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A NEW SPECIES OF NEPETA L. (LAMIACEAE) FROM IRAN

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Abstract
Nepeta farsica of sect. *Psilonepeta* Benth., a new species from Fars province in southwest Iran, is described and illustrated. The new species is closely related to *N. oxyodonta* Boiss., *N. bazoftica* Jamzad, and *N. laxiflora* Benth., but can be distinguished from them by morphological and molecular characteristics. Morphologically, *N. farsica* differs from the close relatives in the inflorescence of many-flowered cymes, condensed at the end of branches, with a few lower verticillasters (vs. lax cymes, few-flowered verticillasters along the branches in *N. oxyodonta*, *N. laxiflora,* and *N. bazoftica*), tomentose indumentum with a few long multicellular hairs (vs. short, dense canescent-velutinous in *N. oxyodonta*, glabrous to minutely papillose-glandulous in *N. laxiflora*, and minutely glandular papillose hairs and long articulated scattered hairs in *N. bazoftica*), calyx 11-14mm (vs. calyx 8-10 mm in *N. oxyodonta*, 7-10 mm in *N. laxiflora*; and 8.5-9 mm long in *N. bazoftica*). The new species also differs from its close relatives in the size of its floral leaves and corolla. In addition, molecular phylogenetic analysis results confirm their differences and show they are closely related compared to other species in the section *Psilonepeta*. Here we describe the new species and discuss the morphological and molecular differences between it and the closely related species. Illustrations and a distribution map of the new species and its close relatives will be presented.

Keywords: Lamiaceae; molecular phylogeny; *Nepeta*; new species; sect. *Psilonepeta*

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گونه جدیدی از جنس .NEPETA L از تیره نعنائیان (LAMIACEAE) از ایران

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چکیده: گونه *Nepeta farsica* از بخش *Psilonepeta* Benth.، گونه‌ای جدید از استان فارس درجنوب غرب ایران شرح داده شده و مصور می‌گردد. گونه جدید با گونه‌های *N. oxyodonta* و *N. laxiflora* و *N. bazoftica* خویشاوند است ولیکن از آنها با صفات مورفولوژیکی و ملکولی متفاوت است. از نظر صفات گل‌آذین با داشتن گرزن‌های پرگل که به‌صورت مجتمع در انتهای شاخه‌های گل‌دهنده متراکم‌شده، همراه با تعدادی چرخه‌های پایینی، از گونه‌های مذکور که دارای گرزن‌های کم‌گل هستند و در طول شاخه‌های گل‌دهنده قرار دارند، قابل تشخیص است. همچنین با داشتن کرک‌های کوتاه نمدی و تعدادی کرک بلند چندسلولی پراکنده روی ساقه در مقابل ساقه با کرک‌های کوتاه نقره‌ای–مخملی در گونه *N. oxyodonta* و بدون کرک یا با کرک‌های ریز زگیل مانند غده‌دار درگونه *N. laxiflora*، کرک‌های ریز زگیلی–غده‌ای و کرک‌های بلند چندسلولی پراکنده در گونه *N. bazoftica* تفاوت دارد. گونه جدید با کاسه گل به طول ۱۱–۱۴ میلی‌متر درمقابل کاسه ۸–۱۰ میلی‌متردر گونه *N. oxyodonta*، ۷–۱۰ میلی‌متر در گونه *N. laxiflora*، ۸/۵–۹ میلی‌متر در گونه *N. Bazoftica* تفاوت دارد. همچنین گونه جدید از نظر برگ‌های گل‌آذینی و اندازه جام گل از گونه‌های نزدیک به خود متفاوت است. به‌علاوه نتایج آنالیزهای ملکولی فیلوژنتیکی تفاوت‌های آنها را با یکدیگر و سایر گونه‌های بخش *Psilonepeta* نشان داد. در این مقاله شرح و تصاویر گونه جدید و نقشه پراکندگی جغرافیایی آن ارایه می‌گردد.

INTRODUCTION

Nepeta is one of the most important genera in Nepetinae (Nepetoideae, Lamiaceae), with the highest number of species in Asia. In Southwest Asia, Iran is the center of speciation for some groups/sections of *Nepeta*. Bentham (1848) provided an infrageneric classification of the genus, dividing it into nine sections, some of which were restricted to Iran. The *Nepeta* section *Psilonepeta* Benth. was described with three species from Iran. The section members are characterized by having a hairy ring inside the calyx tube, a long corolla tube, exserted from the calyx, and the lower corolla lip deflexed. Later, more species were described, increasing the number to 13 (Bunge 1873; Bornmüller 1899; Freitag 1972; Rechinger 1980, 1982; Jamzad 1998, 2009).

In a molecular phylogenetic study (Serpooshan & al. 2018), the genus *Hymenocrater* Fisch. & C.A. Mey. and other genera in Nepetinae, including *Drepanocaryum* Pojarh., *Dracocephalum* L., *Lallemantia* Fisch. & C.A. Mey., *Lophanthus* Adans, *Marmoritis* Benth., and *Nepeta* L. were analyzed. The results revealed a close relationship among the *Nepeta* species of section *Psilonepeta* and the genera *Lophanthus*, *Hymenocrater,* and *Marmoritis*. They proposed that the genera mentioned above be incorporated into *Nepeta* to establish a monophyletic taxon. Based on the results of this study, *Lophanthus turcicus* Dirmenci, Yıldız & Hedge, was recognized as *Nepeta turcica* (Dirmenci, Yildiz & Hedge) Jamzad & Serpooshan, as well as new combinations in the genera *Hymenocrater*, *Lophanthus*, and *Marmorirts* (Serpooshan & al. 2018). Furthermore, a study by Rose & al. (2023) showed similar results, indicating the genera *Hymenocrater, Lophanthus*, and *Marmoritis* were located in a subclade of a clade containing *Nepeta* and *Drepanocaryum*. It should be noted that they analyzed a limited number of *Nepeta* species, and the species in *N.* sect. *Psilonepeta* were not examined in their study. Moazzeni & al. (2025), in a molecular phylogenetic and biogeography study of *Lophanthus*, analyzed the species of the same genera as the above-mentioned studies. The results of their analysis were mostly the same as those of Serpooshan & al. (2018) and Rose & al. (2023), with these genera grouping in one monophyletic clade. They recognized the species of *N.* section *psilonepeta* as *Lophanthus*, following Budantzev (1992). In their phylogenetic trees, the relationships within *Lophanthus* s.l. were largely unresolved, and the genera *Hymenocrater*, *Lophanthus,* and *Marmoritis* were polyphyletic.

Based on current records (Freitag 1972; Rechinger 1982; Dirmenci & al. 2010; Jamzad 2012), the total number of species of section *Psilonepeta* is 13, of which 12 are endemics to Iran, one to Turkey, and one to Afghanistan. With the new species described here, the total now reaches 14, as follows: *Nepta allotria* Rech. f.; *N. adenoclada* Bornm.; *N. archibaldii* Rech. f.; *N. bazoftica* Jamzad; *N. depauperata* Benth.; *N. dschuparensis* Bornm.; *N. farsica* Jamzad, Zeraatkar & Panahi; *Nepeta hedgei* Freitag; *N. iranshahrii* Rech. f.; *N. laxiflora* Benth.; *N. makuensis* Jamzad; *N. oxyodonta* Boiss. *N. sessilifolia* Bunge; and *N. turcica* (Dirmenci, Yildiz & Hedge) Jamzad & Serpooshan.

Comprehensive floristic studies in the west and southwest of Iran were planned to develop targeted in-situ and ex-situ conservation plans, enhancing our understanding of local biodiversity and prioritizing efforts to protect endemic, rare, and vulnerable species (Hamzeh'ee, 2020 [no. 01-09-09-9551-95003]; Zeraatkar & al., 2021). Among the newly collected *Nepeta* specimens in Fars province, some belong to the section *Psilonepeta,* exhibiting notable differences from other known species. Furthermore, a review of the identified *Nepeta* species section *Psilonepeta* in the TARI herbarium resulted in the renaming of some older specimens. The specimens identified as *N. oxyodonta* formed two morphologically distinct groups: one with condensed verticillasters at the ends of branches, and another with lax, few-flowered verticillasters that align with the protologue of *N. oxyodonta*. A detailed examination of the morphological characteristics of these samples and the newly collected specimens revealed their differences from other species in this section. In addition, the primary results of a molecular phylogenetic study on the genus *Nepeta* (Z. Jamzad & M. Panahi, in progress) helped to infer the results and determine the species, leading to the description of a new species. This paper presents a detailed comparison of the morphological and molecular characteristics of the new species and its closest relatives. Additionally, a distribution map and illustrations of the new species are presented.

MATERIALS AND METHODS

Specimens of *Nepeta* were collected in Fars province, as part of a seed collection project for the Natural Resources Seed Bank of Iran during fieldwork in 2019 and deposited in the herbarium of the Research Institute of Forests & Rangelands (TARI). The specimens were studied and identified using Flora of Iran (Jamzad, 2012) and Flora Iranica (Rechinger, 1982). Furthermore, the identified *Nepeta* specimens of *N.* section *Psilonepeta* in the TARI herbarium were reviewed. Diagnostic characters, including leaves, indumentum, inflorescence, calyx, corolla, and nutlet, were used for identification and comparison with the closely related species (Table 1). The voucher specimens are preserved in TARI and D (acronyms according to Thiers 2023). In addition, the total DNA of the new collection and some previous collections in TARI were extracted, from the dried leaf material of the herbarium specimen, sequenced, and analyzed with the other species in another ongoing project, on the genus *Nepeta* (Jamzad & Panahi, in progress), using DNA extraction kit (Sinaclon Co., Iran) based on CTAB protocol following the manufacturer's instructions (Table 2). The PCR amplification was performed using ready-to-use MasterMix Red (2X) buffer following the protocol (The reagent contains an optimized mixture of Taq DNA Polymerase, PCR buffer, $MgCl_2$, and dNTPs). The ITS region of the nuclear ribosomal gene was amplified. Sequencing was performed using Big Dye terminators (Applied Biosystems, Foster City, CA, USA) in the laboratories of Pishgam Biotechnology Inc. in Tehran. Phylogenetic analyses were performed using the Maximum Likelihood (ML) and Bayesian inference (BI) methods using the PhyloSuite v1.2.3 (Xiang & al., 2023). Some previously sequenced species (Jamzad & al., 2003; Serpoushan & al., 2018; Moazzeni & al., 2025) were incorporated into the analysis. The analysis results were used to refine the identification of the new species by distinguishing it from potentially similar species.

Table 1. Comparison of morphological characters between *Nepeta farsica* and its morphological allies.

species	Stem Indumentum	Cauline leaves	Petiole length (mm)	Bracts (mm)	Inflorescence	Calyx/teeth (mm)	Corolla (mm)
N. farsica	Tomentose with scattered long multicellular hairs	Broadly ovate-cordate, 34-39×29-34	14	Lanceolate to subulate, 4-6×0.2-0.5	Many flowered, capitate, with 2-3 lower shortly pedunculated verticillasters	11-14/5-6	Blue, 22-24 long
N. bazoftica	Minutely glandular papillose with long articulated scattered hairs	Broadly ovate, 15-25×20-25	10-15	Linear lanceolate, 3-3.5×0.5	Lax cymes, all pedunculate, 15-20	8.5-9 / 2-2.5	Pale blue,15-16 long
N. laxiflora	Glabrous to minute papillose glands	Ovate, ovate-oblong, 20-30×15-20	15	Subulate, 3-5 mm long	Lax cymes	7-10/1-2	Purple,17-25 long
N. oxyodonta	Short, densely canescent-velutinous	Ovate to broadly ovate, 5-32×4-19	2-12	Subulate, 3-5	Lax cymes, subsessile	8-10/ 3-5	Blue 14-18 long

Table 2. The collection data and the NBCI accession numbers of the studied species incorporated in the analysis.

Taxa	Collecting data	NCBI Accession No.
Nepeta bazoftica Jamzad	Iran, Chaharmahal-e Bakhtiar, Mozaffarian *77892* (TARI)	PV590664
N. farsica Jamzad, Zeraatkar & Panahi	Iran, Fars, Marvdasht, Dorodzan synoptic station, Mt. Zaneh, 1900 m, A. Zeraatkar 86302 (D &TARI)	PV590665
N. laxiflora Boiss.	Iran, Chaharmahal-e Bakhtiar, south slope, Mt. Kallar, 2600-3200 m, Mozaffarian 58154 (TARI)	PV590667
N. oxyodonta Boiss.	Iran, Fars, Eghlid, Dasht Namdan, 2350-2900 m, Mozaffarian 71541 (TARI)	PV590666
N. oxyodonta Boiss.= *N. farsica*	Fars, Bamou National Park, 1800- 1900 m, Jamzad & al. 69391 (TARI)	AJ420996

RESULTS & DISCUSSION

Nepeta farsica Jamzad, Zeraatkar & Panahi **sp. nov.**
Figs. 1-2.

Diagnose

Nepeta farsica is closely related to *N. oxyodonta*, and *N. laxiflora* but differs from them in stem leafy in the whole length, covered by dense tomentose hairs intermixed with a few long scattered multicellular hairs (vs. stem leafy in the lower part, short, dense canescent-velutinous in *N. oxyodonta* and glabrous to minute papillose glandulous in *N. laxiflora*); leaves broad ovate-cordate, 34-39 × 29-34 mm (vs. ovate to broad ovate 5-32 × 4-19 mm in *N. oxyodonta;* ovate to ovate-oblong, 20-30 × 15-20 mm, in *N. laxiflora*); inflorescence many-flowered cymes condensed in verticillasters at the end of branches with a few lower verticillasters (vs. lax few-flowered cymes, along the branches in *N. oxyodonta* and *N. laxiflora*); calyx 11-14 mm with 5-6 mm long lanceolate-subulate acute teeth (vs. 8-10 mm long, teeth 3-5 mm in *N. oxyodonta* and 7-10 mm long, teeth 1-2 mm in *N. laxiflora*); corolla 22-24 mm long (vs. 14-18 mm in *N. oxyodonta* and 17-25 mm in *N. laxiflora*). *Nepeta bazoftica* is another closely related species to *N. farsica*, but differs from it in indumentum with minutely glandular papillose hairs and long articulated scattered hairs (vs. dense tomentose with a few scattered long multicellular hairs in *N. farsica*); floral leaves sessile amplexicaul (vs. oblong-ovate with 2 mm long petioles in *N. farsica*); inflorescence lax cymes with 15-20 mm long peduncles, across the branches (vs. dense verticillasters, almost sessile at the end of branches and a few dense lower verticillasters); calyx 8.5-9 mm long, teeth 2-2.5 mm, lanceolate, acute (vs. calyx 11-14 mm long, teeth 5-6 mm long, lanceolate-subulate, with the long narrow apex in *N. farsica*).

Perennial, stems branched from the base, 50-100 cm high, woody at base, branched, covered by dense short tomentose hairs intermixed with scattered long multicellular hairs, leafy in whole length. Lower cauline leaves 34-39 × 29-34 mm, broad-ovate, cordate, crenate- dentate; petiole 12-17 mm long, pubescent, with sessile glands on the lower surface; upper cauline leaves ovate, 21-28 × 16-21 mm; petiole 0-7 mm long; floral leaves oblong-ovate to lanceolate, serrate, 6-23 × 2-11 mm; petiole 0-2 mm long. Inflorescence short pedunculated cymes, condensed in 17-18 flowered verticillasters, at the end of flowering branches, 2.5-3 cm long, 1.6-1.9 cm wide, with one close 0.3-1.2 cm apart, 9-14 flowered verticillasters and 2-3 further distant verticillasters, 5-14.5 cm apart. Bracts lanceolate to subulate, 4-6 × 0.2-0.5 mm, with long linear tips, covered by short papillose hairs. Calyx 11-14 mm long, tubular, erect, papillose, with 15 purple prominent nerves, with a ring of hairs inside the throat at the base of teeth, teeth lanceolate-subulate, acute, 5-6 mm long. Corolla 22-24 mm long, blue; tube long, narrow, widening gradually towards the throat, resupinate; the middle lobe of the lower lip 3.2 × 3.8 mm, emarginate, crenate, deflexed; the upper corolla lip bilobed; lobes oblong-ovate, obtuse, 2.3 × 1.5 mm. Nutlet 2.6 × 1.2 mm, oblong, verrucose on the surface; attachment scar bilobed; lobes 0.6-0.7 × 0.4-0.5 mm.

Holotype: Iran, Fars province, Marvdasht, Dorodzan area, Dorodzan synoptic station, Mt. Zaneh 1900 m, 13 May 2019, A. Zeraatkar 86302 (TARI, Isotypes D).

Paratypes: Iran, Fars province, Marvdasht, Dorodzan area, between Bizjan-e Sofla and Bizjan-e Olya villages, opposite Dorodzan Synoptic Station, Mt. Zaneh, 1862 m, A. Zeraatkar 7418 (D, TARI); Fars, Bamu National Park, 1800-1900 m, Jamzad & al. 69391 (TARI); Fars, Nourabad, Doshman Ziari, region, Ab Zalou Village, Kuh-e Tasak, 1990-2500 m,

Mozaffarian 45799 (TARI); Fars, Bakhtegan County, north Tashk Lake, north Khajeh Jamali, Khales Pass (Gardaneh-ye Khales), 2100 m, 15 May 2020, *Zeraatkar 7584* (D, TARI).

Other specimens examined: Iran, Fars province. Marvdasht, Dorodzan area, Bizjan-e Sofla village, Mt. Zaneh, 30.1802 N, 52.4558 E, 1800-1850 m, 13 May 2018, *A. Zeraatkar 86062* (TARI, D). Fars province, Nourabad, Abzalo, 2110 m, 23 May 2020, *Zeraatkar* 7585 (D, TARI).

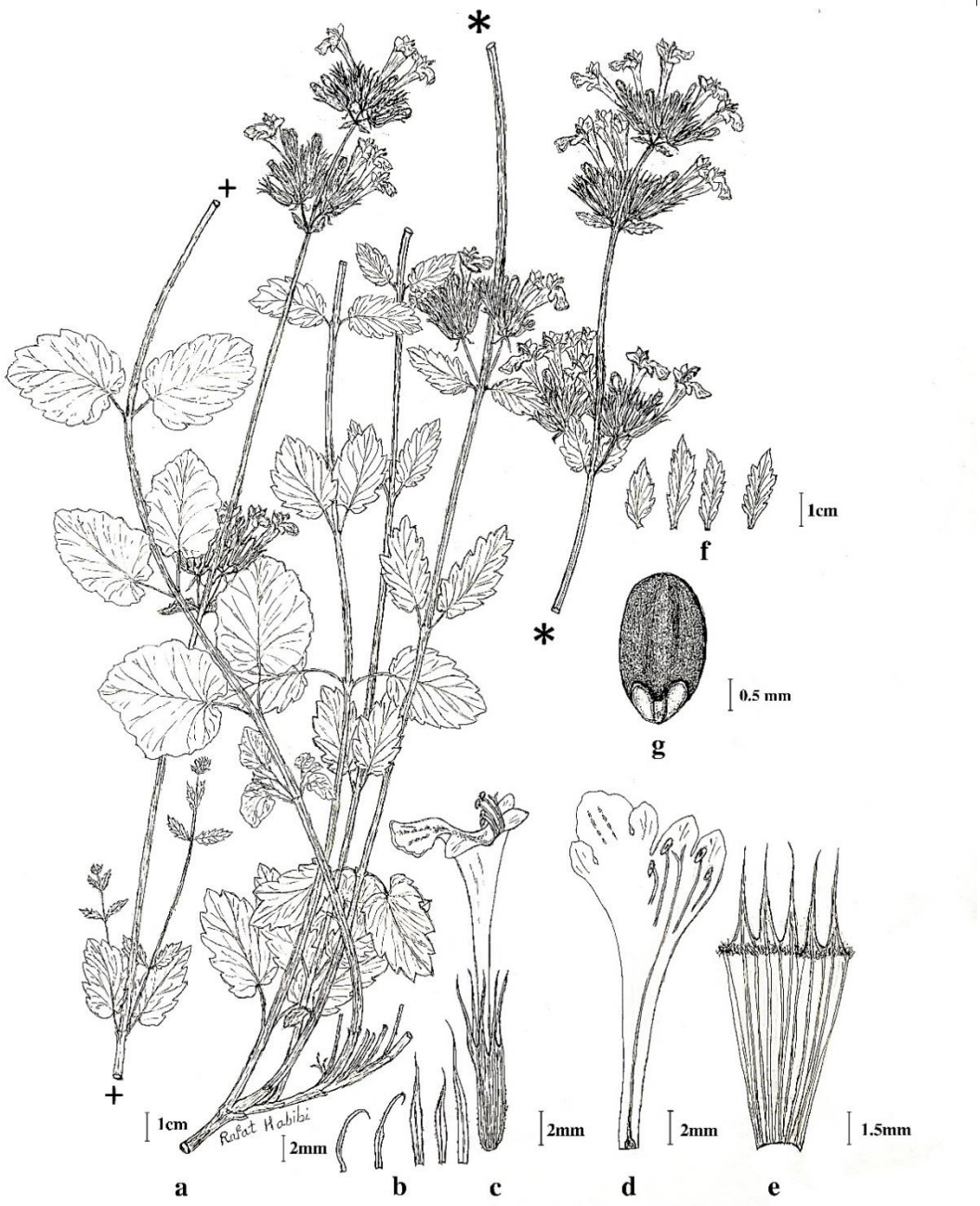

Fig. 1. *Nepeta farsica*. a, habit; b, bracts; c, flower; d, corolla opened; e, calyx opened; f, floral leaves; g, nutlet.

Fig. 2. *Nepeta farsica* in its natural habitat. The plant habit (right) and inflorescence (left). Photo by A. Zeraatkar.

Distribution, habitat, and phenology: *Nepeta farsica* is endemic to Fars Province. In Mount Zaneh, the species grows on mountain slopes in *Prunus scoparia* (Spach) C.K. Schneid associations, on north-facing slopes, at elevations between 1800-1920 m a.s.l. The other companion species are as follows: *Acantholimon asphodelinum* Mobayen, *Acer monspessulanum* L. subsp. *persicum* (Pojark.) Rech.f., *Aethionema elongatum* Boiss., *Ajuga chamaecistus* Ging. ex Benth., *Alcea kurdica* var. *laxiflora* (I. Riedl) Pakravan, *Alkanna frigida* Boiss., *Allium subnotabile* Wendelbo, *Arum rupicola* Boiss. var. *rupicola*, *Astragalus cephalanthus* DC., *Astragalus rhodosemius* Boiss. & Hausskn., *Bryonia multiflora* Boiss. & Heldr., *Cephalorrhynchus microcephalus* (DC.) Schchian., *Cousinia bornmulleri* C. Winkl., *Delphinium saniculifolium* Boiss., *Ephedra pachyclada* Boiss., *Erysimum laxiflorum* J.Gay, *Fibigia macrocarpa* (Boiss.) Boiss., *Fraxinus rotundifolia* Miller subsp. *persica* (Boiss.) Azadi, *Fritillaria imperialis* L., *Gypsophila persica* Barkoudah, *Helichrysum glanduliferum* Sch. Bip., *Hesperis persica* Boiss., *Hypericum hirtellum* (Spach) Boiss., *Nepeta schiraziana* Boiss., *Onosma* sp., *Ornithogalum* sp., *Paracaryum persicum* (Boiss.) Boiss., *Persepolium aridum* (Boiss. & Hausskn.) Yurtseva & Mavrodiev, *Pistacia atlantica* Desf., *Prunus elaeagnifolia* C.K. Schneider, *P. microcarpa* C.A.Mey. Schneid., *Rhamnus pallasii* Fisch. & C.A. Mey., *Silene spergulifolia* (Willd.) M. Bieb., *Solenanthus stamineus* (Desf.) Wettst., *Tanacetum polycephalum* Sch. Bip., *Tulipa systola* Stapf., *Verbascum austroiranicum* Hub.-Mor. We do not have data on the accompanying species for the older collections of *N. farsica*.

Nepeta bazoftica, N. farsica, N. oxyodonta, and *N. laxiflora* are primarily distributed across the western and southwestern regions of Iran, exhibiting a largely overlapping distribution pattern. However, *N. laxiflora* extends further north compared to the others, with its range scattered toward the northern part of the area. The geographical distribution of *N. farsica* and the three close species is shown in Fig. 3.

Flowering and fruiting times: April to June and May to June, respectively.

Notes on molecular analysis

The ML and Bayesian analyses of the nrDNA ITS region of *Nepeta* provided four main clades, one of which contains species of *Nepeta* sect. *Psilonepeta. Nepeta farsica*, *N. oxyodonta*, and *N. bazoftica* form a monophyletic species group in this clade (Fig.4). Other related species in this clade are *N. archibaldii*, *N. laxiflora*, *N. allotria,* and *N. dschuparensis*. *Nepeta farsica* has differentiated from *Nepeta oxyodonta* at two positions (nucleotide substitution as transition) in the ITS2 region at positions 471 and 530 of the sequence length. Additionally, *N. oxyodonta* has four mutated positions (transition sites at 142, 477, 577, and 676 of the sequence length). Two specimens of *N. laxiflora*, have been differentiated from *N. farsica* and *N. oxyodonta* in sites 152, 92, 56, and 51 (as transversions and transitions, respectively). *Nepeta bazoftica*, was differentiated from these species (*N. farsica* and *N. oxyodonta)* through one transversion (in position 153), six transitions (in positions 518, 444, 203, 118, 111, and 56), and one gap of 2 bp in the sequence length. These molecular differentiation and other possible ecological factors resulted in some morphological characteristics and differences in *N. farsica* as discussed in the diagnosis.

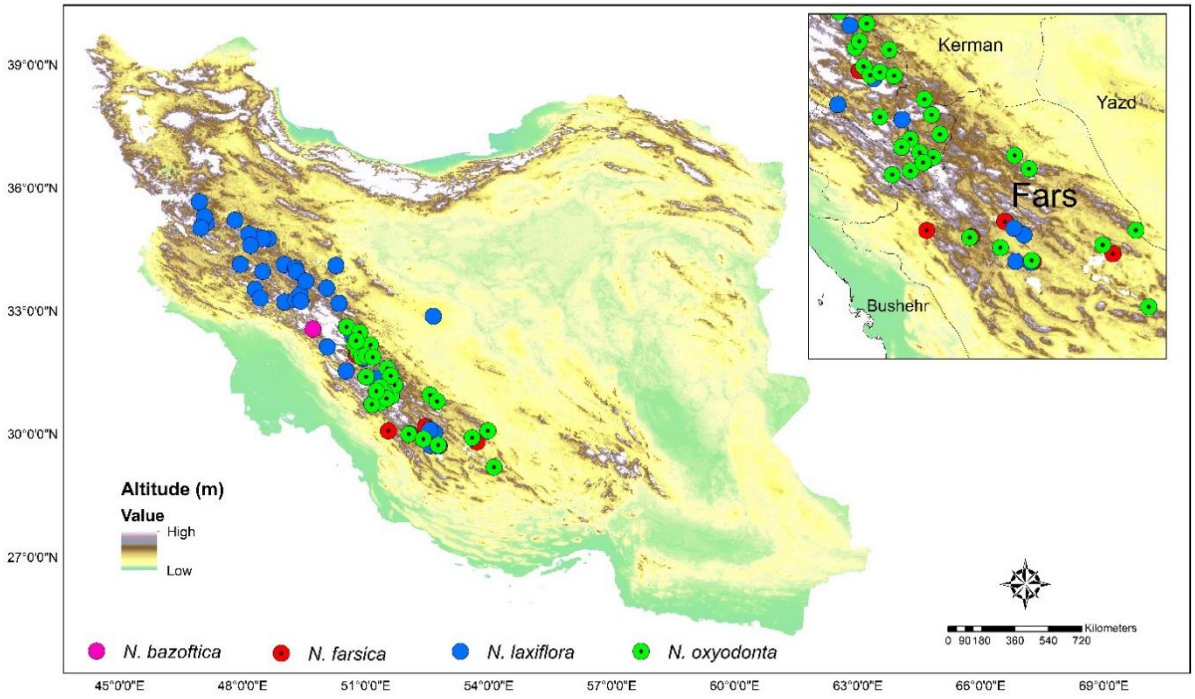

Fig. 3. Geographical distribution of *Nepeta farsica*, *N. laxiflora*, *N. oxyodonta,* and *N. bazoftica* in the west and southwest of Iran.

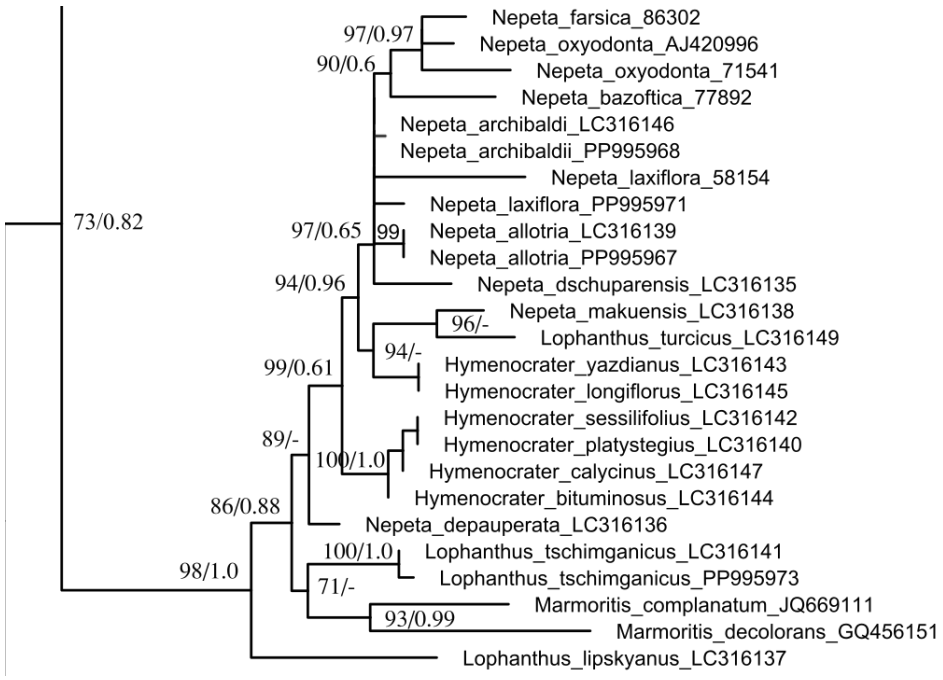

Fig. 4. The clade containing the *Nepeta* species of section *Psilonepeta* from the consensus tree of ML inferred from ITS data for *Nepeta* with Bootstrap support and the posterior probability (of BI analysis) along branches.

Conservation status

Nepeta farsica is restricted to the central Zagros region, in the Fars province of Iran, and was collected in four localities. In Mt. Zaneh, the estimated Area of Occupancy (AOO) is 0.005 km², but we do not have field data on other localities. The Extent of Occurrence (EOO) was estimated at 4933 km², using GeoCat software (Bachman & al., 2011). Except for the population located in Bamu National Park, all other known populations are under severe threat from overgrazing, agricultural expansion, and mining activities encroaching upon their habitat. Based on field observations, the number of locations, and following the IUCN Red List Categories and Criteria (IUCN, 2024), *Nepeta farsica* is assessed as Endangered (EN) under criteria B1a (iii, iv), B2b (ii, iii, iv).

Etymology: The epithet 'farsica" refers to Fars province in southwest Iran, where the type specimen of the new species was collected.

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