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Research Article

Distribution patterns and priorities for conservation of endemic Iranian Monocots: determining the Areas of Endemism (AOEs)

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Abstract

Iranian endemic monocotyledons include 152 species belonging to 35 genera of 10 plant families and comprise about 2.08% of Iranian plant flora and approximately 6.9% of Iran's endemic flora. Amaryllidaceae, with 71 species, is the largest family of endemic monocots in Iran. Endemic species were categorized based on topographic zonations including basins (less than 300 m a.s.l.), lowlands (300–1000 m a.s.l.), semi-mountainous (1000–1500 m a.s.l.), mountainous (1500–2500 m a.s.l.), alpine (2500–3500 m a.s.l.), and subnivale (3500–4500 m a.s.l.). Iranian endemic monocots included critically endangered (CR): 60% (89 spp), endangered (EN): 17% (26 spp.), near threatened (NT): 12% (18 spp), vulnerable (VU): 8% (12 spp), and the least concern (LC): 3% (4 spp.). Besides, the Kurdistan–Zagros range and the Atropatenian phytogeographical units feature the highest numbers of critically endangered taxa and form the first class in conservation value and priority. This will aid in management planning, *in situ* and *ex situ* conservation, and modeling habitat suitability for rehabilitation and restoration plans.

Keywords: Conservation management, diversity, endemism, south-west Asia, species richness

Introduction

The concept of endemism is considered a focal point of biogeographic studies (Crisp et al., 2001). Endemic taxa, as surrogate elements (Caro, 2010), are the most effective components in recognizing conservation priorities as well as hotspots (Myers et al., 2000). As it relates to evolutionary processes and conservation (Mittermeier et al., 2005), phytogeography is a focus of attention for conservationists (Lopez–Pujol et al., 2011). As important units of biodiversity, centers of endemism have also attracted conservationists' attention (Myers et al., 2000). In conservation-based approaches, not all taxa and habitats have similar significances; some are widespread, and others show restricted distribution. They also show differing levels of vulnerability to human activity (Langhammer et al., 2007). It is, therefore, essential to weigh the alternatives available (because of limited resources) to assess conservation priorities (Arponen et al., 2005), which play a vital role in conservation planning (Myers et al., 2000). Myers (1990) used richness, restricted endemics, and threatened taxa to select priorities, while Williams et al. (1997) used rarity. Similarly, Tsiftsis et al. (2008) used rarity and distribution tolerance. Protected areas are the most important focus for protecting biological diversity (Bruner et al., 2001) and prioritizing conservation. Moreover, important plant areas (IPAs) (Anderson, 2002), as a subset of key biodiversity areas (KBAs), “help set national priorities within the global context” and are used to establish a comprehensive system for protected areas (Langhammer et al., 2007). These areas can fill the gaps in protected areas to improve conservation plans. Meanwhile, mapping distribution patterns provides an efficient and powerful tool for designing such areas (Lombard et al., 2003).

Monocots are an important component of vascular plants and comprise 65,000 (Bremer et al., 2009) to 74,273 species (Christenhusz & Byng, 2016) worldwide. They cover a significant ratio of Iranian vascular plants. Iran is host to about 7300 (Noroozi et al., 2015) to 7800 (Assadi et al., 1984–2017) plant taxa, of which about 2200 (Noroozi et al., 2015) are confined (endemic) to Iranian geographical boundaries. Monocots, especially their ornamental species, are heavily threatened by uncontrolled harvesting pressures. Climatological differences, vegetation history, the potential for diversification, and geographical isolation (Frey & Probst, 1986) make Iran an endemic center of the Irano–Turanian region (Leonard, 1991; 1992) and a global center of plant diversity (Barthlott et al., 1996; Kier et al., 2005).

Endemic studies in Iran originated with Hedge and Wendelbo (1978), who published the first detailed study on local endemic taxa. Klein (1991) studied endemic patterns in the highlands of Alborz. Jalili and Jamzad (1999) reported on endemic plants in the context of the Red List. Noroozi et al. (2015) presented a list of endemic alpine plants of Iran. Mehrabian et al. (2015c) published the first map of the distribution patterns of endemic Iranian monocotyledons. The distribution patterns of Onosma L. (Boraginaceae) with emphasis on endemism in southwest Asia (Mehrabian, 2015b), endemic taxa of Kopet Dagh floristic province (Irano–Turanian) (Memariani et al., 2016), distribution patterns, and conservation status of Iranian endemic taxa of trees and shrubs (Mehrabian et al., 2020), and the genus Acantholimon (Khajoei Nasab & Khosravi, 2020) are other recent studies on endemic plant taxa in Iran.

Little attention, however, has been paid to centers of endemism and endemic hot spots in the selection of priority zones for conservation in Iran. Plants have been deemed less important in several cases and neglected in selecting and establishing Iranian protected areas. The present study compiles a list of new taxa of Iranian flora determined after the publication of Flora Iranica (Rechinger, 1963–2015) and Flora of Iran (Assadi et al., 1984–2017). It focuses on the distribution patterns of Iranian endemic monocotyledons and concentrates on important zones for these taxa in a phytogeographical context. This study further elucidates the status of the studied taxa. This is the first study on important plant areas based on endemic taxa in Iran as a center of plant diversity and endemism in southwest Asia.

Material and methods

Study area

Iran lies on the Iranian Plateau and covers an area of 1.6 million km^2 situated between 35º41′ N latitude and 51º26′ E longitude. Iran borders a narrow sector of the oreographic belt, which stretches between the Arabian–African unit and the Asian block (Berberian & King, 1981). Iran features several mountainous barriers (Zagros, Alborz, Kopet Dagh, Makran) and scattered internal mountains. With a mean elevation of 1,200 m above sea level (a.s.l.) and the highest peak at 4,231 m a.s.l. (Zard Kuh), the Zagros mountain chain shapes a wall between the Iranian plateaus and Mesopotamia and the Persian Gulf (Homke et al., 2004). As a section of the Alpine–Himalayan system, the Alborz Mountains form a softly sinuous stretch across the Caspian Sea's southern parts (Stöklin, 1974). Kopet Dagh extends about 700 km from the Caspian Sea's eastern borders to northeastern Iran, Turkmenistan, and northern Afghanistan (Lyberis & Manby, 1999). Djamali et al. (2011) classified the Iranian ecosystems as temperate (northern Iran), Mediterranean (western, northwestern Iran), and tropical (southern coast zones of the Persian Gulf and the Gulf of Oman) macrobioclimates. Moreover, Iran is located in the global arid zones that receive very little rainfall (equivalent to 1/3 of the average global precipitation) (Shakur et al., 2010).

Distribution database

The data used for analyses in this study was taken from 1156 accessions of herbarium records from IRAN, HSBU, and W, WU herbarium abbreviations according to Thiers (2016), Flora Iranica (Rechinger, 1963–2015), Flora of Iran (Assadi et al., 1984–2017) and several publications on recently introduced taxa of Iran.

Conservation Status and Rarity

The conservation status of Iranian endemic monocots was evaluated by Kew GeoCAT (http://geocat.kew.org) which assigned each to one of the following categories: Least Concern (LC), Data Deficient (DD), Near Threatened (NT), Vulnerable (VU), Endangered (EN), or Critically Endangered (CR). Some taxa lacked sufficient data of distribution or were data deficient (DD). Some analyses have been used for assessing conservation priorities. The index of species rarity in the study area (RI) was based on Williams et al. (1996). The scoring revealed a range from zero (0) to one (1) for these indexes. The RI was computed as the inverse of the number of cells with documented species in the broad area as follows: RI=1/Ci, where Ci is the number of grid cells, and l is the number of present taxa.

Species Richness

Species richness was mapped using the number of species in each grid cell 0.25° × 0.25° and Diva-GIS software ver. 7.5.

Areas of Endemism (AOEs)

The Geographical Interpolation of Endemism (GIE) method was applied to identify the areas of endemism. GIE identified endemism areas by estimating the overlap between the distributions of species through a kernel interpolation of centroids of species distribution (Oliveira *et al.,* 2015). Areas of endemism were identified by ArcGIS software ver.10.3 for GIE.

AZEs sites

AZEs sites were mapped using the number of endangered and critically endangered species in each grid cell 0.25° × 0.25° using Diva-GIS software on the basis of Langhammer (2007).

Results

Iranian endemic monocotyledons include 152 species belonging to 35 genera of 10 plant families and comprise about 2.08% of Iranian plant flora and approximately 6.9% of Iran's endemic flora, with various important values (e.g., crop wild relatives, medicinal as well ornamental). Amaryllidaceae, with 71 species, is the largest family of endemic monocots in Iran (Fig.1).

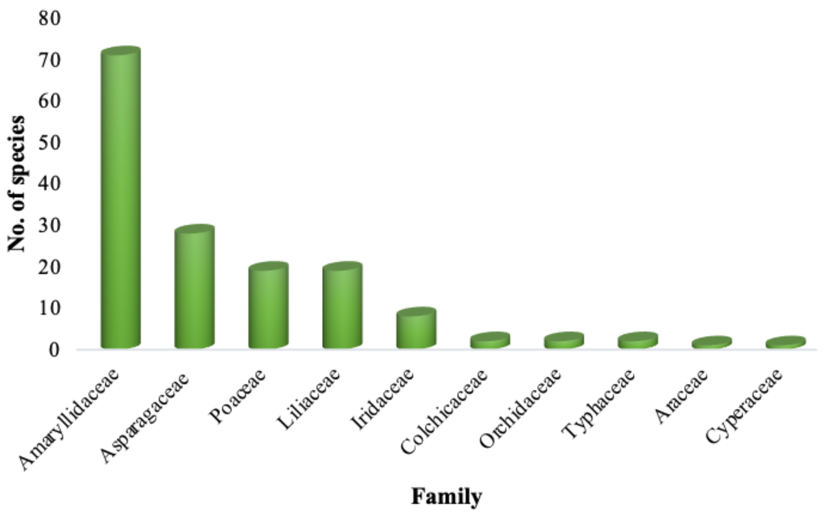

Figure 1. Families of Iranian endemic monocots

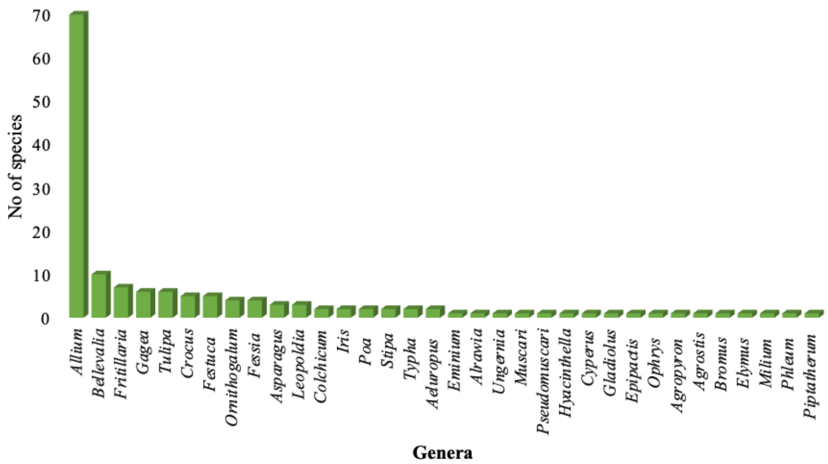

Figure 2. Genera of Iranian endemic monocots

Allium L. had the highest number of endemics, whereas *Eminium* Schott, *Alrawia* (Wendelbo) Perss. & Wendelbo, *Ungernia* Bunge, *Muscari* Mill., *Pseudomuscari* Garbari & Greuter, *Hyacinthella* Schur, *Cyperus* L., *Gladiolus* L., *Epipactis* Zinn, *Ophrys* L., *Agropyron* Gaertn., *Agrostis* L., *Bromus* Scop., *Elymus* L., *Milium* L., *Phleum* L., *Piptatherum* P. Beauv. and *Trisetum* Pers., each with one species, had the lowest endemics (Fig. 2).

Endemic species were categorized based on topographic zonations (Kapos *et al.*, 2000) including basins (less than 300 m a.s.l.), lowlands (300–1000 m a.s.l.), semi-mountainous (1000–1500 m a.s.l.), mountainous (1500–2500 m a.s.l.), alpine (2500–3500 m a.s.l.), and subnivale (3500–4500 m a.s.l.). Amaryllidaceae, Liliaceae, and Poaceae comprised the highest percentage of endemics in mountainous zones, respectively. These taxa showed a peak between 1500 and 2500 m a.s.l. Generally, their richness, characterized by a steep gradient, increased up to 2500 m a.s.l., after which it decreased to 4000 m a.s.l. *Allium graveolens* (R.M. Fritsch) R.M. Fritsch, and *Allium scotostemon* Wendelbo with a range of 950–3900 m a.s.l. covered the widest range of elevation. On the other hand, *Cyperus celans* Kukkonen (140 m a.s.l.) as well as *Poa damavandica* Assadi and Kavousi (3700–4350 m a.s.l.) covered the lowest and highest elevation categories of distribution, respectively. Monocots stretched mostly between latitudes of 35˚ and 37˚ North (Fig. 3) and afterward experienced a dramatic decrease to 35˚ North latitude.

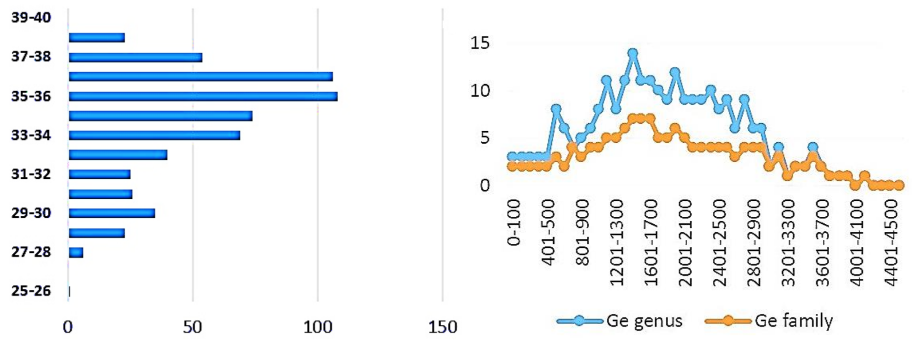

Figure 3. Endemic species-latitude curve(left); Altitudinal richness of geophytes (right)

Considering a mixture of all monocots, 46% (93 spp) of them were distributed in Mediterranean pluviseasonal–continental, 32% (64 spp) in Mediterranean xeric–continental, 13% (26 spp) in Mediterranean desertic–continental, and 9% (18spp) in other (Mediterranean pluviseasonal–oceanic, Tropical xeric, Temperate oceanic (Toc), and Tropical desertic) bioclimatic units. The largest number of species, i.e. 44% of all them (120 spp), occurred in the sedimentary geological formations, followed by 21% (58 spp) in igneous formations. Furthermore, 34% (75 spp) occurred in Zagros, 17% (37 spp) in the northwest, 13% (29 spp) in the north, 11% in the central (24 spp), 9% in the northeast (21 spp), and 16% (35 spp) in other geological units (SW, E, SE) or a combination of them. Kurdistan–Zagros with 44% (75 spp), Atropatenian with 31% (53 spp), Khorasan with 14% (23 spp), Fars–Kerman with 6% (11 spp), Hyrcanian and Sudano–Zambezian each with 2% (4 spp), and Nubo-Sindian with 1% (1 spp) constituted the phytogeographical units of Iranian monocots.

Life Forms

A total of 128 (83%) taxa, including 20 genera of Amaryllidaceae, Asparagaceae, Liliaceae, Araceae, Orchidaceae, Colchicaceae, and Iridaceae, belonged to geophytes (Appendix 1). Furthermore, 21 (13%) taxa, including 12 genera belonging to Poaceae and Cyperaceae, were classified as hemicryptophyte. Helophytes, which included two species from the genus *Typha* L. belonged to Typhaceae. Moreover, therophytes with one species belonging to the Poaceae family made up other Iranian monocots' life forms. Three species of the genus *Asparagus* L. have the chamaephyte life form. The genera, as well as the family of geophytes, indicated a peak between 1200–2800 m a.s.l. and 1300–2800 m a.s.l., respectively (Fig. 3). The genera of hemicryptophytes claimed the highest peak from 1300 to 2900 m a.s.l.

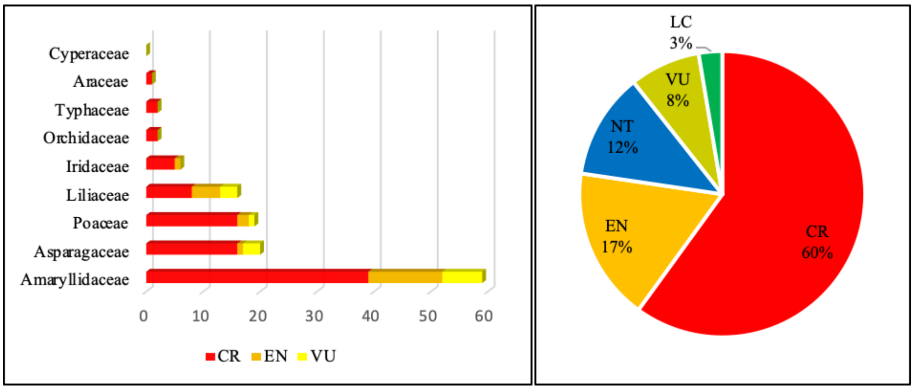

Figure 4. IUCN categories for the species (right) and IUCN categories for the families studied (right).

Conservation Status and Rarity

Iranian endemic monocots were assessed for the first time in Iran based on the global IUCN Red List and included critically endangered (CR): 60% (89 spp), endangered (EN): 17% (26 spp), near threatened (NT): 12% (18 spp), vulnerable (VU): 8% (12 spp), and the least concern (LC): 3% (4 spp) (Fig. 4.). Amaryllidaceae, Asparagaceae, and Poaceae covered the highest CR rankings, respectively (Fig. 4). Rare taxa were classified based on the Rarity Index (RI) and categorized as very rare (VR) (Fig. 5), rare (R), middle distribution (MD), and widespread (W). Accordingly, those taxa present in 1, 2–4, 5–7, and more than 7 grid cells were considered as VR (66 spp: 43%), R (51 spp: 34%), MD (16 spp: 12%), and W (16 spp: 11%), respectively. Moreover, Amaryllidaceae (31 spp) and Asparagaceae (11 spp) covered the highest percentage of very rare taxa, respectively. A synopsis of the data is presented in Appendix 1.

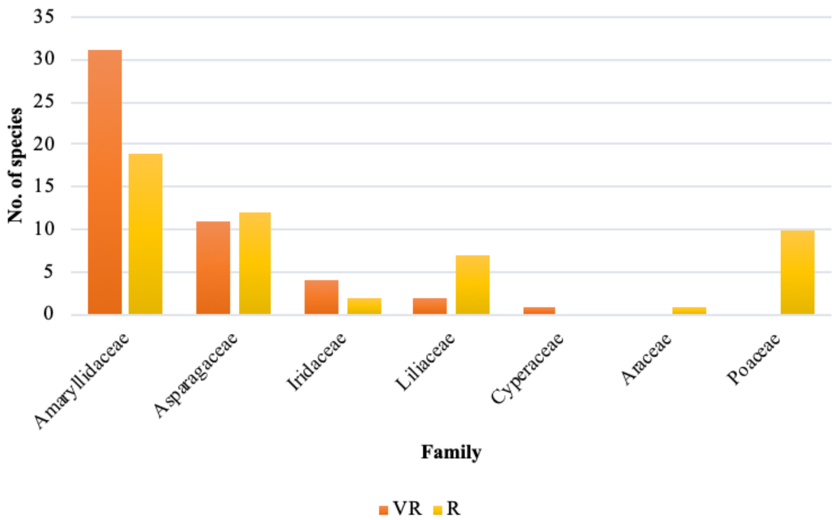

Figure 5 Rarity index for families and genera

Species Richness

The species richness map of all endemic monocots shows that parts of the central Alborz region and Zagros mountain ranges have the highest species (Fig. 6). This study categorized the species richness map cells into five groups of 1 to 14 species. The highest species richness (14 species) of Iranian endemic monocots occurred in two grid cells in parts of the Alborz and Markazi provinces.

Five grid cells have 9-11 species: two cells in Chaharmahal and Bakhtiari, and one grid each in Mazandaran, Hamedan, and Kurdistan provinces. Besides, 8 grid cells have 7-8 species, often concentrated in Lorestan, Fars, Yazd, Kermanshah, Tehran and Semnan provinces.

Figure 7 demonstrates the species richness map and distribution patterns of all the genus Allium's subgenera, the largest genus of the Iranian endemic monocots.

Areas of Endemism (AOEs)

Four main areas of endemism of Iranian endemic monocots were identified using the GIE method: **AOE1** is located in the Kurdistan-Kermanshah provinces, **AOE2** in the Lorestan-Hamedan-Markazi provinces, **AOE3** in the Chaharmahal and Bakhtiari province and **AOE4** is situated in central Alborz (Fig. 8). (Three of these areas are situated in the Zagros Mountains.) These regions have the highest rates of the Kernel index, followed by regions in the Kohgiluyeh and Boyer-Ahmad provinces, Kopet Dagh mountains, and parts of northwest of Iran (East and West Ardebil provinces).

AZE sites

The sites hosting at least 95% of the known population of CR or EN taxa were classified as the alliance for zero extinction (AZE) sites. Based on this method, one grid cell in Alborz province had the highest CR and EN taxa (Fig. 9). Parts of Chaharmahal and Bakhtiari (2 grids) and Lorestan provinces (2 grids) with three CR species are included as main AZE sites of monocot endemics in Iran (Fig. 9).

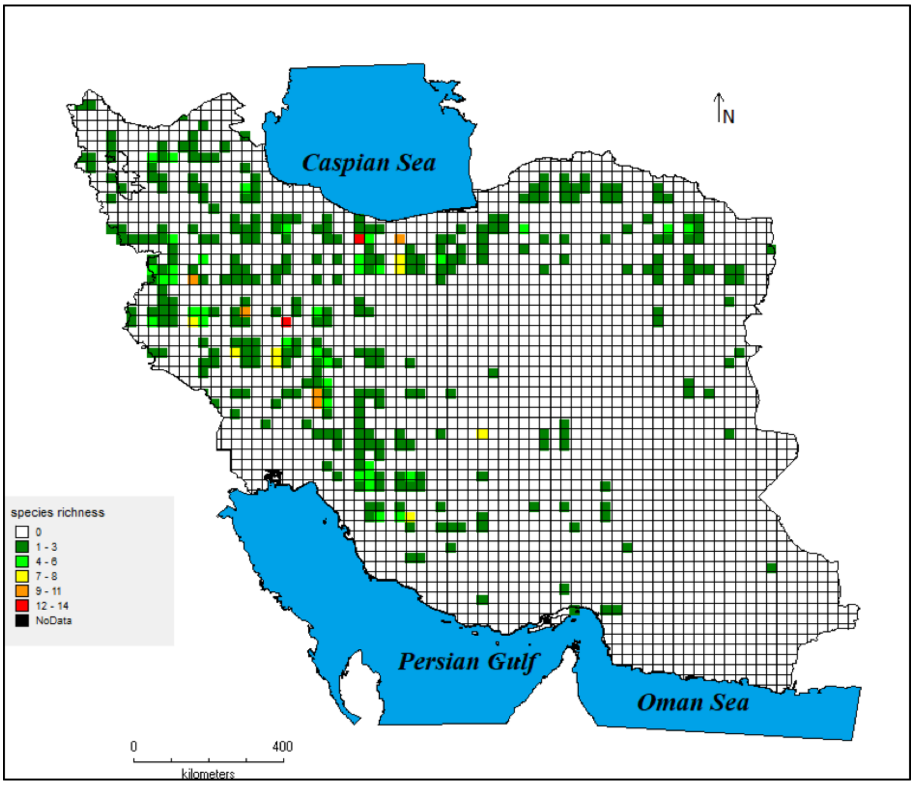

Figure 6. Species richness map

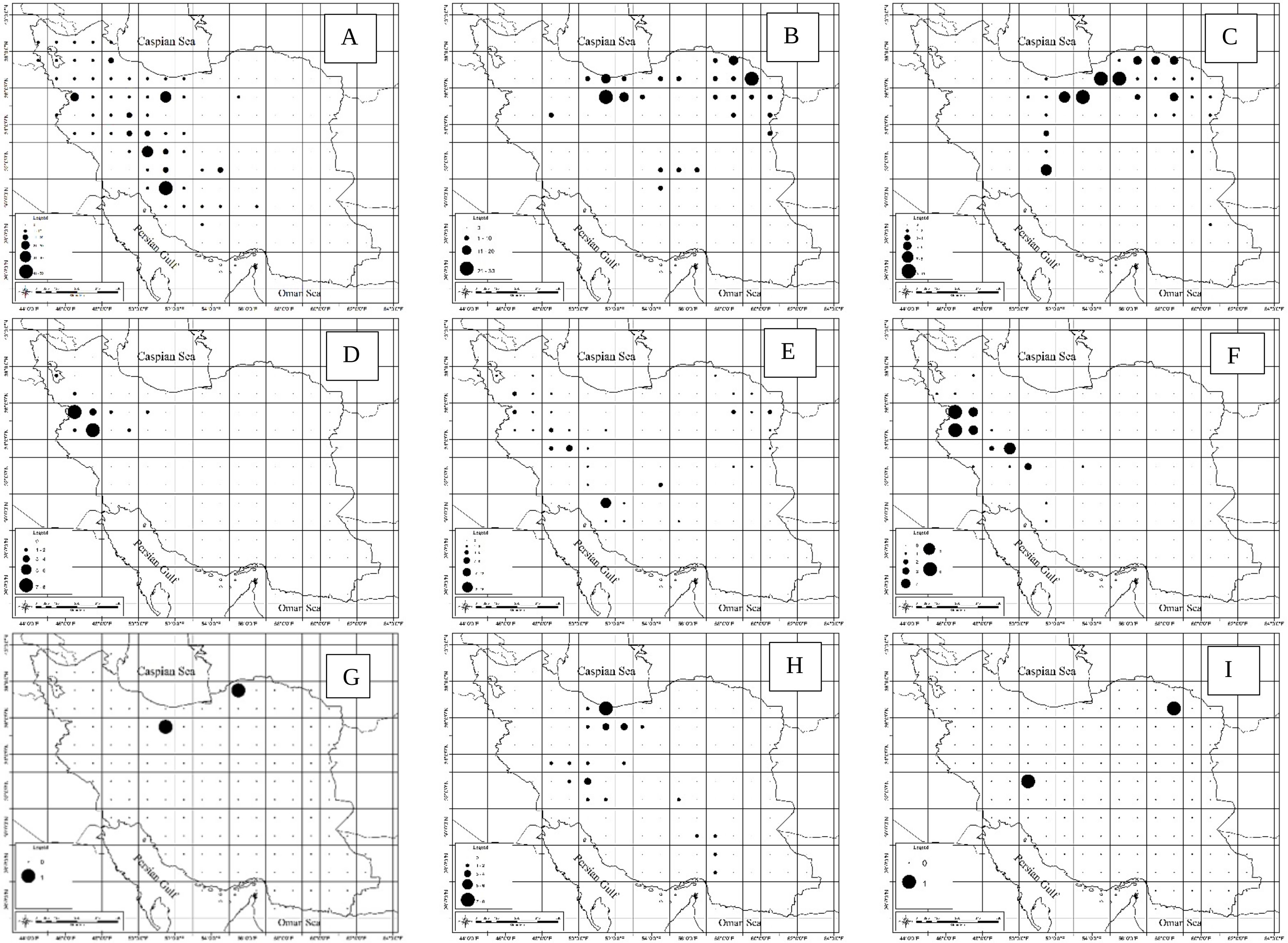

Figure 7. Distribution map of: Subgen. *Melanocrommyum*: a. Sect. *Acanthoparson*, b. Sect. *Asteroparson*, c. Sect. *Megaloparson*, d. Sect. *Melanocrommyum*, e. Sect. *Perocerallium*, f. Sect. *Pseudoparson*, Subgen. *Allium*: g. Sect. *Pallasii*, h. Sect. *Scorodon*, i Sect. *Longivaginata*.

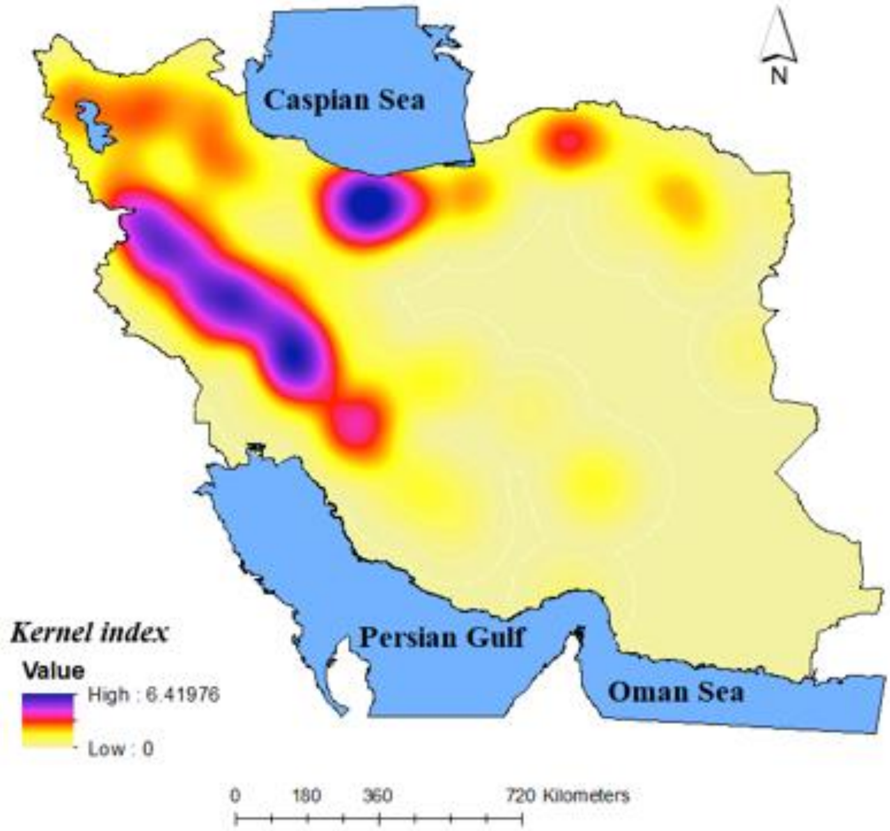

Figure 8. Areas of endemism of the Iranian endemic monocots in identified using GIE.

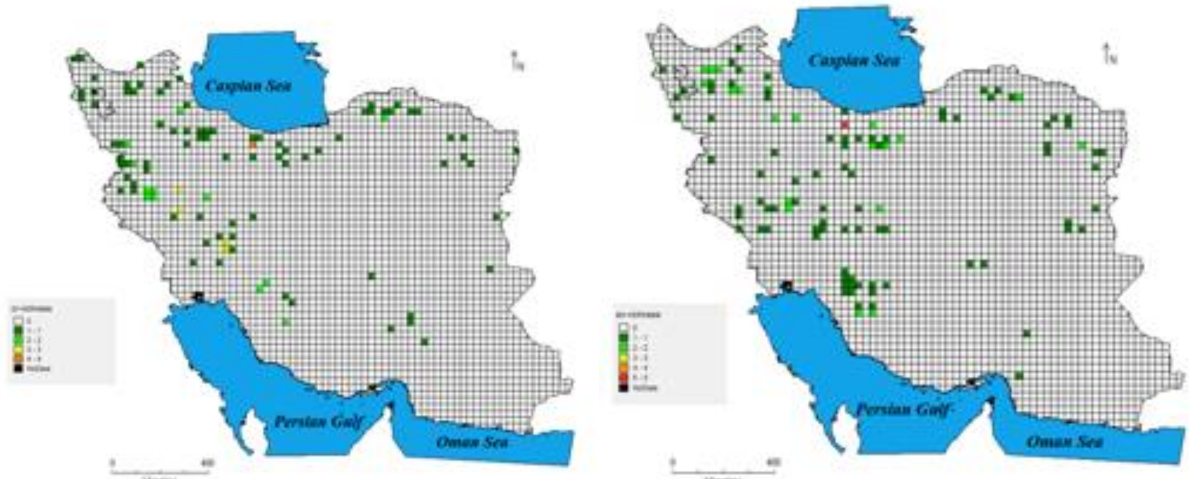

Figure 9. AZEs map of the studied taxa in Iran: endangered taxa (left); critically endangered (right).

Discussion

This first assessment of distribution patterns and conservation status of Iranian endemic monocotyledons has produced several significant findings. Iran is host to about 2200 endemic plant taxa (Noroozi et al., 2015; Assadi et al., 1984; 2017), which cover about 0.7% of the world's flora (RBG Kew, 2016). Because of their high ornamental value, monocots are heavily affected by anthropogenic pressure (Mehrabian, 2015a). Klein (1991) believes that the Alborz and Zagros mountain ranges function as zones for speciation in the Irano–Anatoly Region center. Other studies have confirmed these results (Rechinger, 1963–2015; Wagenitz, 1986; Mehrabian, 2015a) and suggest that the Zagros, Alborz, and to a lesser degree, Kopet Dagh (Memariani et al., 2016) mountains host a wide spectrum of endemic Iranian plants. The recent rankings are following the distribution pattern of Iranian alpine endemics (Noroozi *et al.*, 2008) and endemic trees and shrubs (Mehrabian et al., 2020). The relative contribution to endemism increases as the altitude rises in Iran. This situation is also seen in the Himalayan Mountains (Vetaas & Grytnes, 2002); however, rich endemism exhibits an inverse pattern in the adjacent areas along the Hindu–Kush Mountains (Breckle, 1974, 2004).

The Atropatenian phytogeographical unit with xerophyte vegetation (Takhtajan, 1986) in Iran is similar to the eastern zones of the Mediterranean regional center of endemism (Heywood & Duloo, 2005), covering about 25.4% of all endemic monocots in Iran. An increase in endemic richness also occurs near the northern districts of Caucasia. Some authors (Frey & Probst, 1974; Klein, 1991; Akhani, 1998; Akhani et al., 2013) have shown that the Alborz tree line's upper zone is a sector of recent phytochorions and occupied by broad spectra of endemic taxa. It is noteworthy that more than 80% of Atropatenian endemism stems from the Amaryllidaceae and Liliaceae families.

The Kurdistan–Zagros area serves as a critical Irano–Turanian regional center of endemism and includes 44% of all Iranian endemic monocots, primarily Amaryllidaceae, Liliaceae, and Poaceae. Exposure to the eastern Mediterranean ecosystem's moisture-bearing winds give the western slopes of the Zagros Mountains a wider variety of flora than the eastern slopes. The low density of oak forests provides open spaces under their canopy to establish a broad spectrum of steppe and semi–steppe plants (Zohary, 1973). Recent findings have confirmed the zone's classification as the richest zone of endemism and diversity in Iran (Jalili & Jamzad, 1999) and southwestern Asia (Heywood & Duloo, 2005). Hyrcanian province and the Sudano–Zambezian Region has shown few endemic monocots.

With about 70 species, Allium claims the highest value (46%) of Iranian endemic monocots. These results prove that the rate of endemism increases from east to west and from south to north in Iran, where annual rainfall is higher, especially in zones affected by Mediterranean bioclimatic units. A high percentage of endemic monocots find shelter in sedimentary rocks, and a significant number of mountainous to alpine taxa are distributed in igneous, volcano-sedimentary, and metamorphic rock. These findings confirm those obtained by Rechinger regarding soil's role in the creation of high endemism in Iran (Hedge & Wendelbo, 1978). The richness of endemism fluctuates widely according to latitude, primarily because of temperature fluctuation. Species richness can be observed in Atropatan on the gentle slopes from 500 to 3000 m a.s.l. and even up to 4000 m a.s.l. These fluctuations also occur on the steep slopes of the Kurdistan–Zagros range.

The Most Important Priority Endemic Taxa

Because of their ornamental, medicinal, and ecological values, some of the mentioned taxa (e.g., Amaryllidaceae, Iridaceae, Asparagaceae, etc.) prioritize over other studied taxa. Amaryllidaceae is distributed mostly between 25° and 45° latitudes in northern and southern Africa, North America, and Europe and in Asia's drier zones (Rahn, 1998). The genus *Allium* is primarily distributed in the Northwest and with less diversity in the northeast of Iran as a center of diversity and endemism for the subgenus *Melanocrommyum*. This subgenus is centered in the Irano–Turanian floristic region, especially in the Middle East and the eastern Mediterranean, although some plants are also distributed in the central and western parts of southern Europe. Mediterranean taxa are eventually dispersed during immigration events from centers of development in the Near East and the Middle

East. The subgenus is a monophyletic group (Fritsch, 1992; Kruse, 1992) from xerophilous and heliophilous taxa adapted to dry steppes, semi-deserts, arid mountain slopes, scrub, and open parklands (Hanelt et al., 1992). With 19 endemic species, the subgenus *Allium* represents the second largest group of endemic *Allium* in northern, western, and central Iran. The heterogeneous subgenus (Kollmann, 1984) forms about 40% of all species in the Mediterranean and Irano–Turanian floristic regions in open dry environments and sometimes open woodlands. It stretches sporadically into northeast Asia (Hanelt et al., 1992). *Allium* sect. *Rhizirideum* is a rhizomatous species called *Allium asarense* in restricted habitats in the southern Alborz range in northern Iran. This group occurs in the Eurasian steppes and neighboring mountainous habitats of Middle and Central Asia and decreases toward the Mediterranean (Hanelt et al., 1992).

Asparagus, including diverse life forms (e.g., herbaceous perennial, shrubs, woody veins), is comprised of 100–300 species distributed in the arid and sub-arid zones of the Old World (Hamdi & Assadi, 2009). Their endemic species of Iran take a perennial form and include *A. azarbaidjanensis (*subgen. *Asparagopsis)* in northwestern Iran, *A. touranensis (*subgen. *Asparagopsis)* in northeastern as well as southeastern Iran, and *A. khorasanensis* (subgen. *Asparagos*) found only in the restricted zone of northeastern and eastern Iran. Thus, the members of the two mentioned subsections show western and eastern zones of distribution in Iran, respectively. The genus *Muscari* Miller (Asparagaceae) is centered mainly in the Caucasus, temperate Europe, Africa, northwestern and southwestern Asia (Jafari & Maassoumi, 2011).

Colchicaceae has a marked center in the summer rainfall zones of South Africa, Australia, western Asia, and North America (Vinnersten & Manning, 2007). *Colchicum* is an endemic species distributed in western and southwestern zones of Iran. The rate of endemism strongly increases toward the west and southwest such that Turkey and Greece have 10 and 14 endemic taxa, respectively (Akan & Eker, 2005). Araceae are centered in western and northern Iran. Three taxa and nine species of *Eminium* found in western Iran (Bonger & Boyce, 2008) show similar distributions, except for Europe. Araceae is mainly concentrated in the tropics of Africa, America, and Southeast Asia and shows a decrease in diversity in the temperate zones of Eurasia (Rahn, 1998). Cyperaceae are distributed worldwide. Endemism at the species level can be recognized by a single specimen from a single locality (Rahn, 1998).

Iridaceae has a poorly endemic taxon in Iran and is centered mostly in western and northeastern regions of the country, increasing westward, especially in Turkey (Kerndorff et al., 2013). *Crocus* is a Eurasian and North African element distributed from the lowlands to the alpine tundra. Its distribution centers around the Aegean Sea and in western Turkey and the Balkans (Eastern Mediterranean) (Rukšâns, 2013) and stretches into the Irano–Turanian region (Erol et al., 2014). Iran is located in the far western zone of the center and shows a low extent of endemism. *Crocus almehnsis* is a restricted endemic taxon that is only distributed at 1450–1500 m a.s.l. in Golestan National Park (northeastern Iran). *C. gilanicus* is a Hyrcanian element distributed in restricted sites in the forests of Guilan (northern Iran).

Poaceae comprise 26 species belonging to nine tribes of *Pooideae* and are primarily distributed in the Zagros, Alborz, and Kopet Dagh mountains and to a lesser extent in the mountains of central Iran (Irano–Turanian region). *Henrardia persica* is a hemicryptophyte taxon widely distributed in diverse zones of the Irano–Turanian region in Iran. Recently, the genus has appeared as three endemic species in the Irano–Turanian region, stretching from the northwestern Himalayas to Anatolia, then to Syria (Takhtajan, 1986).

Liliaceae grow primarily in the temperate and alpine zones of Holarctic (Rahn, 1998). Iran has about 18 species, five of which are endemic, showing a relatively rich flora of these taxa. The main gene center of Sect. *Tulipa (Leiostemones* Boiss.) with 40 species is Central Asia. *T. faribae*, belonging to a recent section, are found in a restricted locality (type only) in western Iran (Ghahreman et al., 2007). *Tulipa montana* Lindl. is a species found in the Iranian mountains. It has the species' characteristic yellow flowers and is distributed throughout a broad range of elevations (250–3150 m a.s.l.) in western, northwestern, northern, and northeastern regions of Iran. *Fritillaria* comprises about 160 species (Rix, 2001) and is distributed throughout the northern hemisphere. The eastern Mediterranean region and the U.S. state of California are considered centers of diversification of the genus (Rix & Rast, 1975), including five species which are distributed mainly in western Iran which has a Mediterranean climate. *F. kotschyana* have been reported in restricted zones in their distribution range. *F. kotschyana* Herbert subsp. *Kotschyana* has been reported in restricted localities in northwestern and northern Iran zones at altitudes between 1500 and 3700 m a.s.l. *Gagea* are an important Eurasian genus with species distributed in North Africa, having about 70–250 taxa, as estimated by different authors (Zarrei et al., 2007). The genus includes five endemic species, which are distributed in northern and western zones of Iran. The genus of *Bellevalia* with 11 species shows a high level of endemism in Iran. All taxa distributed in the Zagros range are in accordance with its global central distribution (Mediterranean and west-central Asia) (Johnson, 2003). The results suggest that the Irano–Turanian region is an important center for monocots' speciation and diversification. The Sudano–Zambezian region appears to contain few endemic monocots in Iran, although there are high endemism levels in other zones (Takhtajan, 1986).

Priorities for Conservation

The IUCN Red List of species (single-species approach) is the most important criterion for selecting priority taxa. Others (Callmander et al., 2007; Wilhere et al., 2008) prefer conservation of multiple species; however, some authors consider rarity (Tsiftsis et al., 2008, 2009), species distribution (Selvi, 1997; Solymos & Fehr, 2005), degree of endemic richness (Myers et al., 2000), species specialization by habitat (Tsiftsis *et al.*, 2008), and conservation value as valuable criteria, and some accept a combination of indicators (Tsiftsis et al., 2009).

Species richness by habitat (Myers, 1990; Prendergast et al., 1999; Williams et al., 1996; Solymos & Feher, 2005; Traba et al., 2007) is another factor used in the selection of priorities. Vulnerable areas with a higher number of taxa are considered as the most important priority for conservation. Some, however, insist on conservation of the ecosystem. The richest zones of very rare and rare endemic monocots enjoy the highest priority for conservation. In Iran, 70.3% of taxa can be classified in these categories and are distributed mostly in the Zagros and Alborz mountain ranges. Those taxa showing a higher value on this index have a greater vulnerability and need to be prioritized for conservation. About 41.7% of the studied taxa show a high degree of vulnerability to threatening factors. Based on endemic richness, the central Zagros, central Alborz, and Kopet Dagh ranges are areas of top priority for conservation.

The Kurdistan–Zagros range and the Atropatenian phytogeographical units feature the highest numbers of critically endangered taxa and form the first class in conservation value and priority.

Alliance for Zero Extinction (AZE) Sites

Key biodiversity areas should be assessed based on vulnerability and irreplaceability (Langhammer et al., 2007). A site falls into the vulnerability category when it is host to globally–prominent numbers of one or more globally–threatened taxa (Williams et al., 1994). Irreplaceability of a site means that the geographic options for protection will be lost if that particular site is lost (Williams et al., 1996).

Two levels of priority have been defined in the present study. The sites hosting at least 95% of the known CR or EN taxa population have been classified as the alliance for zero extinction (AZE) sites (Langhammer et al., 2007). Some AZE sites occur along the boundaries of protected areas, where suitable ecological conditions for viability and efficient action for their conservation do not exist. The mountainous and alpine zones are severely threatened by overgrazing, mountain climbing, overharvesting of medicinal and ornamental taxa, and extensive and rapid change in land–use (Noroozi et al., 2008; Akhani et al., 2010; Mehrabian, 2015a). Some taxa could be protected by establishing plant micro–reserves (Laguna et al., 2004).

Conclusion

The present study has mapped the geobotanical patterns of endemic monocots to highlight the priority taxa and priority zones to improve the database of endemic plants. This will aid in management planning, *in situ* and *ex situ* conservation, and modeling habitat suitability for rehabilitation and restoration plans. This process is ongoing through the efforts of the authors of this study. Complementary research will provide valuable data to map and rank endemism centers on a global scale. The present research reaffirms the Irano–Turanian region as a center for plant endemism in Iran and worldwide. Major efforts for conservation must focus on these centers. Additionally, these endemic taxa as unique genetic treasures have a high potential for domestication to produce new crops as well as orchards, thereby reducing the negative anthropogenic pressures on their populations and protecting them efficiently.

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