Turczaninowia 28, 1: 5–15 (2025)
https://www.doi.org/10.14258/turczaninowia.28.1.1
http://turczaninowia.asu.ru

ISSN 1560–7259 (print edition)
TURCZANINOWIA
ISSN 1560–7267 (online edition)

УДК 581.95(571.54)

Diversity and distribution of parasitic flowering plants in Iran

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Keywords: conservation, Iran, Orobanchaceae, parasitic flowering plants.

Summary. Iran is home to a number of taxa of parasitic plants that are distributed in diverse ecological zones of the country. The present study examined the diversity and distribution patterns of these taxa. The geo-referenced dataset of Iranian parasitic species was formed using the distributional data available in "Flora of Iran" and "Flora Iranica" as well as several herbaria. To evaluate species richness and determine the main hotspots of parasitic flora in Iran, species distribution points were mapped on 0.25° × 0.25° grid cells using the Geographic Information System. In addition, the area-corrected species richness of parasitic angiosperms was calculated for each provincial unit. According to the results, the flora of Iran includes 104 species of 21 genera belonging to parasitic plant families that cover about 1.3 % of angiosperm species nationwide. Overall, the highest species richness occurs in parts of northwestern Iran and the Central Alborz. The richness of parasitic angiosperm species is very diverse among provinces of Iran. East Azarbaijan and South Khorasan provinces have the highest and lowest number of species, respectively.

Разнообразие и распространение паразитических цветковых растений в Иране

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Поступило в редакцию 21.01.2024
Принято к публикации 10.12.2024

Submitted 21.01.2024
Accepted 10.12.2024

Ключевые слова: Иран, охрана, паразитические цветковые растения, Orobanchaceae.

Аннотация. В Иране произрастает ряд таксонов паразитических растений, приуроченных к различным экологическим зонам. В настоящем исследовании изучены разнообразие и особенности распространения этих таксонов. Набор геопривязанных данных по иранским паразитическим видам был сформирован с использованием информации о распространении, имеющейся во "Flora of Iran" и "Flora Iranica", а также материалов нескольких гербариев. Для оценки видового богатства и определения основных очагов разнообразия паразитической флоры в Иране точки распространения видов были нанесены на ячейки сетки 0,25° × 0,25° с помощью геоинформационной системы. Кроме того, для каждой провинциальной единицы было рассчитано видовое богатство паразитических покрытосеменных с поправкой на площадь. Согласно полученным результатам, флора Ирана включает 104 вида из 21 рода растений, относящихся к паразитическим семействам, которые охватывают около 1,3 % видов покрытосеменных по всей стране. В целом, наибольшее видовое богатство наблюдается в северо-западной части Ирана и Центральном Эльбурсе. Видовое богатство паразитических покрытосеменных очень различно в разных провинциях Ирана. Провинции Восточный Азарбайджан и Южный Хорасан имеют наибольшее и наименьшее количество видов, соответственно.

Introduction

Parasitic plants are a diverse taxonomic group of angiosperms, and approximately 4750 parasitic species belonging to 292 genera (about 2.2 % of the genera and 1.6 % of the species of total angiosperms) have been reported throughout the world (Nickrent, 2020). They are special functional groups that obtain part or all of their nutrients from other plants (hosts) through haustoria (Zhang et al., 2018). They can be classified into two main groups: holoparasites (lack chlorophyll, nonphotosynthetic) and hemiparasites (chlorophyll when mature, photosynthetic). Moreover, hemiparasites can be facultative or obligate (Nickrent, Musselman, 2004). The mentioned groups also comprise stem parasites, root parasites, or a mix of them (Westwood et al., 2010). Most parasitic plants are classified as parasitic organisms of crops that negatively affect agricultural ecosystems by absorbing a remarkable percentage of the nutrients of their hosts, eventually leading to the host's death (Zwanenburg et al., 2016). Additionally, parasites reduce the capabilities of their hosts, negatively affecting the hosts' growth and reproduction (Mutikainen et al., 2000). Holoparasites are completely dependent on their hosts for all their water and nutrient needs (Kaiser et al., 2015). Parasitic plants are also keystone species and ecosystem engineers that affect the structure and function of ecosystems (Press, Phoenix, 2005). These taxa are not classified as a monophyletic group, so they appear highly diverse in ecological as well as evolutionary contexts (Westwood et al., 2010; Bellot, Renner, 2013). The distribution patterns of parasitic plants depend on the ecological conditions as well as the characteristics of their hosts (Zhang et al., 2015). These taxa are distributed in diverse natural and semi-natural habitats of different biomes throughout the world (Stewart, Press, 1990; Poulin, 2011). They are ubiquitous species and occur in all ecosystems and climatic zones except Antarctica and aquatic habitats (Kuijt, 1969). The distribution patterns and diversity of parasitic plants have been studied in numerous countries around the world (Sürmen et al., 2015; Zhang et al., 2018).

With an area of 1648000 km^2, Iran is one of the biggest countries in West Asia and has a wide variation in geology-geomorphology (Alai Taleghani, 2005), pedology (Dewan, Famouri, 1964), climatology (Breckle, 2002), and phytogeography (Zohary, 1973), which has facilitated the delimitation of a huge variety of vegetation and floristic elements (Frey, Probst, 1974) and made Iran a main center of endemism and plant diversity in the world (Klein, 1972; Hedge, Wendelbo, 1978). The flora of Iran includes about 8000 plant taxa, 2200–2597 species of which are endemic to Iran (Mehrabian, 2015), which covers about 0.7 % of the world's flora.

Nevertheless, little attention has been paid to the distribution patterns and diversity of parasitic plants in Iran. The current study aimed to provide a checklist of parasitic angiosperms and describe the spatial distribution and diversity patterns of parasitic plants in Iran. In addition, the richness of parasitic species within protected areas and areas of diversity and endemism in Iran will be analyzed. The main questions addressed in this study are: Which areas have a greater richness of parasitic species? What percentages of life forms and phytochorions of the mentioned taxa exist in Iran?

Material and Methods

Study Area

With a total surface area of 1.6 million km^2, Iran is located at 25°–40° N longitude and 44°–64°

E latitude. As a limited section of the orogenic belt (Zagros, Alborz, and other mountain chains), Iran covers the Asian block along with Arabian-African unity (Berberian, King, 1981). The most important geomorphological sections of Iran include Zagros, Alborz, Kopet Dagh, and several interior mountain chains (e. g., the NW mountains, Central mountains, Makran, etc.) (Fig. 1). The Zagros Mountain chain is a long mountainous system (about 2000 km) that stretches from northwest (Eastern Turkey) to southeast (Makran Mountains). This topographic construction has shaped an elongated wall between the Iranian plateau (northeast) and the Persian Gulf and Mesopotamian (southwest) basins. The Alborz Mountain chain, with an average elevation of > 2000 m, is an active, arcuate fold-and-thrust belt (Stöcklin, 1974) and a prominent sector of the Alpine-Himalayan geological formation. Shaped as an east-west, softly sinuous crescent in northern Iran, it forms a natural barrier between the Caspian Sea and the central Iranian plateau (Stöcklin, 1974). Kopet-Dagh is a natural massif located in the eastern margins of the Caspian Sea leading into northeastern Iran, Turkmenistan, and northern Afghanistan. The Northwest Mountain chain, Jebal Barez in the center of Iran, and Makran in southeastern Iran, are other prominent orographic formations in the region. These extended massifs form a natural barrier surrounding the central plateau and lead to diverse rainfall patterns in the area. According to Rivas-Martínez et al. (1999), the bioclimate of Iran comprises Mediterranean (western, northwestern Iran), temperate (northern Iran), and tropical (southern coast zones of the Persian Gulf and the Gulf of Oman) macro-bioclimates. Additionally, precipitation patterns represent an average of about 250 mm annually (Amiri, Eslamian, 2010). The severely heterogeneous diversity in climate, vegetation, topography, parent rock, geologic time, and human activities in Iran leads to distinct variations in soil characteristics (Dewan, Famouri, 1964). Dewan and Famouri (1964) classified Iranian geographic boundaries into seven pedological zones: the Khuzistan plain, folded zone, Iran ides, central plateau, Elburz Mountains, Turkeman-Khurasan Mountains, and Caspian littoral region.

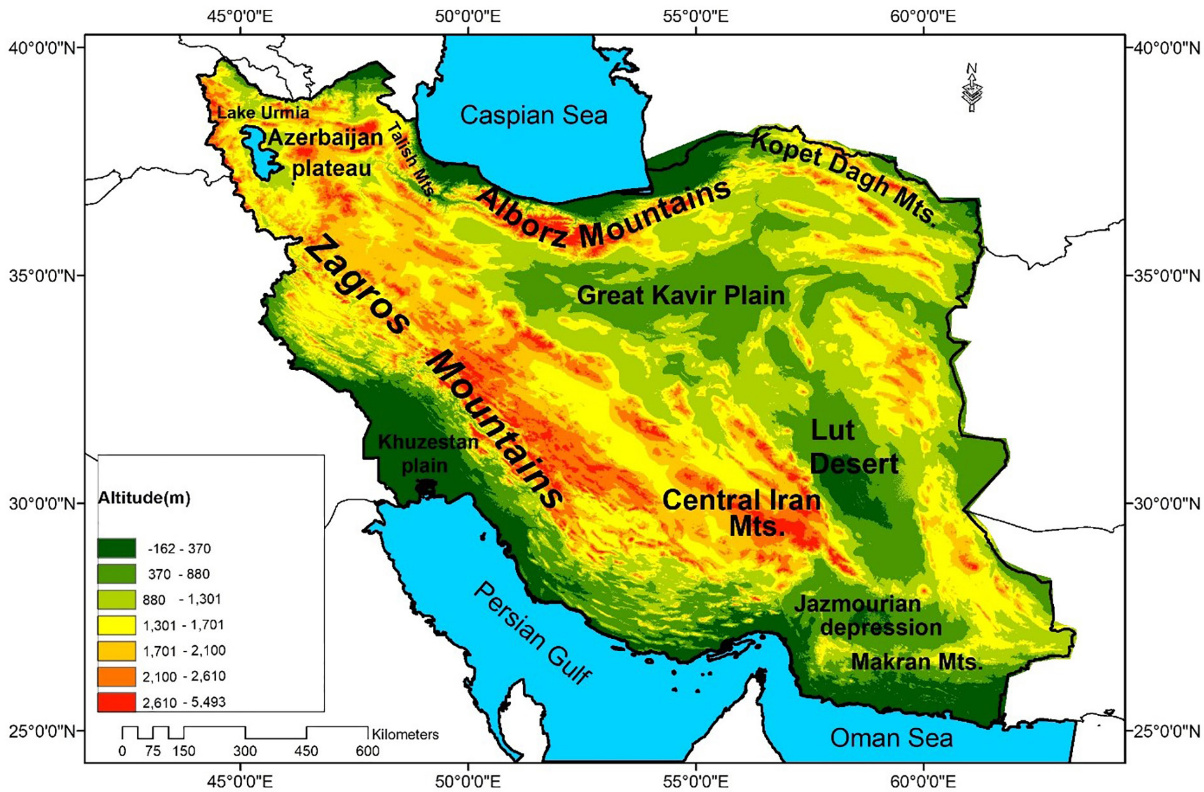

Fig. 1. Topographic map of Iran.

Species occurrence data

The geo-referenced dataset of Iranian parasitic species was formed using the distributional data available on "Flora of Iran" (2011–2017). Data on additional species was also extracted from the herbarium of the Shahid Beheshti University (HSBU) and virtual herbaria, such as W. "Flora of Iran" as well as the scientific websites of "Tropicos"

(URL: www.tropicos.org) and "International Plant Names Index" (IPNI. URL: www.IPNI.org) were used to determine the accepted species names and nomenclatures. The herbarium acronyms follow Thiers (2019). The final occurrence dataset used in this study contained 1646 geo-referenced records (Fig. 2).

Species richness

To evaluate the species richness and determine the main hotspots of parasitic flora in Iran, species distribution points were mapped on 0.25° × 0.25° grid cells using the Geographic Information System (ArcView 10.3). Subsequently, parasitic species were mapped using the circular neighborhood point-to-grid richness analysis tool based on 10 × 10 km grid cells with a radius of 25 km (Spooner, Hijman, 2001) to eliminate border effects caused by assigning the grid origin. Additionally, area-corrected species richness of parasitic angiosperms was calculated for each provincial unit using the formula D = N/log (A), where N is the number of parasitic species and A refers to the unit area (Zhang et al., 2018).

Life form

The C. Raunkiaer (1934) system was used to categorize plant life forms in this study.

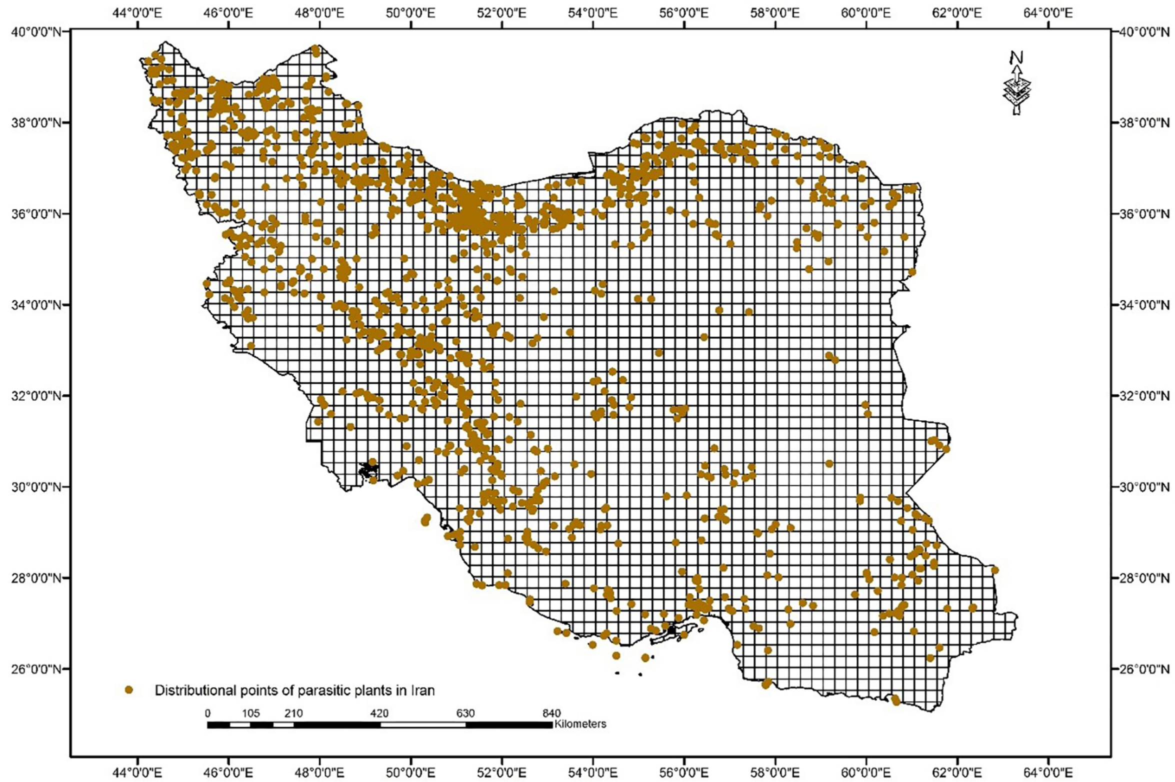

Fig. 2. Distributional points of parasitic plants in Iran.

Results

Parasitic flora of Iran

According to the present study, the parasitic flora of Iran includes 104 species of 21 genera belonging to 6 parasitic plant families that cover about 1.3 % of angiosperm species nationwide (8000 species). Accordingly, Iran is home to about 2.18 % (104) and 7.19 % (21) of the parasitic species and genera, respectively, found in the world. Orobanchaceae, with 13 genera and 71 species, is the largest parasitic plant family in Iran, followed by Convolvulaceae with 20 species and Santalaceae with 9 species (Fig. 3).

The remaining families have fewer than three species. Moreover, *Orobanche* L. (37 sp.) and *Cuscuta* L. (20 sp.) have the largest number of species among the studied taxa in Iran, while *Melampyrum* L., *Macrosyringion* Rothm., *Lathraea* L., *Bellardia* All., *Cynomorium* L., *Pilostyles* Guill., *Phelypaea* L., *Arceuthobium* M. Bieb., *Osyris* L., *Rhinanthus* L., and *Viscum* L. have only one species each in Iran (Appendix). In total, 64 % of the species are holoparasites and 36 % are hemiparasites.

Additionally, these parasites could be divided into root (82 sp.; 79 %) and stem (22 sp.; 21 %) parasitic plants. The former belong to the Orobanchaceae, Santalaceae, and Cynomoriaceae families and account for 79 % of the total parasitic flora, while the Convolvulaceae, Apodanthaceae, Santalaceae, and Loranthaceae families are considered to be stem parasitic plants and contain 21 % of the parasitic flora.

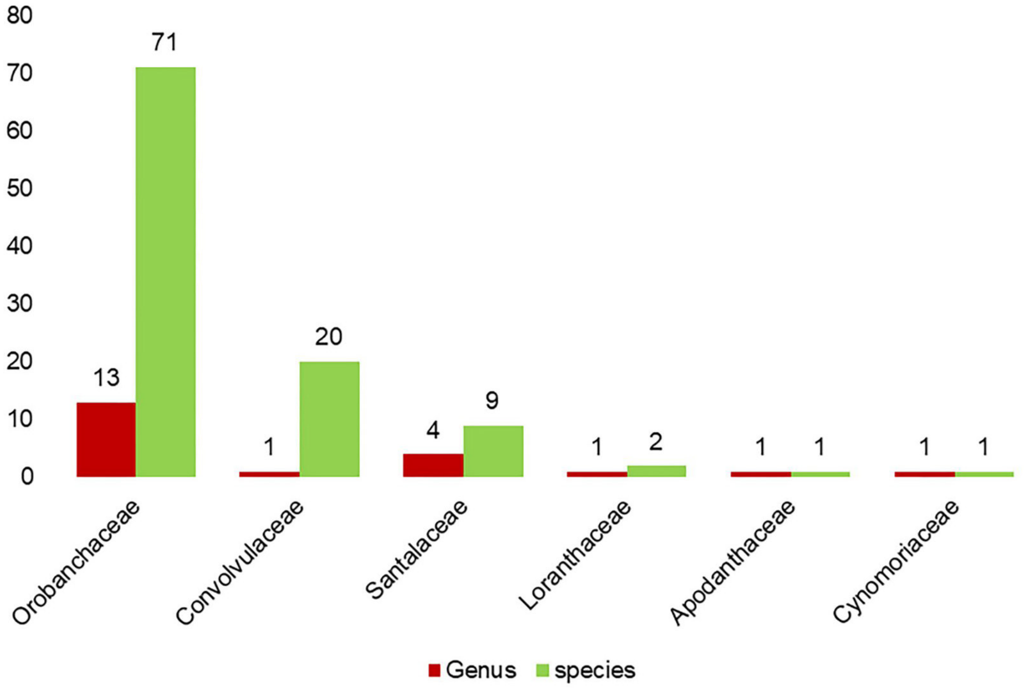

Fig. 3. Family diversity of Iranian parasitic species at genus and species level.

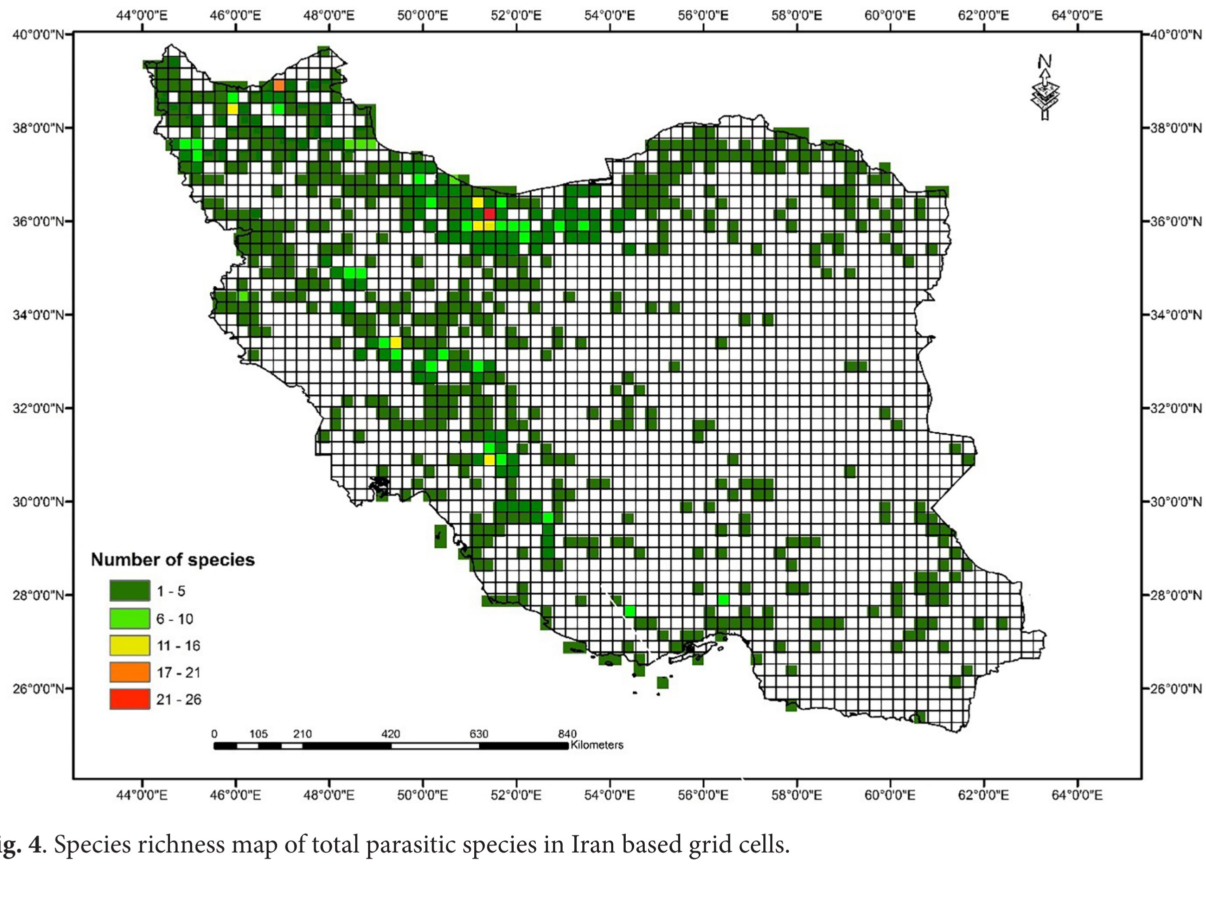

Fig. 4. Species richness map of total parasitic species in Iran based grid cells.

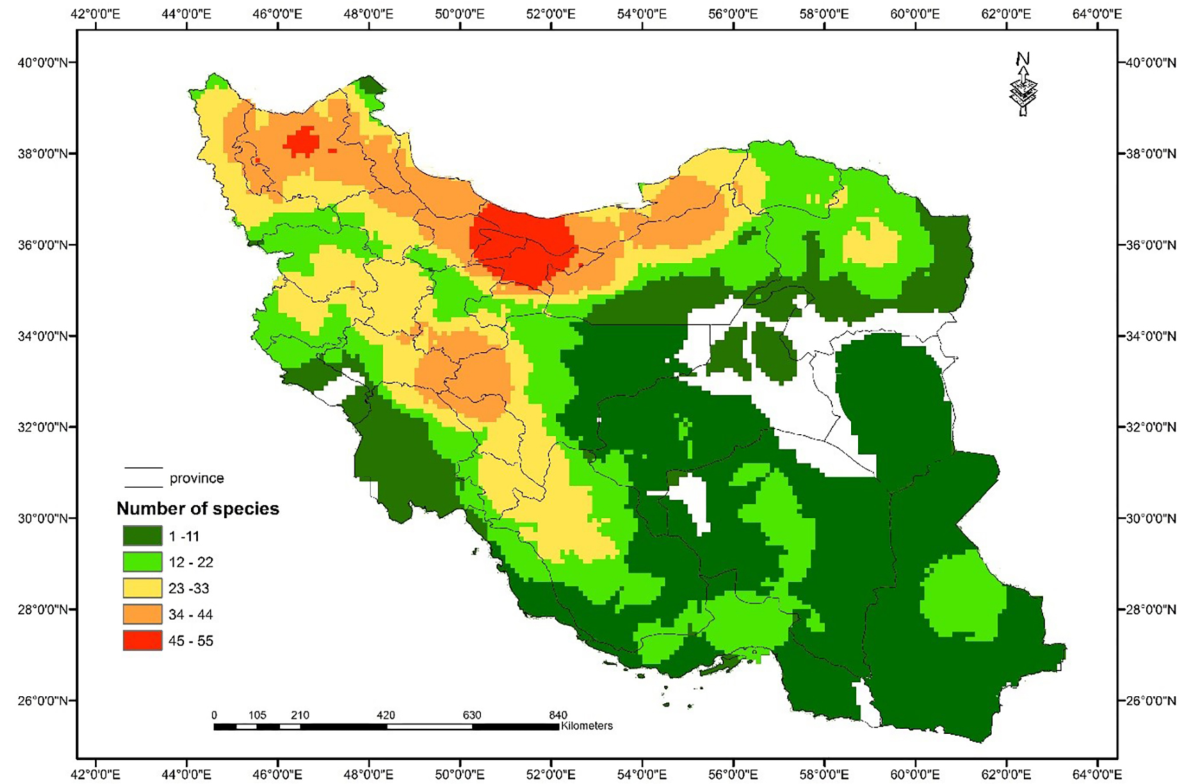

Fig. 5. Species richness map of total parasitic species in Iran based on the circular neighborhood point–to-grid richness analysis.

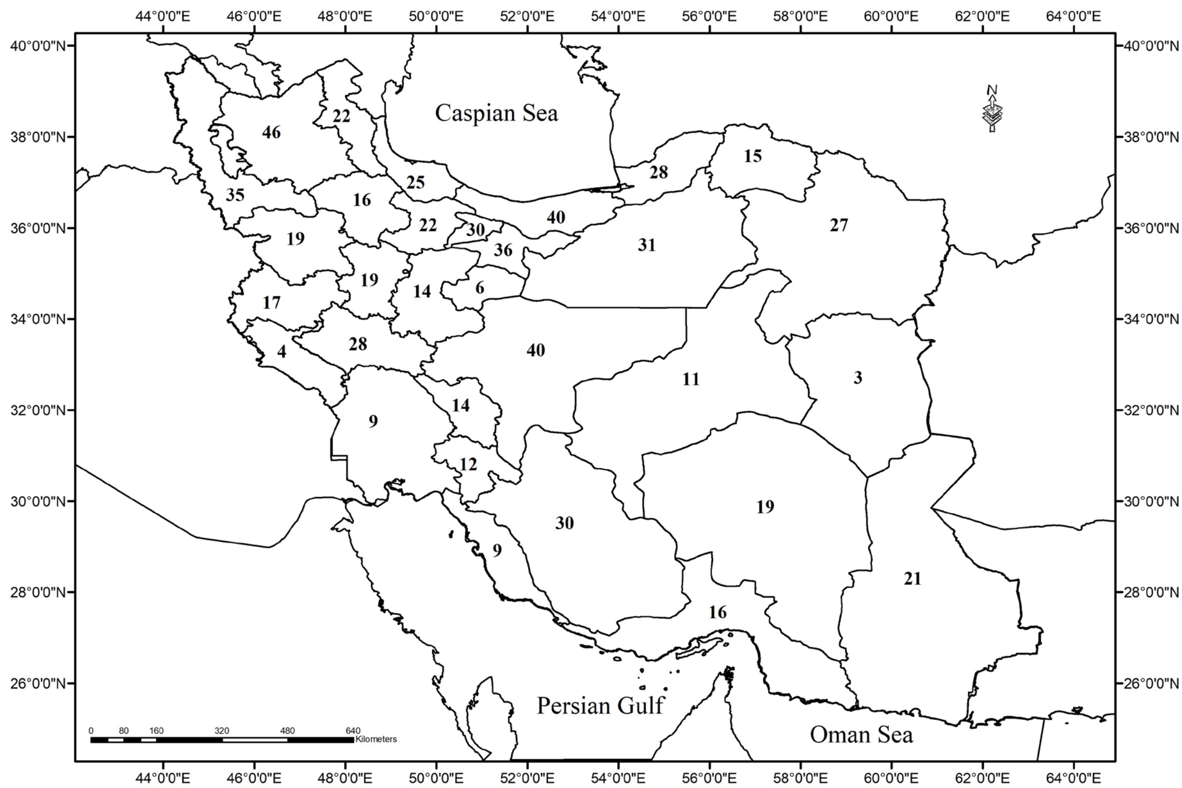

Fig. 6. Species richness in 31 provinces of Iran.

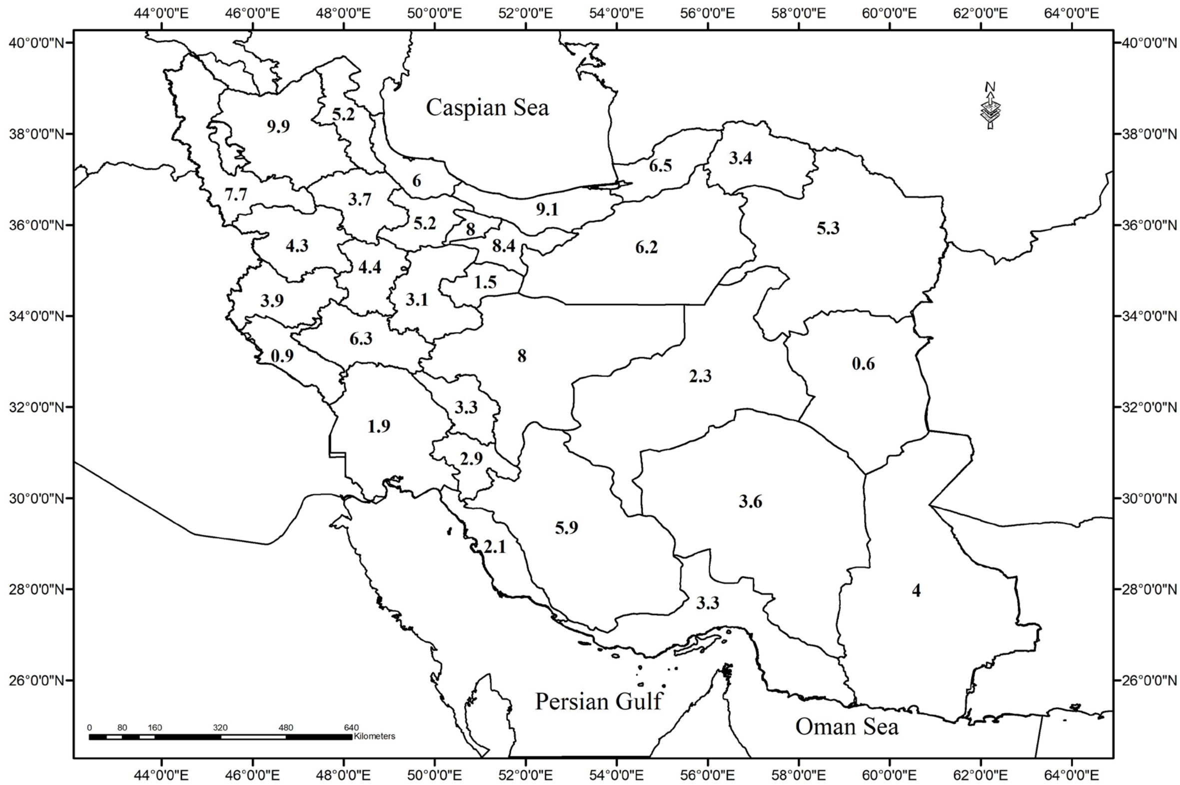

Fig. 7. Area-corrected species richness of parasitic plants in 31 provinces of Iran.

Hotspots of species richness

The grid-based map of richness is categorized into five groups of 1 to 26 species and shows that one grid cell in Gilan province has the highest number of species (26 species) followed by one cell in Ardebil province (21 species) (Fig. 4). Six grid cells in parts of Gilan (1), Tehran (2), Kohgiluyeh and Boyer-Ahmad (1), Lorestan (1), and East Azerbaijan (1) provinces have 11 to 16 species. Moreover, 31 grid cells have 6–10 species, often concentrated in northern, northwestern, western, and southern parts of Iran. The richness map based on the circular neighborhood point-to-grid richness analysis (Fig. 5). Based on this map, Gilan, Alborz, and Tehran provinces as well as a very limited area in the East Azerbaijan province are the main hotspots of parasitic plant richness in Iran. Overall, the richness of parasitic angiosperm species is very diverse among provinces of Iran. East Azerbaijan (n = 46) and South Khorasan (n = 3) provinces have the highest and lowest number of species, respectively (Fig. 6). Moreover, area-corrected species richness also varies largely among provinces, with East Azerbaijan (9.9) and South Khorasan (0.6) provinces have the highest and lowest amounts, respectively (Fig. 7).

Life forms

Hemicryptophytes (54 %) are the dominant life form among parasitic plants in Iran, followed by Therophytes (38 %) (Fig. 8).

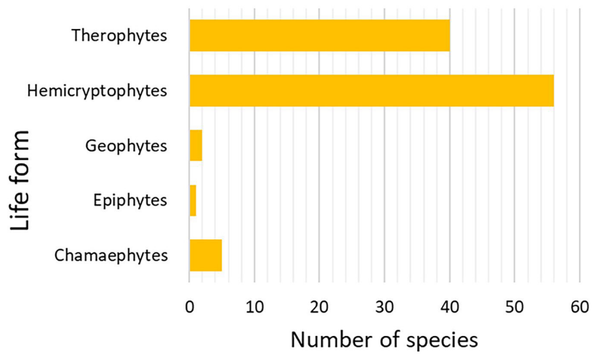

Fig. 8. Life forms of the studied taxa.

Discussion

Parasitic flora of Iran

The present study is the first to report on the distribution patterns and diversity of parasitic plant taxa in Iran. The results of this study showed that there are 104 species of parasitic plants in Iran, which comprises 1.3 % of all angiosperms in this area. Therefore, the presence of parasitic species in the angiosperm flora of Iran is less than the global value (1.6 %) (Nickrent, 2020), Nepal (2.93 %) (Joshi et al., 2000; O'Neill, Rana, 2016), and China (2.28 %) (Zhang et al., 2018) and higher than Turkey (1.29 %) (Sürmen et al., 2015). In addition, there are fewer endemic species of parasitic plants in Iran (7.47 %) than in China (two-thirds of parasitic species), Turkey (13.01 %), and Nepal (8.61 %). In general, the species richness of parasitic plants depends on the richness of all plant species in each region, climatic conditions, types of host plants, and changing ecological conditions also affect the richness of parasitic plants. The special topography and diverse altitude gradient of Nepal has probably given that country more favorable conditions than Iran for the speciation and endemism of parasitic species. Indeed, the endemic taxa of parasites in Iran, China, and Nepal belong mainly to the Orobanchaceae family, and *Orobanche* and *Pedicularis* have the highest numbers of endemic species in these countries. Irano-Turanian elements are the most abundant species of parasitic plant species in Iran, while Turkey has more Euro-Siberian elements. From a phytogeographical position, most of Iran is located in the Irano-Turanian region; only parts of the Hyrcanian forests in northern Iran are in the Euro-Siberian region (Zohary, 1973; Hedge, Wendelbo, 1978). Naturally, therefore, more than half of Iranian parasitic plant species are Irano-Turanian elements.

Hotspots of species richness

The results of the present study showed that the distribution of parasitic plant species in Iran follows the south-to-north pattern. By moving to higher northern latitudes, the number of species increases, and the greatest species richness occurs in parts of northwestern Iran and Central Alborz. This pattern corresponds well with the distribution patterns of other plant species in Iran (Hedge, Wendelbo, 1978; Khajoei Nasab, Khosravi, 2020; Khajoei Nasab, Mehrabian, 2022; Maassoumi, Khajoei Nasab, 2023; Khajoei Nasab, Zeraatkar, 2024; Zeraatkar, Khajoei Nasab, 2024). East Azerbaijan province has the highest number of parasitic species in Iran. The Azerbaijan plateau is located between the Alborz, Zagros, and Caucasus mountains. This floristic province includes very high mountains that harbor many species (Khajoei Nasab et al., 2024a). It is also a special area of endemism and speciation in Iran, which is influenced by the Mediterranean climate (Djamali et al., 2011). Indeed, Alborz is also a very important area of endemism and plant diversity in Iran, as it is affected by the Mediterranean xeric continental climate (Djamali et al., 2011). This region is a heterogenic macroecosystem with a very high mountain range as well as an orographic complex structure (Mehrabian, Khajoei Nasab, 2021). The richness and distribution of plants and animals increased with latitude (Willig et al., 2003; Eo et al., 2008; Xu et al., 2018), and this pattern was named as the latitudinal Rapoport's rule (Rapoport, 1975). It seems that this rule also applies to the diversity and distribution of Iranian parasitic species, as the results of multiple regression showed that latitude is the main environmental factor affecting richness and has a positive relationship with it. Altitude is the second environmental factor affecting the richness of the studied species, and the total richness of the studied taxa decreased in semi-alpine zones, coinciding with ecosystems in Iran. The altitudinal diversity gradient is one of the greatest patterns in the flora of Iran. Previous studies have reported an increasing trend in Iran plant species richness with altitude (Mehrabian, 2015; Khajoei Nasab et al., 2024b). Altitude gradient in Iran has led to climatic diversity, soil heterogeneity, and ecosystem diversity, which subsequently leads to the creation of suitable habitats for species and increased diversity and richness. This altitudinal diversity gradient has also been reported for Chinese parasitic plants (Zhang et al., 2018).

Life forms

In Iran, more than two thirds of the species are holoparasites, while in Turkey (Sürmen et al., 2015) and China (Zhang et al., 2018), hemiparasites are the major parasitic plant species. Therefore, due to the complete dependence of holoparasites on the host plant and their inability to provide food and water, Iranian parasitic species will be highly endangered if the host is widespread or abundant. More than half of Iran's parasitic plants are perennial herbaceous (hemicryptophytes) holoparasites. Hemicryptophytes are one of the predominant life forms in highland ecosystems, and they have found different ways to adapt to the cold and mountainous climate (Klimeš, 2003). As mentioned before, the highest number of parasitic species in Iran occurs in the mountains and at altitudes between 2000–2500 meters. It seems that they have been able to ensure their survival in the mountains with underground vegetative buds, reducing their need for water, no need for leaves for photosynthesis, and reduced vegetative growth. Similar results were obtained in a recent study in China, where perennial herbaceous parasites were the predominant life form and often recorded from mountainous regions (Zhang et al., 2018). About 79 % of Iran's parasitic plant species comprise root parasites. In China, Nepal, and even globally, root parasites are the predominant group of parasitic plants. The predominance of root parasites may result from the stability of the ecological factors of the underground soil (e. g., moisture, temperature, etc.) and the greater accessibility to nutrients, which lead to less vulnerability to herbivores and stronger competitors (Press, Phoenix, 2005; Dueholm et al., 2017). Eventually, the natural dispersal of root parasites gives them a greater fitness than that of stem parasites which move with animals (Zhang et al., 2018).

Conclusion

Determining the current distribution patterns of parasitic plant species have a significant impact on the management of their potential negative effects. A wide range of parasitic plants can have negative effects on total plant diversity, so their management should be based on ecological principles that consider the stability and balance of the ecosystem. The study's findings indicate that although these plant species make up a small percentage of Iran's flora, their diversity and richness hotspots overlap with the richness hotspots of all plant species in Iran. Therefore, this can pose a significant threat to plant diversity in the country. As a result, the research can be used to manage and protect other flowering plant species in Iran.

REFERENCES / ЛИТЕРАТУРА

Alai Taleghani M. 2005. *Geomorphology of Iran.*Tehran: Qoms Publishing. 404 pp. [In Persian].

Amiri M., Eslamian S. 2010. Investigation of climate change in Iran. *J. Environ. Sci. Technol.* 3(4): 208–216.

Bellot S., Renner S. S. 2013. Pollination and mating systems of Apodanthaceae and the distribution of reproductive traits in parasitic angiosperms. *Am. J. Bot.* 100(6): 1083–1094.

Berberian M., King G. 1981. Towards a paleogeography and tectonic evolution of Iran. *Can. J. Earth Sci.* 18(2): 210–265.

Breckle S.-W. 2002. *Walter's vegetation of the earth: the ecological systems of the geo-biosphere*. Berlin – Heidelberg – New York: Springer–Verlag. 527 pp.

Dewan M. L., Famouri J. 1964. *The soils of Iran*. Rome: Food and Agriculture Organization of the United Nations. 319 pp.

Djamali M., Akhani H., Khoshravesh R., Andrieu-Ponel V., Ponel P., Brewer S. 2011. Application of the Global Bioclimatic Classification to Iran: implications for understanding the modern vegetation and biogeography. *Ecol. Mediterr.* 37: 91–114. https://doi.org/10.3406/ecmed.2011.1350

Dueholm B., Bruce D., Weinstein P., Semple S., Lindberg Møller B., Weiner J. 2017. Spatial analysis of root hemiparasitic shrubs and their hosts: a search for spatial signatures of above-and below-ground interactions. *Plant Ecology* 218(2): 185–196. https://doi.org/10.1007/s11258-016-0676-8

Eo S. H., Wares J. P., Carroll J. P. 2008. Population divergence in plant species reflects latitudinal biodiversity gradients. *Biol. Lett*. 4: 382–384. https://doi.org/10.1098/rsbl.2008.0109

Frey W., Probst W. 1974. Vegetation und Klima des Zentralelburs und der südkaspischen Küstenebene (Nordiran). Beiträge zur Physischen Geographie Irans. *Marburger Geog. Schrift* 62: 93–116.

Hedge I. C., Wendelbo P. 1978. Patterns of distribution and endemism in Iran. *Notes Roy. Bot. Gard. Edinb.* 36: 441–464.

Joshi J., Matthies D., Schmid B. 2000. Root hemiparasites and plant diversity in experimental grassland communities. *J. Ecol.* 88(4): 634–644. https://doi.org/10.1046/j.1365-2745.2000.00487.x

Kaiser B., Vogg G., Fürst U. B., Albert M. 2015. Parasitic plants of the genus *Cuscuta* and their interaction with susceptible and resistant host plants. *Front. Plant Sci*. 6: 45. https://doi.org/10.3389/fpls.2015.00045

Khajoei Nasab F., Khosravi A. R. 2020. Identification of the areas of endemism (AOEs) of the genus *Acantholimon* (Plumbaginaceae) in Iran. *Plant Biosyst.* 154: 726–736. https://doi.org/10.1080/11263504.2019.1686078

Khajoei Nasab F., Mehrabian A. R. 2022. Diversity centers as well as conservation priorities of the genus *Onosma* L. (Boraginaceae) in Iran. *Turczaninowia* 25: 137–150. https://doi.org/10.14258/turczaninowia.25.2.13

Khajoei Nasab F., Mehrabian A. R., Chakerhosseini M., Biglary N. 2024b. Climate change causes the displacement and shrinking of the optimal habitats of nectar-producing species of *Nepeta* in Iran. *Theor. Appl. Climatol.* 155: 249–260. https://doi.org/10.1007/s00704-023-04629-4

Khajoei Nasab F., Shakoori Z., Zeraatkar A. 2024a. Modeling the richness and spatial distribution of the wild relatives of Iranian pears (*Pyrus* L.) for conservation management. *Sci. Rep.* 14: 18196. https://doi.org/10.1038/s41598-024-69135-7

Khajoei Nasab F., Zeraatkar A. 2024. Modeling the potential effects of climate change on the distribution of *Tetrataenium lasiopetalum* (Apiaceae) in Chaharmahal and Bakhtiari province, Iran. *Iran. J. Bot.* 30(2): 220–233. https://doi.org/10.22092/ijb.2024.367084.1492

Klein J.-C. 1972. Le Genisteto-Carlinetum macrocephalae ass. nov. de l'étage montagnard et le Ligusticetum corsici ass. nov. de l'étage subalpin des massifs du Cinto et du Campotile orientale. *Vegetatio* 25(1–4): 311–333.

Klimeš L. 2003. Life forms and clonality of vascular plants along an altitudinal gradient in E Ladakh (NW Himalayas). *Basic. Appl. Ecol*. 4: 317–328. https://doi.org/10.1078/1439-1791-00163

Kuijt J. 1969. *The biology of parasitic flowering plants*. Berkeley: University of California Press. 246 pp.

Maassoumi A. A., Khajoei Nasab F. 2023. Centers of richness and endemism of the megagenus *Astragalus* (Fabaceae) in Iran. *Collect. Bot*. 42: e001. https://doi.org/10.3989/collectbot.2023.v42.001

Mehrabian A. R. 2015. Distribution patterns and diversity of *Onosma* in Iran: with emphasis on endemism conservation and distribution pattern in SW Asia. *Rostaniha* 16(1): 36–60.

Mehrabian A., Khajoei Nasab F. 2021. Distribution patterns, diversity centers, and priorities for conservation of aquatic plants in Iran. In: L. A. Jawad (ed.). *Southern Iraq's Marshes*. Coastal Research Library. Vol. 36. Cham: Springer. Pp. 233–249. https://doi.org/10.1007/978-3-030-66238-7-13

Mutikainen P., Salonen V., Puustinen S., Koskela T. 2000. Local adaptation, resistance, and virulence in a hemiparasitic plant-host plant interaction. *Evolution* 54(2): 433–440. https://doi.org/10.1111/j.0014-3820.2000.tb00046.x

Nickrent D. L. 2020. Parasitic angiosperms: how often and how many? *Taxon* 69(1): 5–27. https://doi.org/10.1002/tax.12195

Nickrent D., Musselman L. 2004. Introduction to parasitic flowering plants. *Plant Health. Instruct.* 13. https://doi.org/10.1094/PHI-I-2004-0330-01

O'Neill A. R., Rana S. K. 2016. An ethnobotanical analysis of parasitic plants (Parijibi) in the Nepal Himalaya. *J. Ethnobiol. Ethnomed*. 12(1): 14. https://doi.org/10.1186/s13002-016-0086-y

Poulin R. 2011. The many roads to parasitism: a tale of convergence. *J. Adv. Parasitol.* 74: 1–40. https://doi.org/10.1016/B978-0-12-385897-9.00001-X

Press M. C., Phoenix G. K. 2005. Effects of climate change on parasitic plants: the root hemiparasitic Orobanchaceae. *Folia Geobot*. 40(2–3): 205–216. https://doi.org/10.1007/BF02803235***Rapoport E. H.*** 1975. *Areografía: Estrategias Geográficas de Las Especies*. Mexico City: Fondo de Cultura Económica. 214 pp.

Raunkiaer C. 1934. *The life forms of plants and statistical plant geography; being the collected papers of C. Raunkiaer*. Oxford: Clarendon Press. 632 pp.

Rivas-Martinez S., Sanchez-Mata D., Costa M. 1999. Syntaxonomical synopsis of the potential natural plant communities of North America, 2: North American boreal and Western temperate forest vegetation. *Itinera Geobot.* 12: 3–311.

Spooner D. M., Hijmans R. J. 2001. Potato systematics and germplasm collecting, 1989–2000. *Am. J. Potato Res*. 78(4): 237 –268. https://doi.org/10.1007/BF02875691

Stewart G. R., Press M. C. 1990. The physiology and biochemistry of parasitic angiosperms. *Annu. Rev. Plant Biol.* 41(1): 127–151.

Stöcklin J. 1974. *Northern Iran: Alborz Mountains (Geological Society of London).* Vol. 4, iss. 1. London: Special Publications. Pp. 213–234.

Sürmen B., Kutbay H. G., Yilmaz H. 2015. Parasitic angiosperm plants of Turkey. *J. Inst. Sci. Technol.* 5: 17–24.

Thiers B. 2019. *Index herbariorum: A global directory of public herbaria and associated staff.* New York Botanical Garden's Virtual Herbarium. URL: http://sweetgum.nybg.org/ih (Accessed 15 May 2023).

Westwood J. H., Yoder J. I., Timko M. P., de Pamphilis C. W. 2010. The evolution of parasitism in plants. *Trends Plant Sci*. 15(4): 227–235. https://doi.org/0.1016/j.tplants.2010.01.004

Willig M. R., Kaufman D. M, Stevens R. D. 2003. Latitudinal gradients of biodiversity: patterns, process, and systhesis. *Annu. Rev. Ecol. Evol. Syst.* 34: 273–309. https://doi.org/10.1146/annurev.ecolsys.34.012103.144032

Xu W., Svenning J.C., Chen G., Chen B., Huang J., Ma K. 2018. Plant geographical range size and climate stability in China: Growth form matters. *Glob. Ecol. Biogeogr*. 27: 506–517. https://doi.org/10.1111/geb.12710

Zeraatkar A., Khajoei Nasab F. 2024. Mapping the habitat suitability of endemic and sub-endemic almond species in Iran under current and future climate conditions. *Environ. Dev. Sustain.* 26: 14859–14876. https://doi.org/10.1007/s10668-023-03223-y

Zhang G., Li Q., Sun S. 2018. Diversity and distribution of parasitic angiosperms in China. *Ecol. Evol.* 8(9): 4378–4386. https://doi.org/10.1002/ece3.3992

Zhang M., Chen Y., Ouyang Y., Huang Z., Teixeira da Silva J. A., Ma G. 2015. The biology and haustorial anatomy of semi-parasitic *Monochasma savatieri* Franch. ex Maxim. *Plant Growth. Regul.* 75(2): 473–481. https://doi.org/10.1007/s10725-014-0010-1

Zohary M. 1973. *Geobotanical foundations of the Middle East.* Vol. 2. Stuttgart: Gustav Fischer Verlag Press. 738 pp.

Zwanenburg B., Mwakaboko A. S., Kannan C. 2016. Perspective of suicidal germination for parasitic weed control. *Pest. Manag. Sci.* 72(11): 2016–2025. https://doi.org/10.1002/ps.4222