and increase skin sensitivity to sunlight, leading to skin problems. They are associated with 17 plants representing 12% of toxic plants in our list.

Digestive and renal disorders: gastrointestinal symptoms accompanied by kidney problems, such as kidney damage, are associated with 11 plants representing 8% of toxic plants in our list.

Blood disorders: a small percentage of toxic plants (6%), corresponding to 8 plants, can cause blood disorders, which can include abnormal blood coagulation, anemia, etc.

Reproductive disorders: finally, a plant can cause reproductive disorders, affecting fertility or development in exposed individuals.

Identifying symptoms of toxicity associated with each toxic plant is crucial for timely and accurate diagnosis of intoxication cases, as well as provision of the appropriate treatment to prevent serious complications.

The various symptom combinations observed suggest that toxic plants in Morocco can have diverse effects on human health. This underscores the significance of continual awareness-raising for local populations, emphasizing the potential hazards linked with exposure to these plants.

Lethality of toxic plants

It is crucial to evaluate the lethality of the 138 spontaneous toxic plants in Morocco, indicating their ability to cause fatality when ingested or exposed to.

Fig. 2d illustrates that most recorded toxic plants, specifically 69%, are classified as lethal, thus posing a significant health and life hazard.

Meanwhile, the remaining 31% exhibit toxicity of less severity, causing adverse effects but not lethal.

The significant percentage of poisonous plants that can cause death in the above list underscores the importance of taking precautions when encountering this flora. Acquiring knowledge on the poisonous potency of these plants is crucial in mitigating the hazards of intoxication, primarily in areas where these plants are prevalent.

The presence of non-lethal toxic plants is noteworthy given their potential to cause health issues despite not being deadly. However, the effect of these plants can vary based on dosage, exposure time, and individual susceptibility.

Toxic parts

Regarding toxic plant parts, our results reveal a diversity of parts involved. Fig. 2e shows an overview of the different toxic plant parts.

Seeds are the primary toxic components of 43 plants. This prevalence can be attributed to their reproductive function, which has inspired the development of defensive mechanisms to safeguard their progeny.

Completely toxic plants: 34 plants are toxic as a whole, meaning that all their parts present a toxic risk. This is an important feature to consider, as it indicates that these plants can be particularly dangerous.

Roots: Toxic roots are present in 29 plants. Roots can store toxic compounds in large quantities.

Aerial Parts: Leaves, stems, and flowers found in the aerial parts of 27 plants are significantly toxic, suggesting that these parts may be more accessible to humans.

Fruits: Toxic fruits are present in 26 plants.

The complexity of plant toxicity and the need to consider all parts when assessing potential risks is emphasized by the existence of multiple toxic components in a single plant.

Plants uses

An analysis of the toxic plants listed reveals that 71.01% are utilized for medicinal purposes, highlighting their significance in traditional pharmacology. Additionally, 10.87% of the plants are used as food sources, while 9.42% are known for their aromatic properties. Ornamental use and food additives are less common, representing 2.90% and 2.17% of the plants, respectively. These findings emphasize that toxic plants, despite their potential hazards, play an important role across various fields of use

Poisonous plants and method of use

Poisonous plant intoxication can occur through various methods of use, each resulting in specific toxicity consequences. Examining the data shows the most frequent modes of use linked to toxic plant poisoning. Fig. 2f provides a summary of the primary modes of use that lead to toxicity.

Fresh consumption: Direct consumption of toxic plants in their fresh state is the main source of intoxication, with 77% of plants being toxic when consumed without prior treatment.

Decoction: The preparation of toxic plants in decoction form, where the plant parts are boiled in water, is also a frequent source of intoxication, with 52% of toxic plants concerned.

Infusion: where plant parts are soaked in hot water, is another common method, with 39% of plants becoming toxic when used in this way.

Powdered use: 28% of toxic plants become harmful when ground into powder and used in this way.

Essential oils: Essential oils extracted from certain plants can be toxic, accounts for 12% of toxic plants.

Poultice: Applying toxic plants to the skin in the form of a poultice can also cause intoxication, accounting for 11% of plants.

Maceration: Maceration, where plant parts are immersed in a liquid (usually oil or alcohol) to extract the active compounds, is associated with 9% plants.

Many plants have the potential to become toxic when used in various ways, emphasizing the intricate interactions between plants and their usage patterns.

These results highlight the significance of implementing preventative measures, educational campaigns and increasing public awareness of best practices in handling and using plants, with a focus on the specific usage patterns that can lead to toxicity.

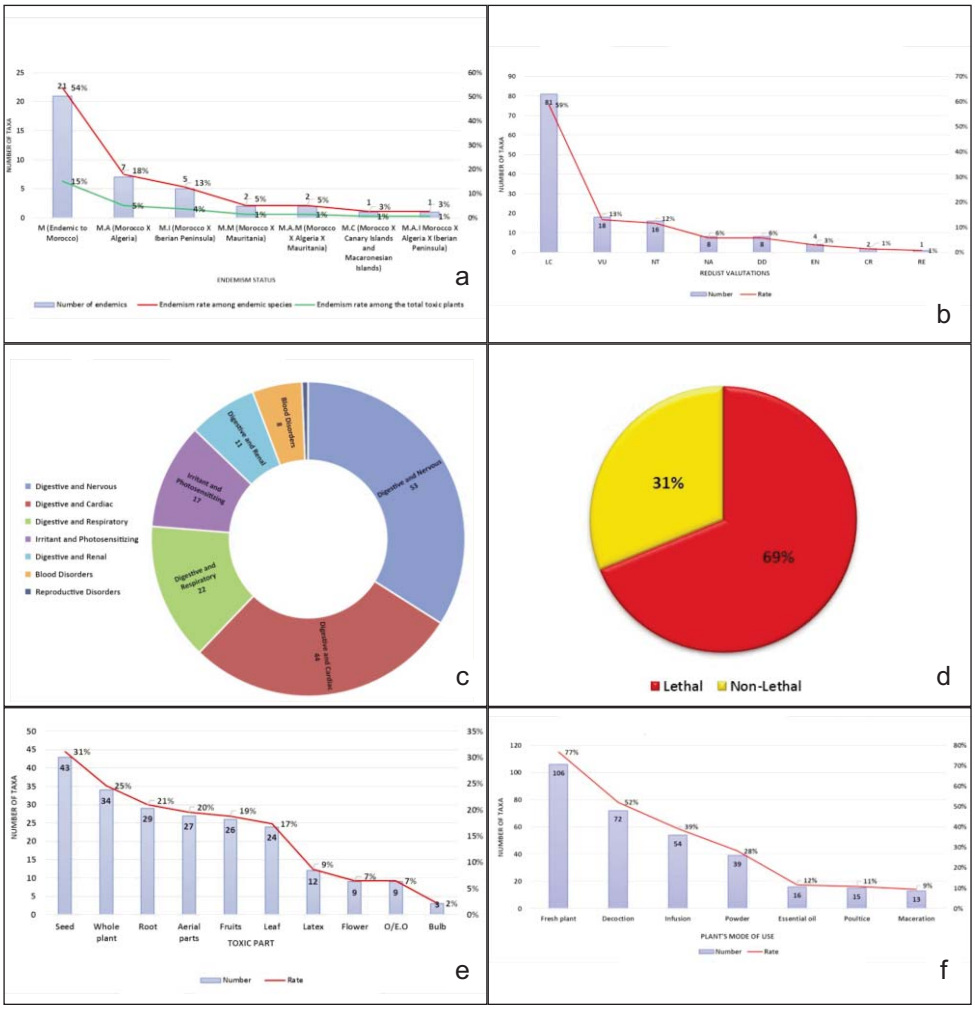

Fig. 2. Spontaneous toxic plants in Morocco: a) endemism; b) Red List criteria (LC: Least Concern, NA: Not Applicable, VU: Vulnerable, NT: Near Threatened, DD: Data Deficient, CR: Critically Endangered, EN: Endangered, RE: Regionally Extinct); c) intoxication symptoms; d) lethality; e) toxic part; f) method of use.

Conclusion

This study presents an extensive examination of toxic endemic plants in Morocco, emphasizing their geographic distribution, toxicity, and conservation status.

The broad range of toxic plant and their adaptation to various environments illustrates a crucial element of Moroccan biodiversity. The plants' presence is influenced by local conditions, as shown by the geographical distribution.

Targeted preservation measures are necessary due to the presence of endemic toxic species and their conservation status. Plant toxicity is a complex issue, evident by the various symptoms of intoxication and parties involved.

Preventing accidental poisoning is fundamentally reliant on increasing awareness about toxic plants. Informing the public, health professionals, and ecosystem managers about the risks linked with toxic plants is crucial to minimize harmful exposure.

Research perspectives

This study establishes a solid foundation for future research on toxic plants in Morocco. The research perspectives include exploring ecological interactions, analyzing toxic compounds for potential medical applications, conserving endangered endemic species, raising awareness among the public and healthcare professionals, and conducting epidemiological surveys on poisoning in human and animal populations (Domina & al. 2024). Expanding our database to include plants toxic to animals, along with developing an automatic identification system based on deep learning (Labrighli & al. 2022), aims to enhance the understanding and management of toxic plants in Morocco, thereby contributing to biodiversity conservation and public health.

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