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A new microrefugial distribution of *Fagus orientalis* Lipsky. (Oriental Beech) in the Mediterranean Region (Antalya, Türkiye)

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Abstract: *Fagus orientalis* Lipsky (Oriental beech) is a keystone species of temperate forests, distributed from the Balkans and Northern Anatolia to the Caucasus and northern Iran, with refugial populations in the Amanos Mountains and surrounding regions of Eastern Mediterranean Türkiye. Here, we report a newly identified refugial population in the Gidengelmez Mountains (Akseki district, Antalya Province, Türkiye), located under Mediterranean climatic influence and beyond the species' previously documented range. This discovery highlights the ecological and biogeographical significance of southern Anatolia as a reservoir of genetic diversity and contributes to regional conservation priorities. The occurrence of *F. orientalis* in this location provides novel evidence for reassessing Quaternary migration routes, challenging the prevailing view of the Anatolian diagonal as the primary dispersal corridor and suggesting that alternative pathways or localized microrefugia may have shaped the species' historical distribution. Importantly, the persistence of *F. orientalis* under Mediterranean climate underscores the critical role of micro-topographical refugia in sustaining temperate forest species under climate constraints. Given its unique position at the southern edge of the species' range, we recommend that this newly discovered population be prioritized for conservation to safeguard its genetic legacy and ecological function in a warming world.
Keywords: Beech, Biogeography, Distribution, *Fagus*, Flora, Mediterranean, Nature conservation, Refugia

Fagus orientalis Lipsky. (Doğu Kayını)'nın Akdeniz Bölgesindeki (Antalya, Türkiye) yeni bir kalıntı yayılışı

Öz: *Fagus orientalis* Lipsky (Doğu kayını), Balkanlar ve Kuzey Anadolu'dan Kafkasya ve Kuzey İran'a kadar uzanan dağılımı ile ılıman ormanların karakteristik türlerinden biridir. Türün ayrıca Türkiye'nin Doğu Akdeniz Bölgesi'ndeki Amanos Dağları ve çevresinde kalıntı niteliğinde geniş bir yayılışı bulunmaktadır. Bu çalışmada, türün bilinen yayılış alanının ötesinde, Akdeniz ikliminin etkisi altındaki Antalya İli Akseki ilçesinde yer alan Gidengelmez Dağları'ndaki yeni bir mikro-sığınak yayılışı tanıtılmaktadır. Bu yeni yayılış, Güney Anadolu'nun genetik çeşitlilik açısından bir rezerv olarak ekolojik ve biyocoğrafik önemini vurgulamakta ve bölgesel koruma önceliklerine katkı sağlamaktadır. *F. orientalis*'in bu yeni kaydı, Kuvaterner dönemine ait göç yollarının yeniden değerlendirilmesi açısından yeni kanıtlar sağlamaktadır. Anadolu diyagonalinin başlıca yayılış koridoru olduğu yönündeki yaygın görüşü sorgulatmakta ve alternatif güzergâhların ya da yerelleşmiş mikro-sığınakların türün tarihsel yayılışını şekillendirmiş olabileceğini düşündürmektedir. Türün Akdeniz'de bilinen yayılışının çok daha batısında yer alan bu kayıt; ılıman bölge bitkilerinin yayılışında, iklimin kısıtlayıcı koşullarına karşın mikro-topografik sığınakların kritik rolünü ortaya koymaktadır. *F. orientalis*'in bu yeni popülasyonunun benzersiz konumu göz önünde bulundurulduğunda, genetik mirasının ve ekolojik işlevinin korunması amacıyla ivedi bir şekilde koruma altına alınması gerekmektedir.
Anahtar kelimeler: Kayın, Biyocoğrafya, Yayılış, *Fagus*, Flora, Akdeniz, Doğa koruma, Sığınak alanlar

1. Introduction

Global climate changes have profoundly influenced the distribution of forest tree species, reshaping their ranges through both expansion and contraction (e.g. Paffetti et al. 2007; Magri, 2008; Guiot and Kaniewski, 2015). Beech species (*Fagus* L.), which are relatively sensitive to drought, are particularly vulnerable to these shifts, often retreating from lowlands and southern regions while persisting or expanding in upland and northern areas (Sanchez-Gomez and Aranda, 2024; Kurath et al., 2025). Understanding the historical and current refugial distributions of such species is therefore critical for biodiversity conservation and for interpreting migration processes during the Quaternary (Brown et al., 2020).

The genus *Fagus* is a key component of temperate deciduous forests across the Northern Hemisphere (Fang and Lechowicz, 2006), represented in Europe and West Asia by *Fagus sylvatica* L. and *Fagus orientalis* Lipsky (Willner et al., 2017). While *F. sylvatica* dominates much of Europe, *F. orientalis* extends from the Balkans through northern Anatolia to the Caucasus and northern Iran (Bergmeier and

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Dimopoulos, 2001; Tzonev et al., 2006; Kavgacı et al., 2012), with additional refugial populations in the Amanos Mountains and surrounding, Türkiye, in particular, harbors the largest distribution of *F. orientalis*, serving as a major refugium during past glacial phases (Avcı, 2014).

Despite this relatively well-documented range, new refugial populations continue to emerge, offering fresh insights into the species' ecological resilience and historical biogeography (Sękiewicz et al., 2022). In this study, our purpose is to report a previously undocumented refugial distribution of *F. orientalis* in the Gidengelmez Mountains of Antalya Province, southern Türkiye. Situated under Mediterranean climatic influence, this population lies outside the species' known range and highlights the ecological and conservation significance of southern Anatolia. Moreover, our second goal is to make a discussion on Quaternary migration routes providing new evidences, particularly challenging the long-held view of the Anatolian diagonal as a dispersal corridor.

2. Material and methods

A previously undocumented refugial population of *F. orientalis* was initially detected during a reconnaissance field excursion in October 2025. To validate the taxonomic identification and confirm the presence of this population, a comprehensive field survey was subsequently conducted. Through this systematic investigation, the natural occurrence of *F. orientalis* within the administrative boundaries of Akseki District, Antalya Province, was verified (Figure 1).
During the survey, a comprehensive site assessment was carried out. The study area was systematically explored, and all locations where the species occurred were recorded (Figure 1). For each occurrence, geographic coordinates, aspect, elevation, and landform characteristics were documented. Branch and fruit samples were collected from representative trees and subsequently prepared as herbarium specimens. The dried specimens were deposited and catalogued in the Herbarium of the Faculty of Forestry, Istanbul University–Cerrahpaşa.

3. Results and discussion

The new refugial distribution of *F. orientalis* was identified at Gidengelmez Mountain, within the boundaries of Akseki district (Antalya province), extending towards Seydişehir district (Konya province). The locality of this occurrence, together with visual documentation of the distribution, is presented in Figures 1 and 2.

This population lies approximately 400 km west of the previously known refugial distribution areas of the species in the Mediterranean region, namely the Amanos Mountains, Adana-Pos, and the vicinity of Kahramanmaraş (Aytaç and Semenderoğlu, 2011). The newly discovered population occurs on the northern slopes of mountain at elevations between 1750 and 1800 m. The site is underlain by limestone bedrock and exhibits a fully karstic structure. Soil depth is extremely shallow; however, accumulations of soil within bedrock fissures provide suitable conditions for forest establishment and persistence (Efe, 2013).

The forest structure of the area is dominated by Taurus fir (*Abies cilicica* subsp. *isaurica* Coode & Cullen), and the vegetation type belongs to the *Abieti-Cedrion* alliance (Kavgacı and Čarni, 2012). Alongside *F. orientalis*, other characteristic species of temperate forests were recorded, including *Acer platanoides L.*, *Ulmus glabra Huds.*, *Sambucus ebulus L.*, and *Euonymus latifolius (L.) Mill.*, all of which belong to the Euro-Siberian phytogeographic region (Davis, 1965-1985). Additionally, *Quercus trojana* Webb and *Acer hyrcanum* Fisch. C.A.Mey. are other decidious tree species in the area (Figure 3).

Figure 1. The distribution of *F. orientalis* based on EUFORGEN (Kandemir and Kaya, 2009) with the location of new microrefugial one (red dot) at Gidengelmez mountain, Akseki, Antalya, Southern Türkiye

Figure 2. Views from the *F. orientalis* distributions at Gidengelmez mountain in Antalya, Türkiye. 1, 2, 3, 4, 5: different localities in the province, 6: stem, 7: dry leaves and cupules on the ground, 8: cupule, bud and leaves (As observed in the locality 4, certain trees exhibit leaves with eight veins (occasionally seven). Furthermore, the cupule scales are subulate and lack spathulate forms (see the picture 8), which are diagnostic characteristics of *F. sylvatica*. These morphological features suggest that further investigation is warranted regarding the precise identification of the species at this location)

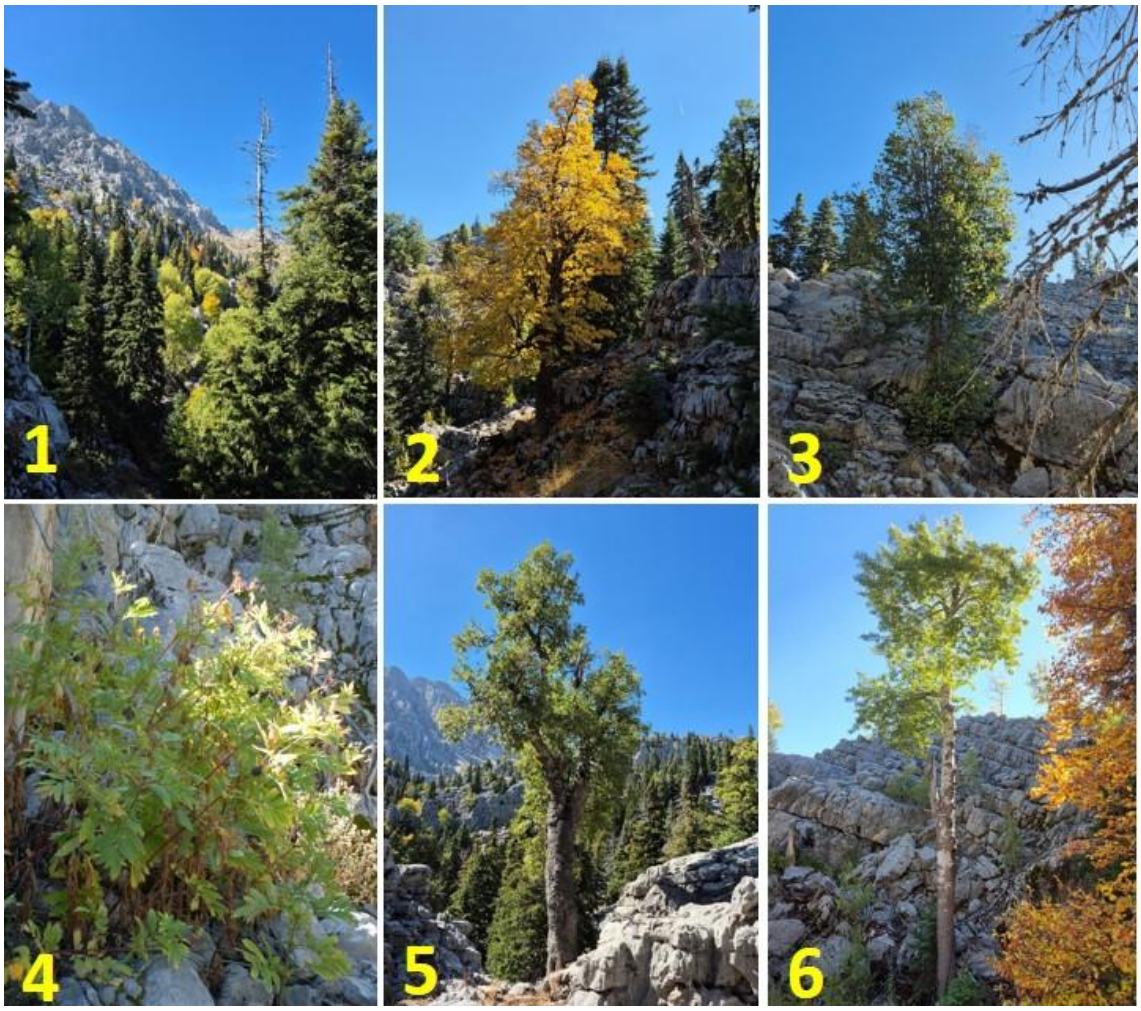

Figure 3. General view dominated by *Abies cilicica* subsp. *isaurica* from Gidengelmez mountain (1) and some other species from the area, some of which are Euro-Siberian (ES) element. *Acer platanoides* (2-ES), *Ulmus glabra* (3-ES), *Sambucus ebulus* (4-ES), *Quercus trojana* (5), *Populus tremula* (6)

The occurrence of *F. orientalis* on the northern slope of the mountain is likely related to the higher humidity of northern exposures compared to southern slopes in the Mediterranean region (Mayer and Aksoy, 1998) on about 1750m a.s.l. Detailed examination of the distribution revealed that the species is primarily confined to sinkholes, where moisture availability is high and soil depth is relatively greater. The northern slopes of Mount Gidengelmez are characterized by numerous sinkholes (dolines) (Şimşek et al., 2020), and the species was found in one particularly large, contiguous pair of sinkholes. In addition, three further sites with deeper soils, located on sloping terrain in close proximity to the sinkholes, also support populations of the species. In total, five distinct but spatially close localities of *F. orientalis* were documented, with coordinates and general topographic features presented in Table 1.

Both seed-originated juvenile individuals and coppice-originated stools were observed within these populations, the latter interpreted as may be a consequence of local harvesting activities, given the high value of beech wood as timber wood or for grazing. This finding may highlight the anthropogenic pressures acting upon this newly discovered refugial population despite its considerable remoteness from human settlements.

The discovery of this new microrefugial population of *F. orientalis* provides important insights into the biogeographical history and ecological resilience of the species. Situated at a substantial distance from the known refugial areas, this population extends the western boundary of the species' southern Mediterranean distribution. Its occurrence in karstic sinkholes and on humid northern slopes highlights the critical role of micro-topographical features in sustaining beech forests under otherwise limiting climatic conditions (McNichol et al., 2024; Ogee et al., 2024).

Historical distribution models suggest that *F. orientalis* was largely distributed in the Amanos Mountains and surrounding areas during the Last Glacial Maximum (LGM), and occupied much larger areas during the mid-Holocene across the southern Mediterranean and Aegean Türkiye (Dağtekin et al., 2020). This extensive distribution under warmer and drier mid-Holocene conditions may be interpreted as the retreating pathway of the species. The current remnant populations in the eastern Taurus Mountains, together with the newly identified population in southwestern Türkiye, therefore challenge the long-standing hypothesis of the Anatolian diagonal as the primary migration route.

Table 1. Coordinates, topographical and structural characteristics of *F. orientalis* distribution at Gidengelmez Mountain (Akseki, Antalya, Türkiye)

Location	Coordinates	Elevation (m)	Aspect	Slope (%)	Structural characteristics
1	N:37°14.392' E:31°52.400'	1745	North	30	Two individuals of *F. orientalis* were recorded, exhibiting diameters at breast height (DBH) of 39.5 cm and 29.0 cm, and total heights of 17.0 m and 11.0 m, respectively.
2	N:37°14.632' E:31°52.410'	1760	sinkhole	sinkhole	A distribution consisting of two coppice-origin stools was observed. The sinkhole has an approximate diameter of 30 m. Coppice-origin individuals exhibit varying stem diameters, with some reaching up to 20 cm.
3	N:37°14.621' E:31°52.625'	1755	sinkhole	sinkhole	This site represents the largest distribution area within the refugia, covering approximately 0.5 ha. It is located immediately north of Distribution No. 2. The sinkhole has an estimated diameter of 70 m. In addition to seed-originated individuals, coppice-origin stems are also present, occurring in stools. Some individuals reach diameters of up to 35–40 cm.
4	N:37°14.611' E:31°52.571'	1760	North	40	In this hillside site, a total of 14 individuals were recorded. Most of the trees are coppice-origin, with stem diameters reaching up to 35–40 cm.
5	N:37°14.624' E:31°52.466'	1760	North	40	At this site, a total of 12 individuals were recorded, all originating from stump sprouts. The trees reach stem diameters of up to 35 cm, although most are of relatively small diameter.

Namely, Davis (1971), hypothesized that Euro-Siberian vegetation, composed of less drought-resistant species, reached the eastern Taurus Mountains via migration along the Anatolian diagonal during the Pleistocene glacial phase. This diagonal was considered a remarkable floristic break across central Anatolia (Davis, 1971; Ekim and Güner, 1986), and the reduced distribution of *F. orientalis* forests in the eastern Taurus Mountains was traditionally accepted as a Pleistocene remnant. However, the potential distribution of the species during mid-holocene and LGM (Dağtekin et al., 2020) does not support this interpretation as previously indicated by Kavgacı et al. (2018). Instead, *F. orientalis* shows stronger distributional connections with western and southern Türkiye rather than with the Anatolian diagonal. No potential habitat characteristics for *F. orientalis* were observed along the diagonal either during the LGM or the mid-Holocene (Dağtekin et al., 2020; Kavgacı et al., 2018.), weakening the hypothesis that it functioned as a migration pathway (Avcı, 1993).

Additional evidence from other Euro-Siberian and temperate climate species reinforces this conclusion. For instance, *Taxus baccata* exhibits reduced distributions in southwestern Türkiye, and Avcı et al. (2016), argued that its presence reflects migration along western Türkiye rather than the Anatolian diagonal. Similarly, *Quercus robur* was modeled to occur in western Anatolia during the LGM without presence along the diagonal (Ülker et al., 2017). Other woody Euro-Siberian elements such as *Carpinus betulus*, *Castanea sativa*, *Corylus avellana*, *Fraxinus excelsior* subsp. *excelsior*, *Sorbus torminalis* var. *torminalis*, *Tilia rubra* subsp. *caucasica*, and *Ulmus glabra* also appear in Mediterranean mountain ranges beyond the eastern Taurus (Öztürk et al., 2008). Species composition analyses further show that *F. orientalis* forests in the eastern Taurus share greater similarity with northwestern Türkiye than with northeastern populations (Kavgacı et al., 2012).

Pollen records also provide decisive support for this west–south Anatolian migration pathway. Studies by Van Zeist et al. (1975) and Bottema and Woldring (2015), clearly demonstrated the presence of beech in southwestern Türkiye during the late Quaternary. Thus, in addition to the Euro-Siberian vegetation in the eastern Taurus Mountains, this new finding of *F. orientalis* from southwestern Türkiye is more plausibly interpreted as a remnant of migration along western and southern Anatolia rather than dispersal via the Anatolian diagonal.

4. Conclusion

The identification of *F. orientalis* in the Gidengelmez Mountains represents a significant extension of its known refugial distribution in the Mediterranean region. This population persists under specific micro-topographical and climatic conditions, particularly humid sinkholes and northern slopes, which mitigate the broader limitations imposed by summer drought and high temperatures.

The persistence of *F. orientalis* in southwestern Mediterranean Türkiye is best explained by migration along western and southern Anatolia rather than the Anatolian diagonal. This finding has broader implications for understanding the biogeographical history of Euro-Siberian vegetation in Anatolia and for predicting future distribution patterns under climate change. Conservation of this refugial population is critical, as it represents both genetic reservoirs (Kandemir et al., 2016) and ecological indicators of species' adaptive capacity in the face of ongoing environmental pressures.

F. orientalis is a drought-resistant species in comparison with *F. sylvatica* (Fang and Lechowicz, 2006), which may indicate its importance for future distribution patterns beyond Türkiye. This resilience highlights the potential role of *F. orientalis* as a key species under climate change scenarios, particularly in regions where *F. sylvatica* may face increasing stress from summer droughts.

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