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ORIGINAL ARTICLE

RELICT SPECIES FROM AN AFRICAN ORIGIN IN SOUTHWEST ASIA: INSIGHTS INTO THEIR BIOGEOGRAPHY AND CONSERVATION

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ABSTRACT

The Zagros Mountain range in western Iran is an area of species endemism within the Irano-Anatolian biodiversity hotspot. A couple of relict and morphologically isolated species have been reported for the Zagros Mountains, yet their distribution patterns in relation to the geological and climatic history of the region are not fully understood. *Clinopodium kallaricum* (Jamzad) Bordbar, 2019 (Lamiaceae), *Hypericum dogonbadanicum* Assadi, 1984 (Hypericaceae), and *Iranoaster bachtiaricus* (Mozaff.) Kaz. Osaloo, Farhani & Mozaff. 2018 (Asteraceae) are local endemic species restricted to Zagros with no clear affinities to the Irano-Turanian or other Northern Hemisphere temperate species. Previous studies suggested some afromontane relations for these species, beyond the Saharo-Sindian lowlands. Here, we provide dated phylogenies for these three species, to assess the most probable drivers behind this pattern of distribution. Our results represent that the split between these taxa and their relatives is not contemporaneous, implying different biogeographical histories. *I. bachtiaricus* originated in the Middle Miocene, while *C. kallaricum* and *H. dogonbadanicum* are relatively younger (late Miocene early Pliocene). The divergence of these taxa coincided with the major geological and climatic events of the Miocene, mainly the collision of the Afro-Arabia and Eurasia plates in 18-16 Mya and the aridification of the Sahara (started in 11-7 Mya), followed by a shift in the vegetation of the Sahara from subtropical/steppe to arid desert. The possible relict nature of these species is discussed, and the role of the Saharo-Sindian Region as a vicariant agent is highlighted, which could have subdivided formerly uniform populations and subsequently accelerated the allopatric speciation.

Keywords: *Clinopodium*, Disjunctend distribution, *Hypericum*, *Iranoaster*, Relict species.

INTRODUCTION

The Irano-Turanian phytogeographical region is a vast area covering many highlands in south western Asia (Zohary, 1973). It is characterized by a high degree of continentality and a low amount of precipitation during the growing season (Djamali *et al.*, 2011). This region harbors many species-rich plant lineages, such as *Astragalus* L., *Cousinia* Cass., *Acantholimon* Boiss., *Eremurus* M.Bieb., *Silene* L., and *Nepeta* L. Recent phylogeographical studies have confirmed that the Irano-Turanian Region was the center of origin and diversification of many plant lineages, which then radiated to other neighboring areas, including the Mediterranean region (some examples are: Font *et al.*, 2009; Manafzadeh *et al.*, 2014; Malik *et al.*, 2017; Panahi, 2019; Žerdoner Calasan *et al.*, 2021; Doostmohammadi *et al.*, 2022).

The Zagros Mountain range, which extends from the northeast of Iraq to the south of Iran, is situated in the central part of the Irano-Turanian Region. It is covered by the so-called "Kurdo-Zagrosian steppe-forest" composed of *Quercus brantii* Lindl. Woodlands mostly in the northern and western regions, *Artemisia* steppes in drier regions, and alpine vegetation in several high peaks (Zohary, 1973; Noroozi *et al.*, 2020). The Zagros mountain is regarded as a separate unit (either in the form of a district, a sub-province, or a province) of the Irano-Turanian region, exhibiting strong and striking distribution patterns (Zohary, 1973; Takhtajan, 1986; Akhani, 2004, 2007) and is identified as an "area of endemism" having a high number of endemic species along with several endemic genera [such as *Azilia* Hedge & Lamond (Apiaceae), *Ergocarpon* C. C. Towns (Apiaceae), *Haussknechtia* Boiss. (Apiaceae), and *Zeugandra* P.H.Davis (Campanulaceae) (Noroozi *et al.*, 2018, 2019)]. A high proportion of the Zagros plant species belong to the Irano-Turanian Region (Noroozi *et al*., 2020), while there are surprisingly some isolated and morphologically distinct species such as *Hypericum dogonbadanicum* Assadi (Hypericaceae), *Clinopodium kallaricum* (Jamzad) Bordbar (Lamiaceae), and *Iranoaster bachtiaricus* (Mozaff.) Kaz. Osaloo, Farhani & Mozaff. (Asteraceae), which are of high phytogeographical interest. These species have striking morphological differences with other Irano-Turanian species, and previous studies have proposed some African relations for them (Robson, 1987; Farhani *et al.*, 2018; Bordbar and Mirtadzadini, 2019).

Hypericum dogonbadanicum Assadi, 1984 (Hypericaceae) is a sub-shrubby chasmophyte species, described about 40 years ago from southwestern Zagros (Assadi, 1984). This species is clearly distinct from any other *Hypericum* species known from Iran, and Assadi (1984) suggested a relationship between *H. dogonbadanicum* and *H. balearicum* L. (sect. *Psorophytom* (Spach) Nyman) from the Balearic Islands in Spain, based on its habit, leaf margins, and stamen structure. Later, Robson (1987), criticized this idea, and based on several diagnostic morphological characters, demonstrated that *H. dogonbadanicum* belongs to sect. *Campylosporus* (Spach) R. Keller, with surprising close affinities to the Socotran endemic *H. socotranum* R. D. Good. *Hypericum* sect. *Campylosporus* is a group of about 10 shrubs and trees distributed in sub-tropical and tropical mountains of SW Arabia and eastern Africa [south of the Saharo-Sindian lowlands (Robson, 1985)], and the only species of this section growing above the Saharo-Sindian Region is *H. dogonbadanicum*.

Clinopodium kallaricum (Jamzad) Bordbar 2019 (Lamiaceae) initially was introduced as a species of the genus *Satureja* L. (*S. kallarica* Jamzad, Jamzad, 1992), but was transferred to

Clinopodium simense group by Bordbar and Mirtadzadini (2019) based on morphological and molecular evidences. Members of *C. simense* group are morphologically very similar and apparently closely related to each other (Ryding, 2006). *Clinopodium kallaricum* is confined to the Zagros Mountains (north of the Saharo-Sindian region); while the other species of this group are distributed in the tropical high mountains of eastern Africa, south of the Saharo-Sindian regional zone. They are morphologically similar in a more or less creeping habit, with the sub-sessile glands only on the lower surface of the leaves and the diverging thecae (Bordbar and Mirtadzadini, 2019).

The monotypic genus *Iranoaster* (Mozaff.) Kaz.Osaloo, Farhani & Mozaff., 2018 (Asteraceae), was recently established based on the enigmatic *Aster bachtiaricus* Mozaff., 1996 from western/central Zagros (Farhani *et al.*, 2018). Farhani *et al*. (2018) argued that *A. bachtiaricus* is different from other Northern Hemisphere *Aster* species in "having thick woody rootstock, many heteromorphic leaves, solitary capitulum, 4-seriate phyllaries, reflexed ligulate flowers, and 1-seriate pappus" and their molecular phylogenetic analyses demonstrated that *A. bachtiaricus* is not closely related to the bulk of *Aster* and is placed between the basal lineages of the Southern Hemisphere and other Northern Hemisphere taxa of the tribe Astereae. Therefore, they treated this species as a separate, monospecific genus restricted to the Zagros Mountains.

The co-occurrence of these isolated taxa in the Zagros Mountains brings up the question of whether they share a common evolutionary history. This research aimed to answer this question based on a dating analysis with addressing their phytogeographical aspects. Biogeographical analysis was also carried out for *Clinopodium kallaricum* (Jamzad) Bordbar, 2019 (Lamiaceae) as an example, to examine the hypothesis of the center of origin. Besides, the conservation importance of the Zagros Mountain in relation to save these remarkable species is highlighted.

MATERIALS AND METHODS

The geographical location of The Zagros Mountains within the Irano-Turanian Region in SW Asia is shown in Map (1).

Data matrix preparation and node calibration: Three different sequence data sets were prepared for the three studied species and their allied species, which were then aligned and analyzed separately. All sequences were extracted from Genbank (Appendix). For combining different regions, they were concatenated together without partitioning.

Hypericum dogonbadanicum Assadi, 1984 (Map 2)**:** Sequences of ITS and *trn*L-*trn*F regions for 29 species of *Hypericum* and close genera were extracted from GenBank and concatenated. Our taxon sampling scheme covered all available sequences of members of *H.* sect. *Campylosporus* together with representatives from the major lineages of the genus *Hypericum* as recognized in recent molecular phylogenetic studies (Meseguer *et al.*, 2013; Nurk *et al.*, 2013). Two calibration points were used for *Hypericum dogonbadanicum*. A normal prior was assigned to the crown of Hypericaceae (the split between *Eliea* and the rest of the tree) with a mean of 65.2 Mya and a standard deviation of 11 obtained by Ruhfel (2011). To constrain the crown age of *Hypericum*, a lognormal prior was used with an offset of 33.9 Mya and a standard deviation of 0.7 based on Arbuzova (2005) and Meseguer *et al*. (2013).

Iranoaster bachtiaricus (Mozaff.) Kaz.Osaloo, Farhani & Mozaff., 2018: A subset of sampling from previous studies (Brouillet *et al.*, 2009; Farhani *et al.*, 2018), including 23 species were extracted from Genbank for ITS and ETS regions and then combined for alignment. Our sampling strategy for dating analysis from among the huge tribe Astereae was based on covering major clades of the tribe (from both northern and southern Hemisphere lineages), according to previous phylogenetic studies (Brouillet *et al.*, 2009; Farhani *et al.*, 2018). Nodes were calibrated assigning a normal distribution with the mean of 38.68 million years as the secondary calibration and a standard deviation of 2.1 for the split between the tribes Astereae and Anthemideae according to Panero and Crozier (2016).

Clinopodium kallaricum (Jamzad) Bordbar, 2019 (Map 3)**:** A total of 68 species from *Clinopodium* and related genera were sampled from Genbank for dating analysis. DNA sequences of the nuclear region (ITS) and two chloroplast regions (*mat*K and *trn*L-*trn*F) were combined for alignment. *Clinopodium* is a non-monophyletic group (Bräuchler *et al.*, 2010; Bordbar and Mirtadzadini, 2019), and our sampling covered all main sub-clades and lineages of this genus together with other closely related genera. A node prior was calibrated for the most recent common ancestor (MRCA) of *Acinos* Mill. and *Ziziphora* L. (15.398 Mya with a SD of 2.8) (Rose *et al.*, 2022), with a normal distribution.

Sequence alignments and divergence time estimates: Each data set was aligned using MAFFT (Multiple Alignment using Fast Fourier Transform) v.6.0 (Katoh and Toh, 2008) with manual adjustment. The BEAST.XML input files were generated using BEAUTi v 1.10.4 and divergence times were estimated using BEAST v 1.10.4, (Suchard *et al.*, 2018). Rate evolution was modeled in an uncorrelated lognormal relaxed clock framework (Drummond *et al.*, 2006), and priors for the branch rate were assumed to be a Yule process under an HKY substitution model. The BEAST analyses were performed with two independent runs of Markov Chain Monte Carlo each for 10 million generations, sampling every 200 generations. The convergences of the chains and estimated sample sizes (ESSs) were confirmed to be sufficiently high (>200) in Tracer v 1.7.1 (Rambaut *et al.*, 2014). Tree Annotator v 1.10.4 was used to find the maximum clade credibility reporting median node ages after discarding the first 10% of the generations as burn-in.

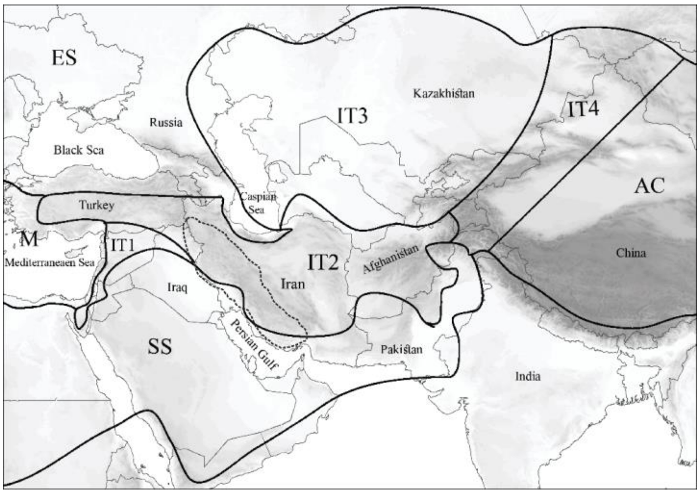
Ancestral area reconstruction: The ancestral area of *Clinopodium kallaricum* was estimated based on the molecular dated tree generated in BEAST. The ancestral area of the tree species was estimated based on three models: the dispersal extinction-cladogenesis (DEC), the likelihood model (DIVA-LIKE) model, and the BAYAREA-LIKE model. For each model, we tested the additional parameter “j” as well (Matzke, 2014). The j parameter represents the relative pre_event weight of the founder event. The best model was selected based on the AIC scores. Considering the patterns of distribution and endemism, we categorized the seven geographical regions. A (East Asia), B (Euro-Siberian Region), C (Mediterranean Region), D

(South-west Asia), E (North Africa), F (Southern America), and G (East and Central Africa). The BioGeoBEARS package in R was used to conduct the analysis (Matzke, 2013).

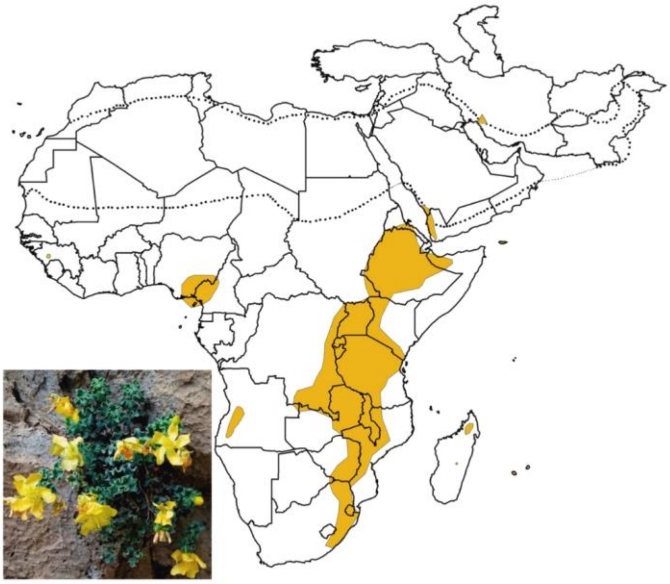
RESULTS

The phylogenetic reconstructions by Beast analysis and based on limited sampling in the present study, are to a large extent, congruent with previous comprehensive phylogenetic studies on *Hypericum* (Meseguer *et al.*, 2013; Nurk *et al.*, 2013), *Clinopodium* (Bräuchler *et al.*, 2010; Bordbar and Mirtadzadini, 2019), and the tribe Astereae (Brouillet *et al.*, 2009; Farhani *et al.*, 2018) and are therefore reliable. Molecular clock calculations indicated different divergence times for the three species. Based on the dating analysis, *Iranoaster bachtiaricus* diverged from its close species in about 17.1 Mya (95% HPD; 11.01–23.51) (Diag. 1). Our Beast analyses confirmed the previous studies, suggesting the intermediate position of *I. bachtiaricus* between Southern Hemisphere lineages and temperate Northern Hemisphere genera (Farhani *et al.*, 2018; Jafari *et al.*, 2015). *Clinopodium kallaricum* assembled in a monophyletic sub-clade together with other members of *C. simense* group, confirming previos studies (Bordbar and Mirtadzadini, 2019) (Diag. 2). The estimated divergence age of *C. kallaricum* is 4.9 Mya (95% HPD; 2.2–8.51). *Hypericum dogonbadanicum* represents a phylogenetic position between the African clade of *H. revolutum* Vahl and some northern Hemisphere (mostly East Asian) species, including *H. ascyron* L., *H. monogynum* L. and *H. elatoides* R.Keller (Diag. 3). It was diverged from the later three species in 8.03 Mya (95% HPD; 4.52–12.25), and the divergence age (stem age) of their clade (composed of *H. dogonbadanicum* and the three mentioned species) is about 10.48 Mya (95% HPD; 6.65–15.25).

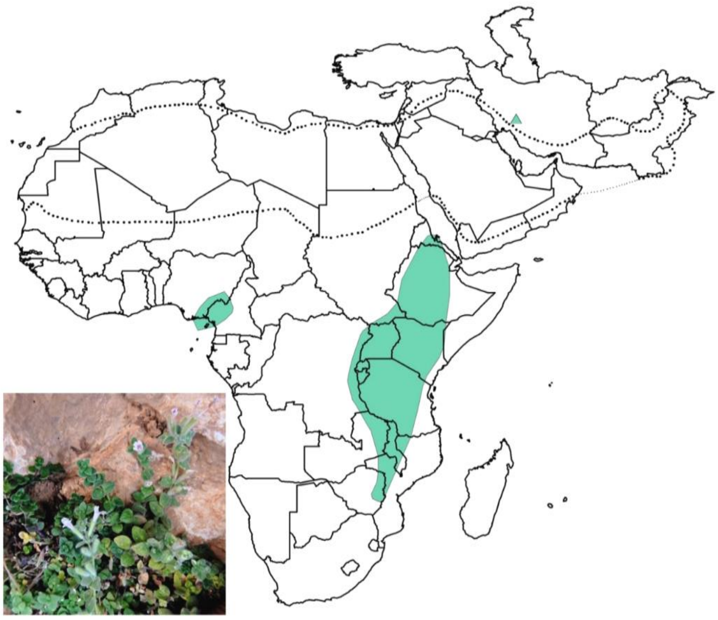
Our result of biogeographical analysis for *Clinopodium kallaricum* and related species showed that DEC (dispersal extinction cladogenesis) is the best model for explaining of *Clinopodium* biogeographical history. Based on the biogeographical result (Diag. 4). *Clinopodium* clade and allied species have had widespread distribution following the vicariance of East Asia and the Afrian clade about 8 Mya. Another vicariance event occurred about 5 Mya between Africa and Southwest Asian (*Clinopodium kallaricum*) species.



Map (1): Phytogeographical subdivisions of SW Asia, according to Leonard (1988-1989) IT: Irano-Turanian Region with its sub-regions designated by numbers 1 to 4, ES: Euro-Siberian, M: Mediterranean, SS: Saharo-Sindian, AC: Central Asiatic. The dashed line outlines the Zagros Mountain range in the west of Iran.



Map (2): General distribution of *Hypericum* sect. *Campylosporus* (based on Robson, 1985 and Assadi, 1984). Triangle and inset photo indicate *H. dogonbadanicum*. [Dashed line represents the Saharo-Sindian regional zone].



Map (3): General distribution of *Clinopodium simense* species group (based on Ryding (2006) and Bordbar and Mirtadzadini (2019). Triangle and inset photo indicate *C. kallaricum*. Dashed line represents the Saharo-Sindian regional zone.

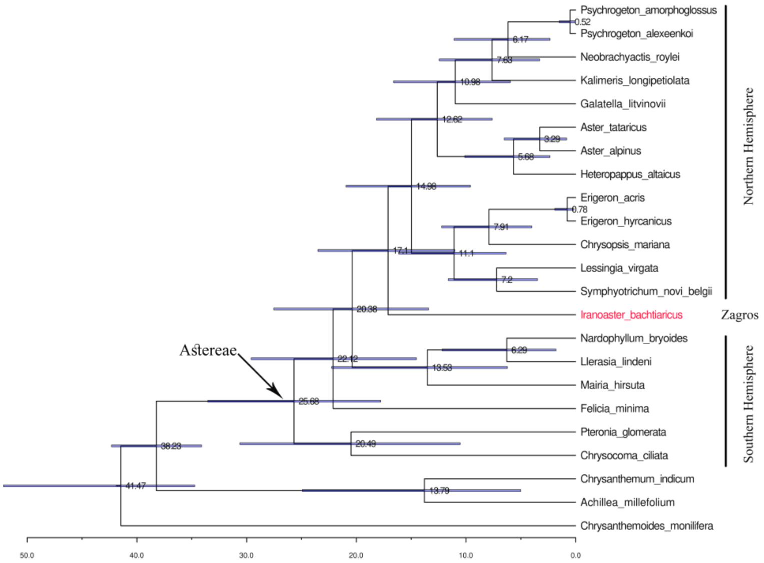


Diagram (1): Dated phylogenetic tree of tribe Astereae retrieved from BEAST. Estimated divergence age values are represented for each node.

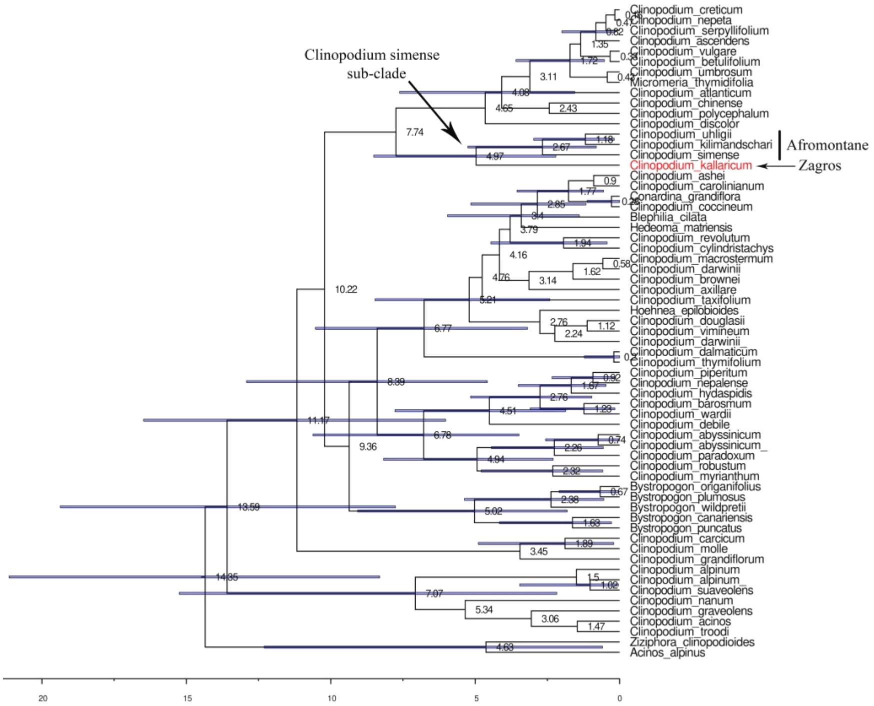


Diagram (2): Chronogram of *Clinopodium* and related genera inferred from BEAST. Dating values are represented above nodes.

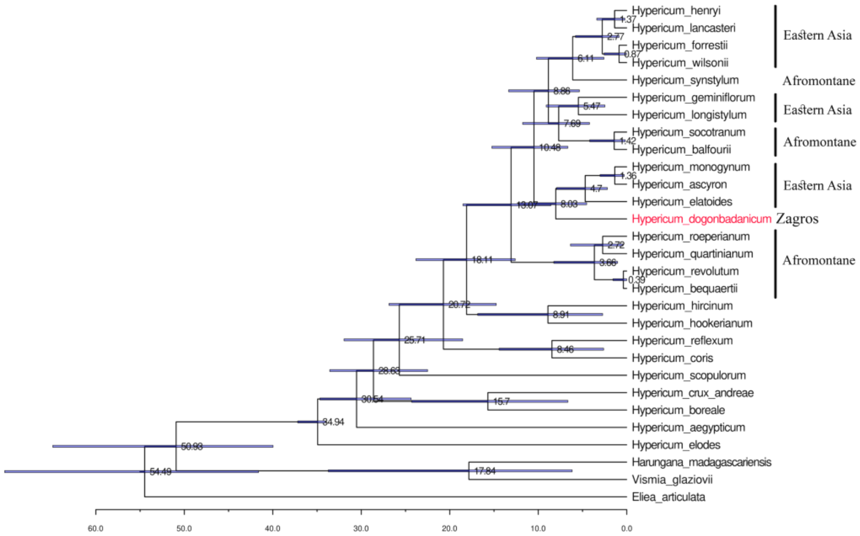


Diagram (3): Dated phylogenetic tree of *Hypericum* inferred from BEAST analysis. Divergence ages are represented for each node.

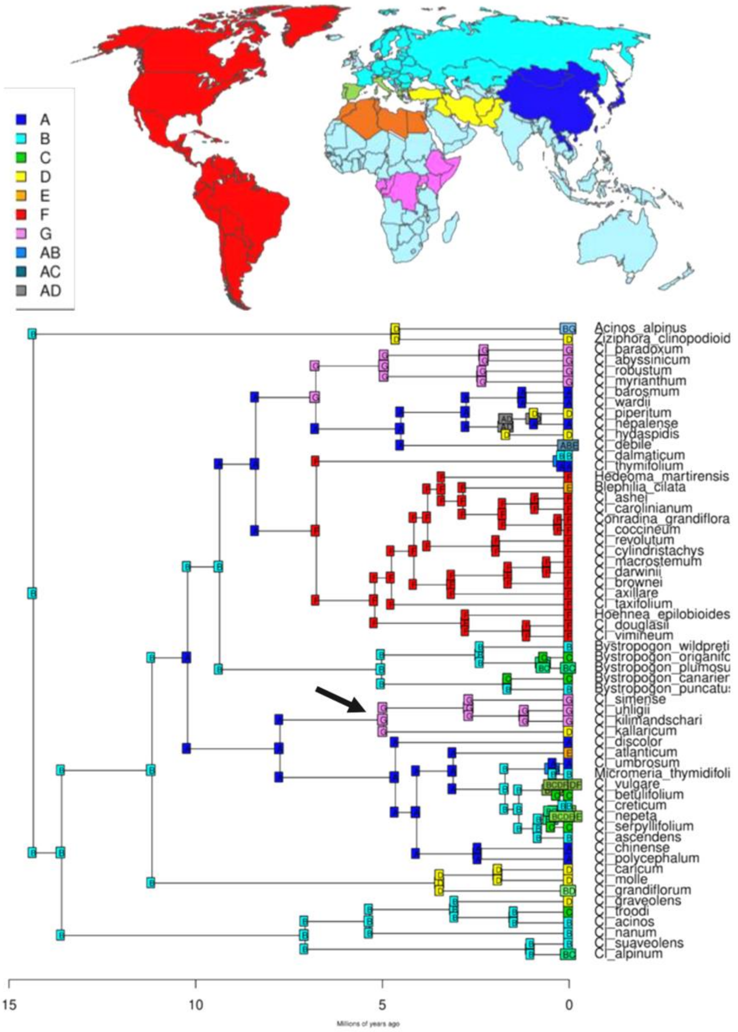
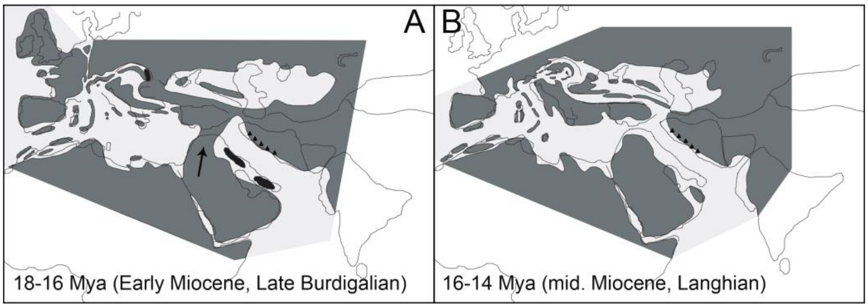


Diagram (4): Ancestral area estimation of the *Clinopodium kallaricum* and allied species based on the DEC model. Single capital letters indicate the different biogeographic units used in this study. Mixed letters represent combinations of units. The units next to species names represent the current geographic range of each species. The black arrow shows the split node of *Clinopodium kallaricum* from the African *Clinopodium* species.

DISCUSSION

Phylogeography: Our dating results represent that the divergence times of these three taxa are not contemporaneous, suggesting that their distributions are ruled by at least two geological/climatic events. Tribe Astereae has been proposed to have originated in the southern hemisphere (most probably in South Africa), and then dispersed to other temperate areas of the northern hemisphere (Brouillet *et al.*, 2009; Mandel *et al.*, 2019). As mentioned before, *I. bachtiaricus* represents an intermediate position between the sothern and northern Hemisphere genera (Diag. 1). The divergence time of *I. bachtiaricus* from its relatives in the early Miocene (about 17 Mya) coincides with the age of the Gomphotherium land bridge, which was created following the first collision of the Afro-Arabia and Eurasia plates (Map 4a). This land bridge disappeared in the middle Miocene (16-14 Mya) following the re-opening of the seaway between the Mediterranean and Indian Ocean (Map 4b; Rögl, 1999). It is therefore likely, that the ancestors of *I. bachtiaricus* could have migrated to western Iran through the first connection between Afro-Arabia and Eurasia and were subsequently left isolated in the Zagros Mountains after the re-opening of the sea between the Mediterranean and Indian Ocean. In addition, the major uplift of the Zagros Mountains took place in 15-12 Mya (Mouthereau *et al.*, 2012), which is another factor that could be responsible for the geographical isolation of this species.



Map (4): Tectonic movements in the Miocene. A: first collision of Afro-Arabia to Eurasia plates and formation of the Gomphotherium land bridge, represented by the arrow, B: re-opening of a seaway between the Mediterranean and Indian Oceans. Triangles represent the Zagros Mountains. (Based on Rögl, 1999).

Regarding *Hypericum dogonbadanicum*, our dated phylogenetic tree represents that it is assembled in a sub-clade with three Northern Hemisphere species. This sub-clade diverged from its African ancestor in about 10.4 Mya. Likewise, the split of *Clinopodium kallaricum* from its African relative dates back to about 4.9 Mya. It was inferred from the biogeographical analysis that the ancestor of *Clinopodium kallaricum* extended across eastern Africa to the late Miocene (Diag. 4). The divergence ages of both species in the late Miocene were probably governed by the same eco/geographical forces. It was formerly believed that the Sahara Desert is about 2-3 My old (Kroepelin, 2006). However, new findings suggest that the aridity of northern Africa and the creation of the Sahara Desert were triggered much earlier, in 11-7 Mya in the late Miocene, due to the shrinkage of Tethys Sea (Zhang *et al.*, 2014). At the end of the Messinian salinity crisis (5.33 Mya), the aridity of the Sahara and the Arabian Peninsula intensified (Colin *et al.*, 2008), which had a great impact on the diversification of plant species, acting as a vicariant agent that divided formerly widely distributed populations north and south of this region (Zhang *et al.*, 2014; Chen *et al.*, 2014). Therefore, relict species of *C. kallaricum* and *H. dogonbadanicum* in the west of Iran are most probably the result of allopatric speciation in isolated populations above the Saharo-Sindian region. Another round of uplift of the Zagros Mountains has taken place about 5 Mya (Axen *et al.*, 2001; Mouthereau *et al.*, 2012), which could have intensified the isolation of these species. The role of the Saharo-Sindian region as a geographical barrier has been previously demonstrated in animals as well. It has been shown that the only species of elephant shrews north of the Sahara (*Elephantulus rozeti*) split from other species south of the Sahara due to the aridification and vegetation change in north Africa (Douady *et al.*, 2003). In addition to this species, there is another surprising biological link between Africa and SW Iran in the genus *Pteraulax* (Afrotropical diptera), with all species restricted to southern Africa while *P. oldroydi* resides in the western foothills of the Zagros Mountains (Abbassian-Lintzen, 1966).

On the opposite direction, the migration barrier of the Saharo-Sindian Region, also blocked plant species dispersal from the Irano-Turanian region into Africa. One example is the genus *Pterocephalus* (Caprifoliaceae), with a major distribution in the Mediterranean and Irano-Turanian regions, and one species, *P. frutescens* Hoscht, in the east African high mountains (Mayer and Ehrendorfer, 2000). In addition, expansion of the Saharo-Sindian lowlands pushed cold adapted Irano-Turanian species to higher elevations, which could lead to allopatric speciation in the sky islands of southern Iran (Doostmohammadi *et al.*, 2018). The evidence from this study points towards the idea that the Saharo-Sindian region has had a major role in diversifying of life in mountainous areas around this region, both on its northern and southern sides.

Conservation aspects: As an area of endemism within the Irano-Anatolian biodiversity hotspot, the Zagros mountain range harbors a rich diversity of plant species with a high rate of endemism (Noroozi *et al.*, 2018). This diversity mostly belongs to some super diverse Irano-Turanian genera such as *Astragalus*, *Acantholimon*, *Allium*, *Cousinia*, *Centaurea*, and *Dionysia*, which diversified not only in the Zagros but also throughout the highlands of the Iranian plateau, with a higher endemicity in alpine elevations. The roles of the geological events of Zagros in the diversification of some of these genera are highlighted in recent studies (Bagheri *et al.*, 2017; Moharrek *et al.*, 2019; Doostmohammadi *et al.*, 2022). Along with this recently diversified species (neo-endemics), there are also some relict, paleo-endemic species in the Zagros Mountains. All three studied species are local endemics in western/central Zagros with small population sizes and limited areas of occupancies, which rank them as threatened species. *Clinopodium kallaricum* and *H. dogonbadanicum* are assessed as Critically Endangered (CR), according to criterion B of the IUCN red list categories, representing 8 and 11.703 km2 of AOO’s and 2.589 and 14.382 km2 of EOO’s, respectively. *Iranoaster bachtiaricus* is assessed as data deficient (DD), since it is known only based on the type collection. Moreover, the Zagros Mountain was a refugia for some Euro-Siberian species (e.g. *Pterocarya fraxinifolia* (Poir.) Spach, *Zelkova carpinifolia* (Pall.) K. Koch and *Quercus castaneifolia* Pant (Zohary, 1973; Akhani and Salimian, 2003; Uzun and Khedir Galalaey, 2022), which, together with several endemic genera, highlights the need for a proper conservation strategy throughout this unique mountain range, harboring the largest oak forests in the Middle East.

Table (1): Details of specimens of *Hypericum* and allies included in this study, including GenBank accession numbers.

Taxa	ITS	trnL-trnF
Eliea_articulata	KC709409.1	KC709111.1
Vismia_glaziovii	KC709410.1	KC709112.1
Harungana_madagascariensis	KC709362.1	KC709062.1
Hypericum_elodes	KC709393.1	KC709095.1
Hypericum_aegypticum	KC709391.1	KC709091.1
Hypericum_scopulorum	KC709395.1	KC709097.1
Hypericum_boreale	KC709374.1	KC709074.1
Hypericum_crux-andreae	KC709399.1	KC709101.1
Hypericum_hookerianum	FJ694205.1	KC709148.1
Hypericum_hircinum	KC709365.1	KC709065.1
Hypericum_coris	KC709320.1	KC709011.1
Hypericum_reflexum	KC709382.1	KC709081.1
Hypericum_quartinianum	KC709428.1	KC709129.1
Hypericum_roeperianum	KC709429.1	KC709131.1
Hypericum_revolutum	KC709425.1	KC709046.1
Hypericum_bequaertii	KC709426.1	KC709128.1
Hypericum_dogonbadanicum	HE653454.1	KC709114.1
Hypericum_socotranum	KC709394.1	KC709096.1
Hypericum_balfourii	KC709397.1	KC709099.1
Hypericum_synstylum	KC709304.1	KC708999.1
Hypericum_elatoides	HE653456.1	KC709157.1
Hypericum_ascyron	KC709330.1	KC709021.1
Hypericum_monogynum	MH711394.1	KC709156.1
Hypericum_longistylum	KC709445.1	KC709153.1
Hypericum_geminiflorum	HM162838.1	KC709000.1
Hypericum_henryi	KC709448.1	KC709159.1
Hypericum_forrestii	FJ694202.1	KC709149.1
Hypericum_lancasteri	KC709444.1	KC709161.1
Hypericum_wilsonii	HE653658.1	-

Table (2): Details of specimens of tribe Astereae included in this study, including GenBank accession numbers.

Taxa	ITS	ETS
Nardophyllum_bryoides	DQ479114.1	DQ479137.1
Felicia_minima	FJ457935.1	-
Chrysocoma_ciliata	FJ457941.1	-
Psychrogeton_alexeenkoi	LC027403.1	LC387698.1
Aster_tataricus	FJ539125.1	JN543749.1
Psychrogeton_amorphoglossus	LC027404.1	LC387702.1
Mairia_hirsuta	FJ457929.1	-
Llerasia_lindeni	DQ479110.1	JQ042789.1
Pteronia_glomerata	FJ457942.1	-
Galatella_litvinovii	LC027393.1	LC387684.1

Chrysopsis_mariana	GQ892729.1	-
Erigeron_acris	ON527430.1	LC387676.1
Erigeron_hyrcanicus	LC027390.1	LC387681.1
Neobrachyactis_roylei	LC027400.1	LC387694.1
Heteropappus_altaicus	KJ711876.1	LC387690.1
Aster_alpinus	MH398798.1	LC387659.1
Symphyotrichum_novi-belgii	EU781308.1	JN315950.1
Lessingia_virgata	AF251624.1	AF251682.1
Kalimeris_longipetiolata	JN315936.1	JN315960.1
Iranoaster_bachtiaricus	LC027374.1	LC387661.1
Chrysanthemum_indicum	EF577298.1	JN315964.1
Achillea_millefolium	KR150185.1	-
Chrysanthemoides_monilifera	FJ861492.1	-

Table (3): Details of specimens of *Clinopodium* and allies included in this study, including GenBank accession numbers.

Taxa	ITS	trnl-trnf	matK
Acinos alpinus	AY227141	AY506594	
Blephila cilata	MK585131	GU381580	GU381743
Bystropogon canariensis	AY506634	-	GU381726
Bystropogon origanifolius	GU381409	GU381565	GU381727
Bystropogon plumosus	AY704586	-	-
Bystropogon wildpretii	AY704584	-	-
Bystropogon_puncatus	AY704582	--	-
Clinopodium aascendens	-	-	AY840152
Clinopodium abyssinicum	GU381403	GU381548	GU381710
Clinopodium alpinum	-	AY840180	AY840145
Clinopodium ashei	DQ667237	-	-
Clinopodium atlanticum	-	GU381531	GU381697
Clinopodium axillare	DQ017565	-	-
Clinopodium barosmum	GU381393	-	GU381683
Clinopodium betulifolium	-	GU381532	GU381698
Clinopodium brownei	GU381426	GU381593	GU381593
Clinopodium caricum	-	KX38187	-
Clinopodium caroliaunum	-	-	GU381748
Clinopodium chinense	-	-	KX526668
Clinopodium coccineum	F369164	GU381585	AY840150
Clinopodium creticum	-	GU381533.	AY840175
Clinopodium cylindristachys	DQ0171562	-	-
Clinopodium dalmaticum	JQ669340	-	-
Clinopodium darwini	-	GU381601	-
Clinopodium debile	-	GU381530	GU381696.
Clinopodium discolor	-	GU381539.	-
Clinopodium douglasii	JQ669081	JQ669026	-
Clinopodium grandiflorum	GU012002	-	KX526666
Clinopodium graveolens	-	-	GU381667
Clinopodium hydaspidis	GU381391	GU381515	GU381681

Clinopodium kallaricum	GU381539.	MK680006	-
Clinopodium klimandschari	-	GU381558	GU381721
Clinopodium macrostemum	JQ669083	385720694	-
Clinopodium molle	-	KX381819	-
Clinopodium myrianthum	GU381405	-	-
Clinopodium nanum	GU381385	-	GU381666
Clinopodium nepalense	-	-	GU381680
Clinopodium nepeta	-	GU381534	AY840151
Clinopodium paradoxum	GU381402	GU381543	GU381706
Clinopodium piperitum	GU381388	GU381511	GU381677
Clinopodium polycephalum	-	-	GU381701
Clinopodium revolutum	GU381436	GU381609	AY840170
Clinopodium robustum	GU381404	GU381553	GU381716
Clinopodium simense	GU381407	GU381559	GU381722
Clinopodium suavelens	-	-	GU381665.
Clinopodium taxifolium	JQ669084	385720695	-
Clinopodium thymifolium	JQ669121	62002162	AY840162
Clinopodium troodi	-	-	GU381671
Clinopodium umbrosum	-	GU381537	GU381700
Clinopodium vimineum	-	-	GU381760
Clinopodium vulgare	JQ669085		MG225194
Clinopodium wardii	GU381392	GU381516	-
Clinopodiumum uhligi	GU381406	GU381561	GU381724
Conradina grandiflora	-	AY943442	AY943512
Hedeoma martirensis	GU381428	GU381596	
Hoehnea epilobioides	-	-	GU381731
Ziziphora clinopodioides	GU381386	GU381508	GU381756

CONCLUSIONS

The Saharo-Sindian region, as a major geographical feature of North Africa and the Arabia, and its ecological changes during that time, have had a considerable impact on plant diversification in the surrounding mountainous areas, both on its northern and southern sides. As shown here, the Saharo-Sindian region acted as a vicariant agent, which resulted in the allopatric speciation of several isolated species in the Zagros Mountains in the west of Iran. These relict and locally endemic species require urgent conservation action.

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CONFLICT OF INTEREST STATMENT

"The authors have no conflicts of interest to declare".

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الأنواع الاثرية من أصل أفريقي في جنوب غرب آسيا: رؤى حول جغرافيتها الاحيائية والحفاظ عليها

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الخلاصة

تعد سلسلة جبال زاغروس في غرب إيران منطقة توطن الأنواع ضمن نقطة التنوع البيولوجي الإيرانية-الأناضولية. تم الإبلاغ عن اثنين من الأنواع الأثرية والمعزولة مظهريا في جبال زاكروس، إلا أن أنماط توزيعها فيما يتعلق بالتاريخ الجيولوجي والمناخي للمنطقة ليست مفهومة بالكامل. و الانواع التالية:

Clinopodium kallaricum (Jamzad) Bordbar, 2019 (Lamiaceae)

Hypericum dogonbadanicum Assadi, 1984 (Hypericaceae)

Iranoaster bachtiaricus (Mozaff.) Kaz. Osaloo, Farhani & Mozaff, 2018 (Asteraceae)

هي انواع مستوطنة محليًا مقتصرة على وسط غرب زاكروس ولا تظهر ارتباطات واضحة مع الأنواع الإيرانية-الطورانية أو الأنواع المعتدلة في نصف الكرة الشمالي. وقد أشارت الدراسات المظهرية والجزيئية السابقة إلى وجود بعض العلاقات الأفريقية الجبلية لهذه الأنواع، بعيدًا عن الأراضي المنخفضة الصحراوية السندية. في هذه الدراسة، تم تقديم سلالات مؤرخة لهذه الأنواع الثلاثة، لتقييم الدوافع الأكثر احتمالا وراء هذا النمط من التوزيع. وتمثل النتائج التي توصلت إليها هذه الدراسة الى أن الانقسام بين هذه الاصنوفات و قريباتها ليس معاصرا، مما يشير إلى ان التاريخ الاحيائي و الجغرافي مختلف

لكل منها. اذ نشأ *Iranoaster bachtiaricus* في العصر الميوسيني الأوسط، في حين أن *C. kallaricum* و *H. dogonbadanicum* أصغر نسبيًا (أواخر العصر الميوسيني و أوائل العصر البليوسيني). و قد تزامنت انقسامات هذه الأجناس مع الأحداث الجيولوجية والمناخية الرئيسية في الميوسين، مثل تصادم صفيحتي أفرو-عربية مع أوراسيا قبل 18-16 مليون سنة و قحل الصحراء الكبرى بسبب انكماش بحر تيثس (بدأ قبل 7-11 مليون سنة) تلاه تحول في الغطاء النباتي للصحراء الكبرى من شبه الاستوائي/السهبي إلى الصحراء الجافة. تمت مناقشة الطبيعة الأثرية المحتملة لهذه الأنواع، وتم تسليط الضوء على دور منطقة الصحراء السندية كعامل بديل، والذي كان من الممكن أن يقسم مجموعات سكانية موحدة سابقًا وبالتالي تسريع عملية الانتواع المتباين.