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New Rust Fungi Records from Aladağlar and Bolkar Mountains (Türkiye)

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Abstract

Aim of study: The primary aim of this research is to contribute Turkish mycobiota by adding ten rust fungi species that have not been previously reported in the country.

Area of study: Aladağlar and Bolkar Mountains are part of the broader Central Taurus Mountains complex situated in the eastern section of southern Anatolia. It is encircled by several key regions: Kayseri to the northeast, Niğde and Ereğli to the northwest, Karaman to the west, Mersin to the south, and Adana to the southeast.

Material and method: For light microscopy (LM) studies, fungal samples from plants and dried hosts were prepared with lactophenol and analyzed using a Leica microscope, Olympus camera, and Image Focus v3 software. For scanning electron microscopy (SEM), spores were fixed on stubs, gold-coated, and examined with an EVO 40XVP microscope at 20 kV.

Main results: As a result of field and laboratory studies, ten species belonging to the *Pucciniales* order were reported for the first time in Türkiye.

Research highlights: This study examines the report of ten previously unidentified species of rust fungi within the mycobiota of Türkiye, specifically gathered from the Aladağlar and Bolkar mountain ranges.

Keywords: New Records, Puccinales, Aladağlar and Bolkar Mountains, Türkiye

Aladağlar ve Bolkar Dağlarından (Türkiye) Yeni Pas Mantarı Kayıtları

Öz

Çalışmanın amacı: Bu araştırmanın temel amacı, Türkiye'de daha önce rapor edilmemiş 10 pas mantarı türünü ekleyerek Türkiye mikobiyotasına katkıda bulunmaktır.

Çalışma alanı: Aladağlar ve Bolkar Dağları, Güney Anadolu'nun doğu kesiminde yer alan daha geniş Orta Toros Dağları kompleksinin bir parçasıdır. Aladağlar ve Bolkar Dağları, Güney Anadolu'nun doğu kesiminde yer alan daha geniş Orta Toros Dağları kompleksinin bir parçası olup Kuzeydoğuda Kayseri, kuzeybatıda Niğde ve Ereğli, batıda Karaman, güneyde Mersin ve güneydoğuda Adana gibi önemli bölgeler tarafından çevrelenmiştir.

Materyal ve yöntem: Işık mikroskobu (LM) çalışmaları için, bitkilerden ve kurutulmuş konaklardan alınan mantar örnekleri laktofenol ile hazırlanmış ve bir Leica mikroskobu, Olympus kamera ve Image Focus v3 yazılımı kullanılarak analiz edilmiştir. Taramalı elektron mikroskobu (SEM) için sporlar saplamalar üzerine sabitlenmiş, altın kaplanmış ve 20 kV'de EVO 40XVP mikroskop ile incelenmiştir.

Temel sonuçlar: Arazi ve laboratuvar çalışmaları sonucunda, *Pucciniales* takımına ait on tür Türkiye'den ilk kez rapor edilmiştir.

Araştırma vurguları: Bu çalışma, özellikle Aladağlar ve Bolkar sıradağlarından toplanan, Türkiye mikobiyotası için daha önce tanımlanmamış on pas mantarlarını rapor etmiştir.

Anahtar kelimeler: Yeni Kayıtlar, Puccinales, Aladağlar and Bolkar Dağları, Türkiye

Introduction

Pucciniomycotina is one of the three subdivisions within the division *Basidiomycota*. The subdivision is characterized by distinctive disc-like spindle pole bodies and possesses simple septal pores, which notably lack both pore caps and dolipores (Bauer et al., 2006). It encompasses a diverse range of fungi, classified into 9 classes, 20 orders, and 37 families, and

includes roughly 8500 species spread across about 215 genera (Aime et al., 2006). The majority of these organisms are microfungi, which exhibit a wide array of ecological roles and environmental adaptations (Helfer, 2014). These range from psychrophilic yeasts, which thrive in cold environments, and animal-pathogenic yeasts, to various molds (Aime et al., 2006). Additionally, it contains a multitude of plant pathogens and saprobes, organisms that feed on decomposing matter (Aime et al., 2014). A significant portion of *Pucciniomycotina* species are concentrated within the order *Pucciniales*. This order is unique in that it solely comprises obligate parasitic fungi known for causing rust diseases in plants (Cummins & Hiratsuka, 2003).

Pucciniales, also known as rust fungi, are distributed globally across vascular plants and constitute an important component of worldwide biodiversity, comprising approximately 7800 species (Helfer, 2014). Rust fungi are a significant group of obligate biotrophic parasites that play a crucial role in the ecological dynamics of terrestrial ecosystems. These fungi, constituting approximately 95% of the species in their subphylum and around 8% of all known fungal species, exhibit a remarkable degree of adaptation to a wide range of host plants (Aime et al., 2014). This adaptation spans from simpler plants such as ferns to more complex ones, covering both angiosperms and gymnosperms, demonstrating their broad spectrum of hosts and variety. Rust fungi, characterized by their unique yellow-orange or powdery appearance, target the crucial, actively developing sections of plants, including leaves, stems, petioles, young shoots, and fruits (Gautam et al., 2021). They are found in every terrestrial ecosystem that has plant life, play a significant role in community dynamics and the diversification of species due to their co-evolution with host plants (Helfer, 2014). These biotrophic plant parasites are represented worldwide, encompassing approximately 166 genera across 14 families (Kirk et al., 2008). The majority of these species are found within the genera Puccinia and Uromyces, with more than 5000 and 1500 taxon names registered for each, respectively (Helfer, 2014).

Over the past few years, there been a notable increase in the newly reported species of rust fungi from Türkiye, as published by numerous researchers (Akata, 2017; Akata et al., 2018, 2019; Akgül et al., 2017; Bahçecioglu, 2014; Bahçecioglu & Kabaktepe, 2012; Bahcecioglu et al., 2006, 2009; Kabaktepe, 2015; Kabaktepe & Bahcecioglu, 2006, 2012; Kabaktepe et al., 2014, 2015a, 2015b, 2015c, 2016, 2017a, 2017b; Kirbag et al., 2011; Özaslan et al., 2015; Sert, 2009). To date, approximately 370 rust fungi species across 28 different genera have been officially reported from Türkiye. Yet, this number only scratches the surface of the existent diversity, considering the extensive variety of host plants in the region. This gap underscores the urgent need for deeper and more extensive studies on the rust fungi species in Türkiye. It is also important to note that specific species such as *Puccinia asperulae-cynanchicae* Wurth, *P. difformis* Kunze, *P. epilobii* DC., *P. leveillei* Mont., *P. nevadensis* Syd. and P. Syd., *P. passerinii* J. Schröt., *P. tumida* Grev., *Uromyces doricus* Maire, *U. scrophulariae* (DC.) Fuckel, and *U. verbasci* Niessl, have yet to be reported within Türkiye.

The present research endeavors to deepen the comprehension of Turkish rust fungi through the documentation of species hitherto unreported within the country. This advancement in knowledge derives from meticulous sample collection in the Aladağlar and Bolkar mountain ranges, areas that have proven to be fertile ground for uncovering the untapped diversity of rust fungi in Türkiye.

Material and Methods

Study Area and Morphological Characterization

Between 2013 and 2016, host species samples were gathered from the Aladağlar and Bolkar mountains, spanning regions including Kayseri, Niğde, Konya, Karaman, Mersin, and Adana in Türkiye. The identification of these host species was primarily guided by the "Flora of Türkiye" publications from Davis (1965 to 1985), and supplemented by Davis et al. (1988). The nomenclature for host plants and their families was aligned with standards set by The Plant List, accessible online, http://www.theplantlist.org (URL-1, 2024).

Rust fungi were identified based on their morphology, utilizing established methodologies from Grove (1913), Gäumann (1959), Wilson and Henderson (1966), Kuprevich and Transhel (1957) and Ellis and Ellis (1987). The fungi names were then verified with the Index Fungorum database, https://www.indexfungorum.org (URL-2, 2024). The entirety of the specimens examined in this study were deposited within the İnönü University Herbarium, located in Malatya, Türkiye, under the collection code INU.

Microscopic Studies

For the study using light microscopy (LM), fungal samples were obtained from plant material by either scraping off surface elements or making thin sections with a razor blade. Additionally, spores were collected from dried host materials and prepared on slides with lactophenol for examination under a light microscope. Digital imagery was captured employing a Leica light microscope coupled with an Olympus SZ65 stereomicroscope camera, and Image Focus v3 software was utilized for the measurement of spores. In contrast, for scanning electron microscopy (SEM) analysis, spores were affixed to stubs using double-sided adhesive tape, subsequently coated in gold, and observed with an EVO 40XVP (LEO Ltd., Cambridge, UK) scanning electron microscope at an accelerating voltage of 20 kV.

Results

Taxonomic Overview

Fungi
Basidiomycota
Pucciniomycetes
Pucciniales
Pucciniaceae

Puccinia asperulae-cynanchicae Wurth (1904) (Figure 1).

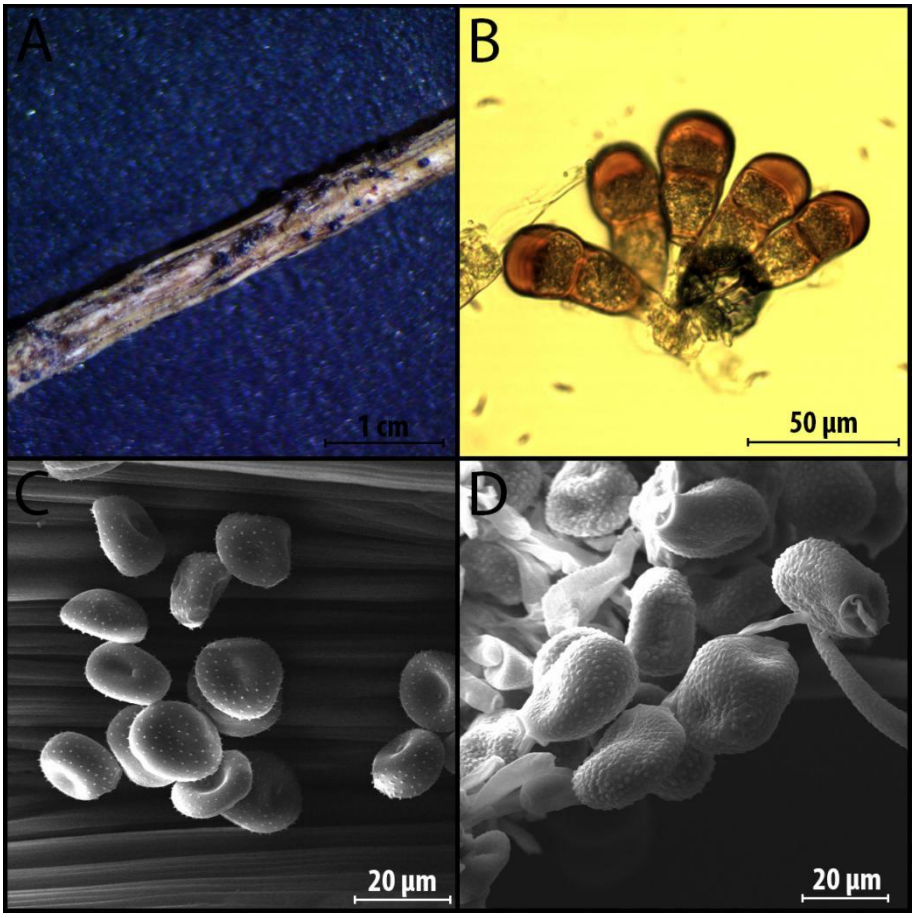

Figure 1. *Puccinia asperulae-cynanchicae*: a. telia (SM), b. teliospores (LM), c. urediniospores (SEM), d. teliospores (SEM)

Spermogonia, aecia, and uredinia are not observed. The uredinia are found on both sides of the leaf, appear dispersed, and can be either round or elongated, with a chestnut brown color. The urediniospores have a globoid to obovoid, measuring 18-34 x 11-29 µm. They are brown and feature two equatorial pores with an echinulate wall. Telia also present on both sides of the leaf, can be round or, more rarely, elongated, and appear either scattered or grouped. These structures are compact, with their margins often obscured by shreds of epidermis, and have a blackish-brown color. Teliospores are oblong to club-shaped or pear-shaped, measuring 30-56 x 14-24 µm, with the upper cell rounded and the basal cell more oval, show a constriction at the septum, and have subapical pores on the upper cell. The spore walls are smooth, with the apical region notably thickened to 5-8 µm and colored yellowish brown. The pedicel, which can be either hyaline or yellowish, is as long as the spore itself. Basidia are not observed in this examination.

Specimens examined: On *Asperula glomerata* (M.Bieb.) Griseb. (*Rubiaceae*), Adana: Pozantı, Dağdibi village, 27.09.2013, Ş. Kabaktepe and I. Akata 7226; Adana: Pozantı, Horoz Boğazı, 2. km, 950-1000 m, 30.10.2014, Ş. Kabaktepe and I. Akata 7920. On *Asperula orientalis* Boiss. and Hohen., Kayseri: Yahyalı, Elmabağ village, 1200-1400 m, 25.09.2013, Ş. Kabaktepe and I. Akata 7174.

Distribution: Reported in Spain (Fragoso, 1918), Ukraine (Gutsevich, 1952); Romania (Savulescu, 1953), Bulgaria (Denchev, 1995); Switzerland (Brandenburger, 1997); the United Kingdom (Henderson, 2000) and Poland (Mulenko et al., 2008).

Puccinia difformis Kunze, (1817) (Figure 2).

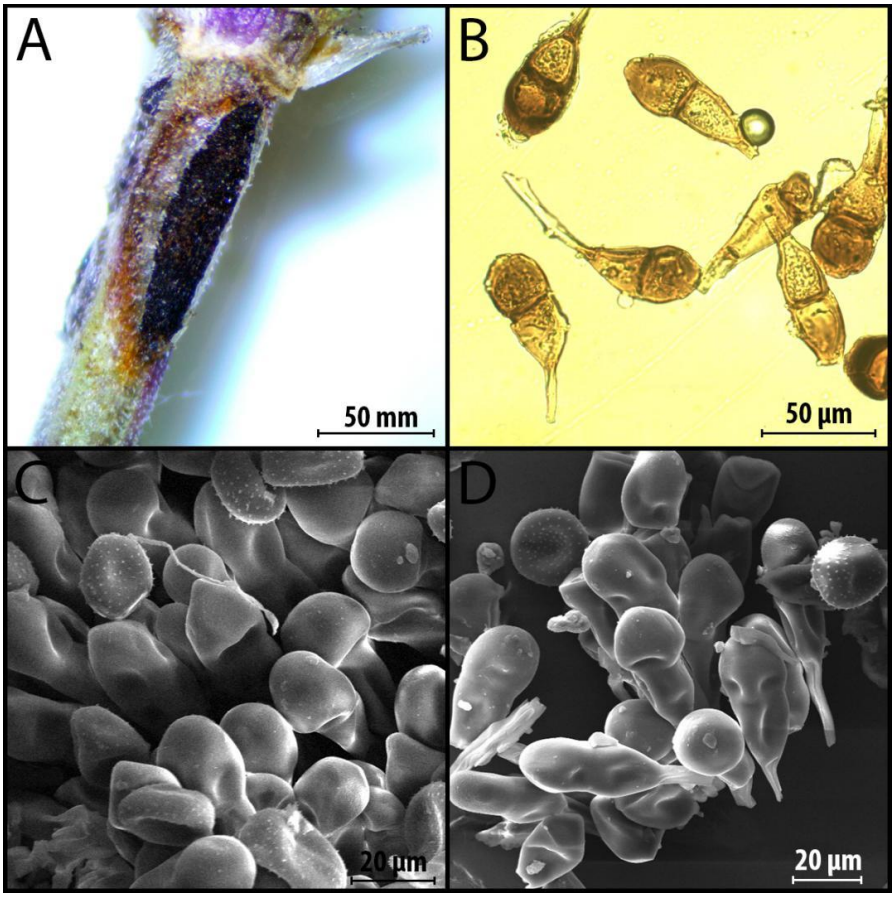

Figure 2. *Puccinia difformis*: a. telia (SM), b. teliospores (LM), c, d. teliospores (SEM)

Spermogonia, aecia, and uredinia are not observed. Instead, telia are found on the undersides of leaves or on stems, appearing as small, solitary or clustered formations. These formations were elongated along the stem, enveloped by an ash-colored epidermis, and exhibited a hard, blackish appearance. Teliospores are observed to be ellipsoid or club-shaped, measuring 35-55 x 15-25 µm. These spores were characterized by a constriction at the septa, a thickening at the apex, and a narrowing towards the base. The coloration of the spores shifted from brownish at the apex to lighter at the base, with subapical pores present on the upper cell near the septa of the basal cell. The spore wall was smooth, with a thickness of 1.5-2 µm, expanding up to 10 µm at the apex, and had a yellowish-brown. The pedicel, similar in color, was as long as or longer than the spore itself. Basidia are not observed.

Specimens examined: On *Galium aparine* L. (*Rubiaceae*), Kayseri: Yahyalı-Derebağ village, 1200-1400 m, 25.09.2013, Ş. Kabaktepe and I. Akata 7162.

Distribution: Widely distributed species (Farr & Rossman, 2024).

Puccinia epilobii DC., (1815) (Figure 3).

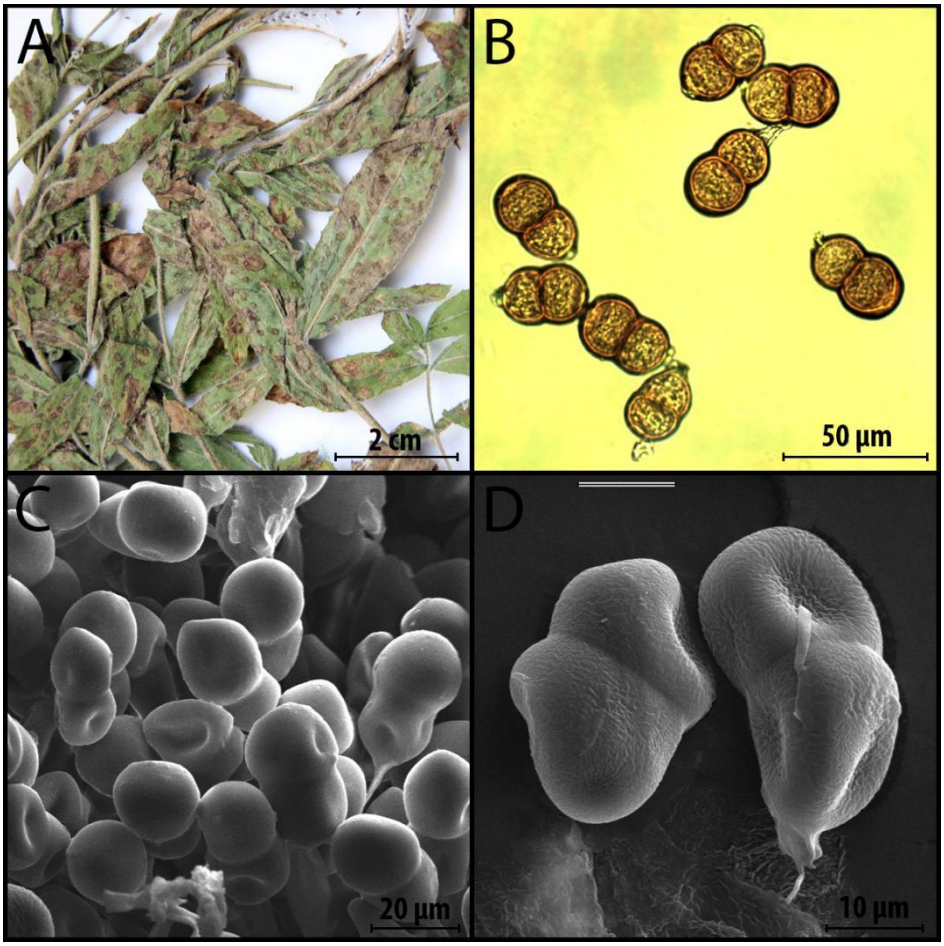

Figure 3. *Puccinia epilobii*: a. telia (SM), b. teliospores (LM), c,d. teliospores (SEM)

Spermogonia, aecia, and uredinia are not observed. The infected plants undergo deformation and sterility, exhibiting pale and thickened leaves. Telia appear on both sides of the leaves, either scattered or clustered, and in some cases, covering the entire leaf surface. They remain under the epidermis, presenting a dusty, pulverulent texture, with a reddish-brown color. The teliospores are ellipsoid, oblong, or pear-shaped, sometimes clavate, and are rounded at both ends, measuring 27-48 x 16-25 µm. These spores show a

constriction at the septum and have a light brown, verrucose wall that is 1.5-2.5 µm thick. The apical pores of the upper cell feature a small papilla, while those of the basal cell are placed just below the equator. The pedicel is clear and can extend up to 20 µm. Basidia are not observed.

Specimens examined: On *Epilobium angustifolium* L. (*Onagraceae*), Mersin: Toroslar, 3 km from Aslanköy to Fındıkpınarı, 20.09.2014, Ş. Kabaktepe and I. Akata 7876; Mersin: Mezitli, 3 km from Tepeköy to Kocayer, 1140 m, 20.09.2014, Ş. Kabaktepe and I. Akata 7885.

Distribution: Widely distributed species (Farr and Rossman, 2024).

Puccinia leveillei Mont., (1852) (Figure 4).

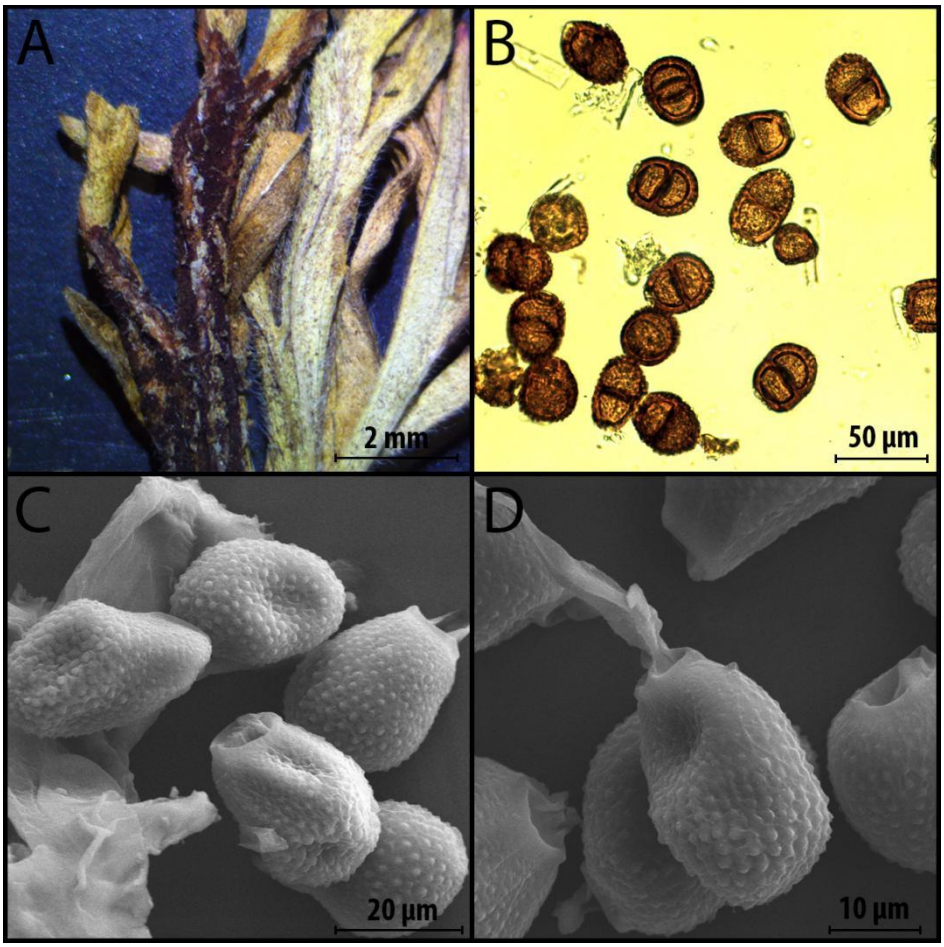

Figure 4. *Puccinia leveillei*: a. telia (SM), b. teliospores (LM), c, d. teliospores (SEM)

Spermogonia, aecia, and uredinia have not been observed. The telia are found on both sides of the leaf, appearing either scattered or clustered together, and are initially covered by the plant's epidermis. They display a brownish color. Teliospores are globoid, ellipsoid, or nearly globular, with both ends being round, measuring 40-48 x 20-24 µm. These spores are not constricted at the septa and have a wall thickness of 2 to 3 micrometers. The wall is brown and has a verrucose. Each spore is attached by a short, hyaline pedicel, which is easily detached. Basidia are not observed.

Specimens examined: On *Geranium tuberosum* L. (*Geraniaceae*), Konya: Halkapınar, North of Çakıllar village, 1280 m, 19.05.2014, Ş. Kabaktepe and I. Akata 7412.

Distribution: Widely distributed species (Farr and Rossman, 2024).

Puccinia nevadensis Syd. & P. Syd., (1916) (Figure 5).

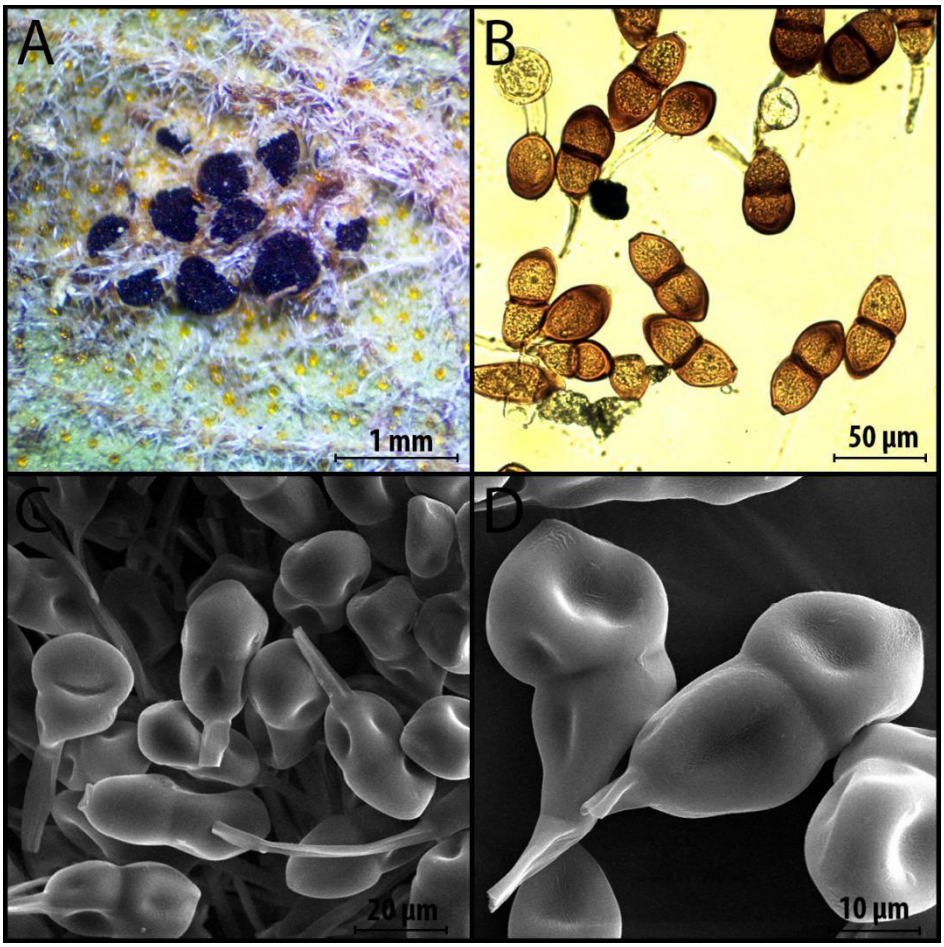

Figure 5. *Puccinia nevadensis*: a. telia (SM), b. teliospores (LM), c, d. teliospores (SEM)

Spermogonia, aecia, or uredinia are not observed. However, telia are hypophyllous, appearing scattered and occasionally rounded, measuring between 0.75 and 1.5 mm, with a powdery texture and a blackish. The teliospores are described as ellipsoid-oblong, with the upper cell rounded and the base either elongated or rounded, measuring 40-52 x 20-28 µm. A notable constriction at the septa is present. The spore walls are 1.5 to 2.5 µm thick, widening up to 6 µm at the apex, and exhibit a light brown or chestnut brown color with a smooth texture. The pedicel is transparent (hyalin) and can extend up to 190 µm. Mesospores are ellipsoid or ovoid, measuring 22-38 x 18-26 µm. Their walls, smooth, are 1.5 to 2.5 µm thick and light brown. Basidia are not observed.

Specimens examined: On *Salvia tomentosa* Mill. (*Lamiaceae*), Niğde: North of Dündarlı village 1300-1500 m, 26.09.2013, Ş. Kabaktepe and I. Akata 7202; Adana: Pozantı, 3 km from Ömerli to Kamışlı, 1200 m, 20.05.2014, Ş. Kabaktepe and I. Akata 7433; Adana: 10 km from Mansurlu to Aladağ, 1400 m, 21.05.2014, Ş. Kabaktepe and I. Akata 7467; Konya: Halkapınar, South of İvriz village, 1150-1350 m, 14.07.2014, Ş. Kabaktepe and I. Akata 7578; Niğde: Çamardı, Demirkazık village, Cımbar Boğazı, 1650-1800 m, 15.07.2014, Ş. Kabaktepe and I. Akata 7585; Mersin: Tarsus, Gülek, 550 m, 19.09.2014, Ş. Kabaktepe and I. Akata 7851.

Distribution: Reported in Spain (Fragoso, 1918) and Cyprus (Georghiou & Papadopoulos, 1957).

Puccinia passerinii J. Schröt., (1876) (Figure 6).

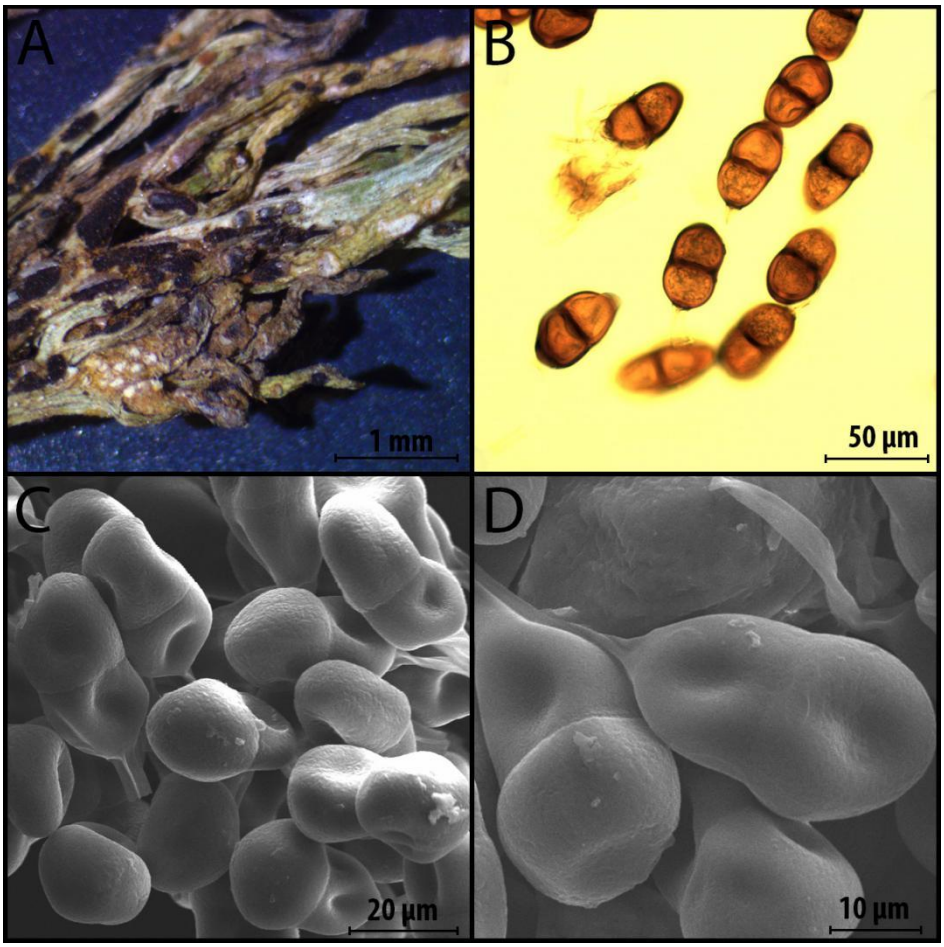

Figure 6. *Puccinia passerinii*: a. telia (SM), b. teliospores (LM), c, d. teliospores (SEM)

Spermogonia, aecia, or uredinia are not observed. On both sides of the leaf surface, telia appear scattered or grouped together, forming rounded patches that are powdery and pulverulent. Telia are predominantly found on older leaves, exhibit a blackish-brown. Teliospores are characterized by their ellipsoid-oblong, measuring 32-48 x 25-31 µm, rounded at both ends, and occasionally display elongation at the upper cell. A slight constriction at the septa is notable, and the apical pores of the upper cell feature a small papilla, whereas those at the basal cell are located equatorially. The spore wall, measuring 3-4 µm in thickness, is light brown in color and finely verrucose. Additionally, the pedicel is hyaline, short, and tends to be deciduous. Basidia are not observed.

Specimens examined: On *Thesium arvense* Horv. (*Santalaceae*), Kayseri: Yahyalı, Elmabağ village, 1200-1400 m, 25.09.2013, Ş. Kabaktepe and I. Akata 7171.

Distribution: Widely distributed in Asia and Europe (Farr & Rossman, 2024).

Puccinia tumida Grev., (1824) (Figure 7).

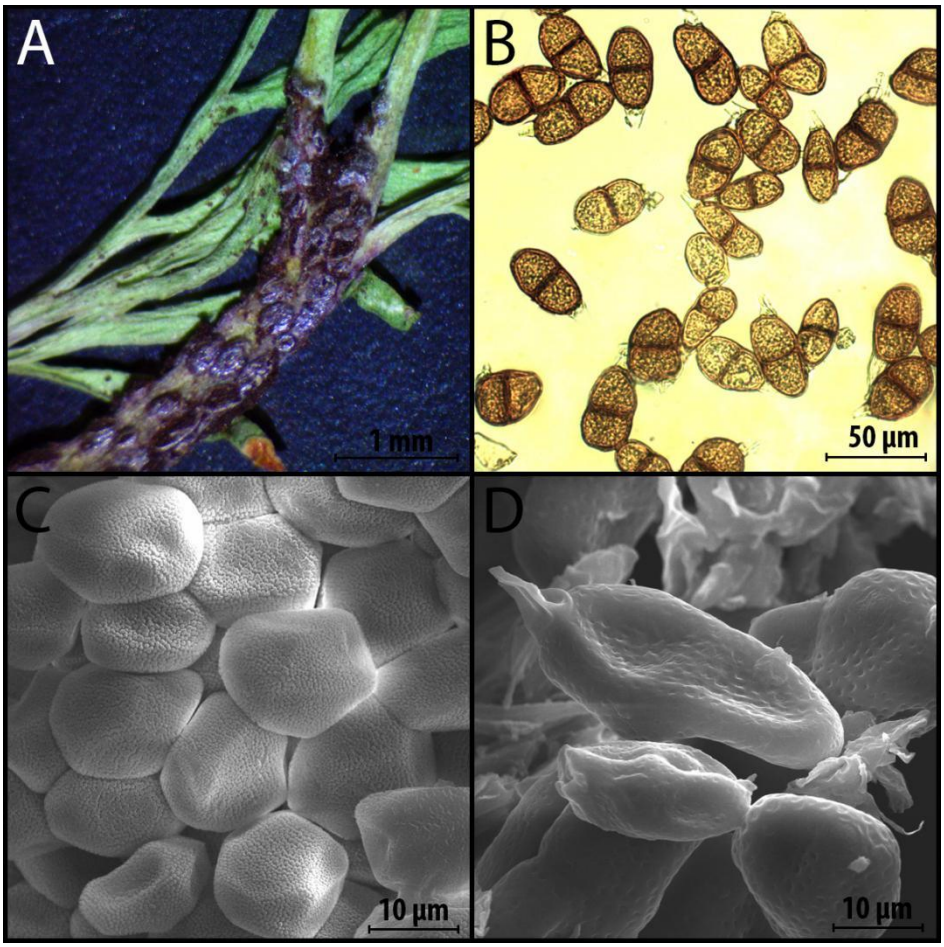

Figure 7. *Puccinia tumida*: a. telia (SM), b. teliospores (LM), c, d. teliospores (SEM)

Spermogonia, aecia, and uredinia are not observed. However, telia are observed on both surfaces of leaves, stems, and petioles, forming noticeable, galled spots. These spots, which can be either round or elongated, reach up to 1 cm, and are covered by an ash-colored epidermis, appearing blackish-brown. The teliospores themselves are characterized by their ellipsoid, oblong, or ovoid, with both ends rounded and occasionally narrowed at the base, measuring 36-50 x 16-25 µm. Although they show little constriction at the septum, apical pores are present at the upper cell. The spore walls are 1-2 µm thick, of a brownish hue, and generally smooth, although some may exhibit a few verrucose features at the extremities. The pedicel is hyaline, short, and tends to break off easily. Basidia are not observed.

Specimens examined: On *Conopodium majus* (Gouan) Loret (*Apiaceae*), Çamlıyayla, Saydibi plateau, 1900-1950 m, 24.04.2014, Ş. Kabaktepe 7379.

Distribution: Widely distributed in Europe (Farr & Rossman, 2024).

Uromyces doricus Maire., (1930), (Figure 8).

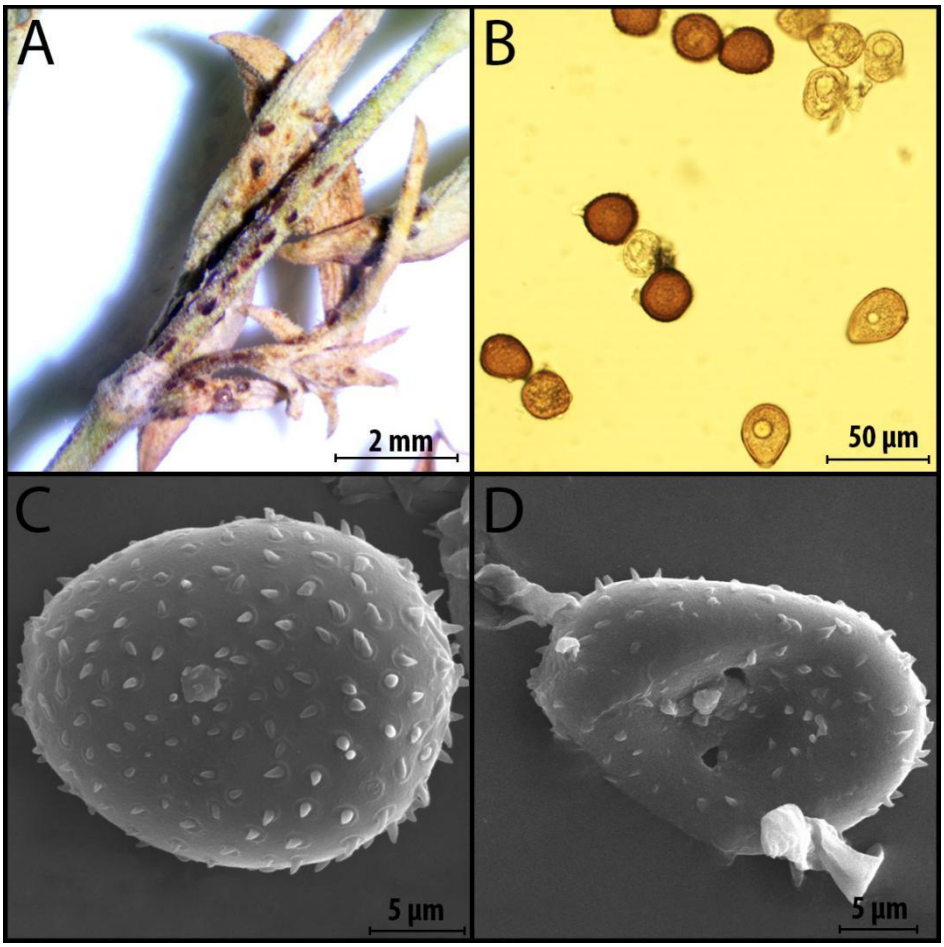

Figure 8. *Uromyces doricus*: a. telia (SM), b. teliospores (LM), c. urediniospore (SEM), d. teliospores (SEM)

Spermogonia and aecia are not observed. The uredinia are found on both sides of the leaves, forming rounded patches up to 1 mm in diameter. These patches are powdery and remain covered by the leaf epidermis. Their color is a cinnamon brown. The urediniospores have an ellipsoid, ovoid, or globoid, measuring 25-0 x 22-25 µm. Their walls are light brown, approximately 2 µm thick, and display an echinulate surface with 2-3 pores located at the equator. The telia are similar in appearance to the uredinia but are distinguished by their darker color. Teliospores range from ellipsoid to ovoid, measuring of 22-30 x 20-25 µm. Their walls are 2-2.5 µm thick, brownish, and either smooth or slightly verrucose at the ends. They have a short, hyaline, and deciduous pedicel. Basidia is not observed.

Specimens examined: On *Silene spergulifolia* M.Bieb. (*Caryophyllaceae*), Adana: Pozantı, Kamışlı village, 27.09.2013, Ş. Kabaktepe and I. Akata 7235.

Distribution: Reperted in Bulgaria (Denchev, 1995), and Greece (Pantidou, 1973).

Uromyces scrophulariae (DC.) Fuckel, (1870), (Figure 9).

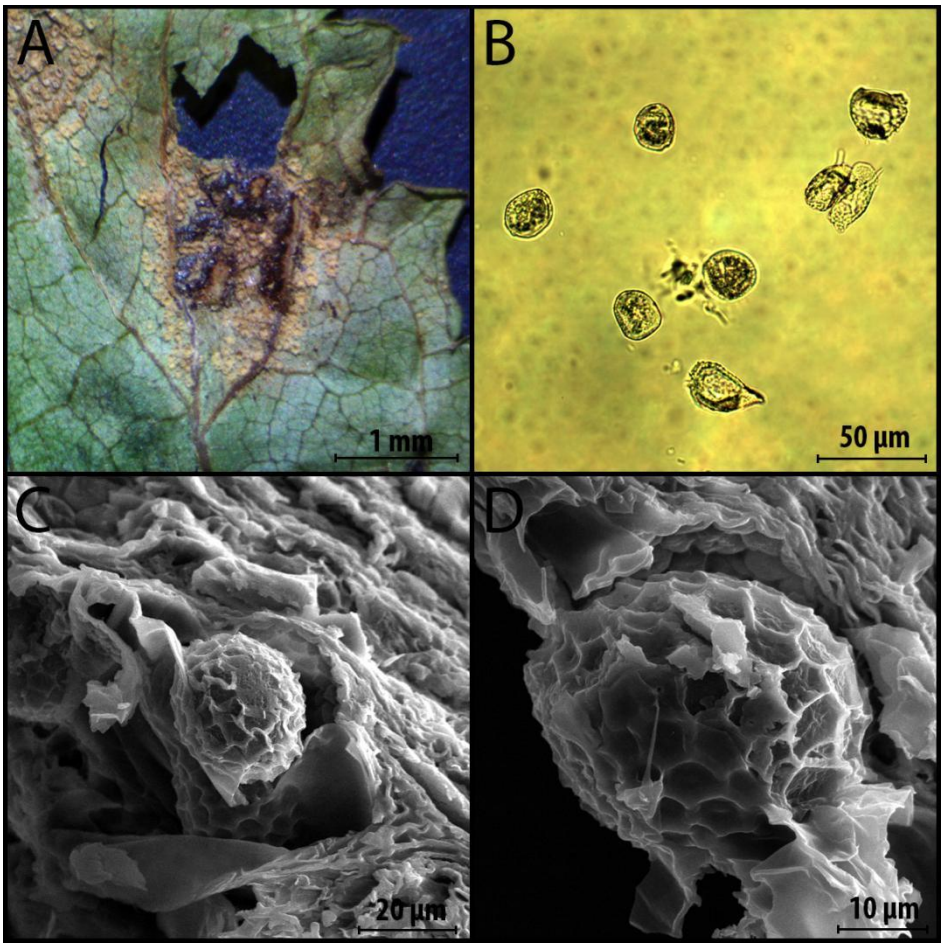

Figure 9. *Uromyces scrophulariae* a. aecidia (SM), b. aecidiospores (LM), c, d. aecidiospores (SEM)

Spermogonia and uredinia are observed. Aecidia are present on the stems, and there are yellow spots on the undersides of the leaves. These spots are rounded and densely clustered, with a yellowish color. The aecidiospores have an ellipsoid, globoid, or sub globoid, measuring 18-22 x 14-18 µm. Their walls are yellowish, with a thickness of 1.5-2.5 µm, and are echinulate. Each spore has 3-5 equatorial pores. Telia and basidia are also not observed in this specimen.

Specimens examined: On *Scrophularia umbrosa* Dumort. (*Scrophulariaceae*), Kayseri, Yahyalı, 5 km from Çamlıca to Ulupınar, 1350-1400 m, 16.07.2014, Ş. Kabaktepe and I. Akata 7675; Kayseri, 5 km from Yahyalı to Derebağ, 1270 m, 25.08.2016, Ş. Kabaktepe and I. Akata 8506.

Distribution: Widely distributed in Europe (Farr & Rossman, 2024).

Uromyces verbasci Niessl, (1864), (Figure 10).

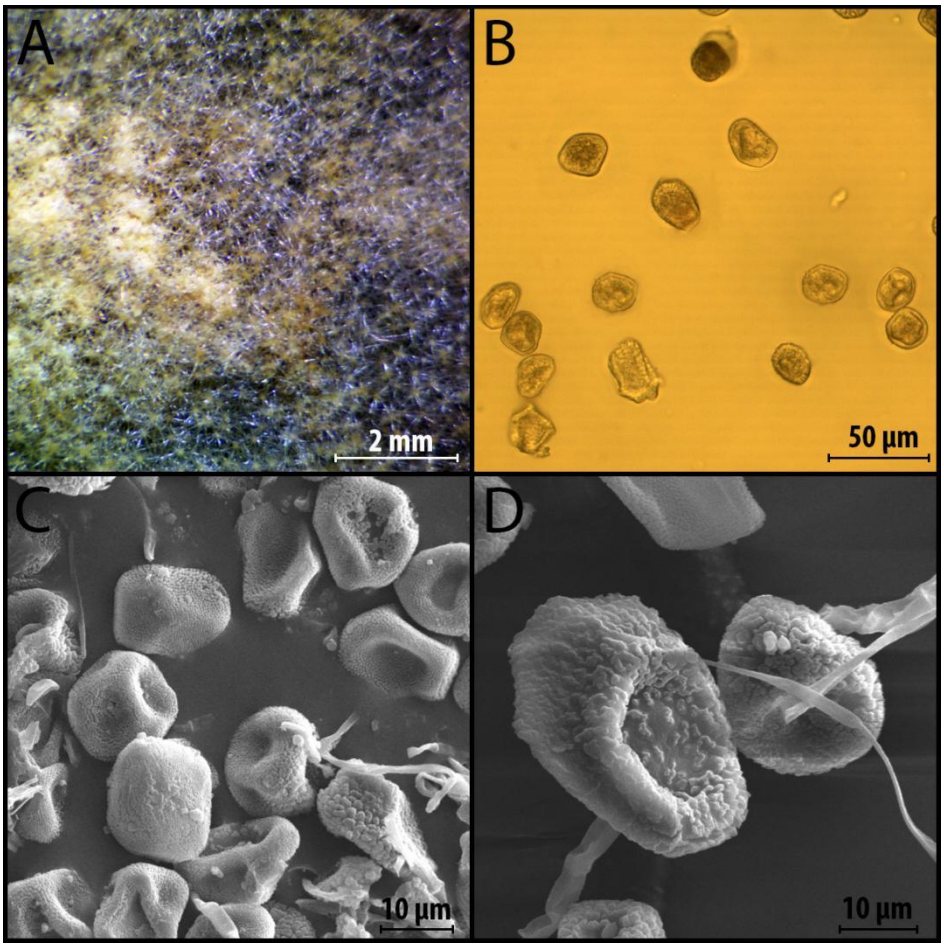

Figure 10. *Uromyces verbasci*: a. aecidia (SM), b. aecidiospores (LM), c. aecidiospores (SEM), d. teliospores (SEM)

Spermogonia and uredinia are not observed. Aecidia appear on both sides of leaves, forming on discolored patches. These structures are cup-shaped with a white peridium and can be either rounded or elongated, displaying a whitish-yellow color. Aecidiospores are either polygonal or globular, measuring 17-30 µm, with a light yellow, 2 µm thick, verrucose wall. Telia, although mixed with aecidia, are notably darker. Teliospores take on ellipsoidal, globular, or ovoid, measuring 20-35 x 10-20 µm. Their walls are thicker at the apex and taper off towards the base, exhibiting a smooth, chestnut brown color. The pedicel is clear and can extend up to 40 µm, but it is deciduous. Basidia are not observed

Specimens examined: On *Verbascum* L. (*Scrophulariaceae*) Niğde, Çamardı, Elek village, 27.09.2013, Ş. Kabaktepe and I. Akata 7225a; Mersin: Çamlıyayla, Saydibi plateau, 1800-1880 m, 09.10.2013, Ş. Kabaktepe and I. Akata 7350.

Distribution: Reported in Ukraine (Gutsevich, 1952). Germany (Braun, 1982), Bulgaria (Denchev, 1995), Poland (Mulenko et al, 2008).

Discussion

Among the ten *Puccinia* species reported on *Asperula* and *Cynanchica* members, four have been previously reported in Türkiye (Bahçecioglu & Kabaktepe, 2012; Kabaktepe et al., 2015a; Sesli et al., 2020). These include *Puccinia asperulae-aparinis* Picb., *P. asperulina* (Juel) Lagerh., *P. coaetanea* Bubák, and *P. punctata* Link. Notably, *P. asperulae-cynanchicae* stands out from the rest due to its distinct characteristics, being recognized by its constricted, yellowish-

brown teliospores, which are oblong or clavate. Furthermore, it exhibits a wide range in the size of teleutospores (30-56 x 14-24 µm) with the pedicel length being as long as the spores themselves (Gäumann, 1959). Denchev (1995) recorded the presence of *Puccinia asperulae-cynanchicae* on *Cynanchica aristata* (L.f.) P.Caputo & Del Guacchio, *Cynanchica tenella* (Heuff. ex Degen) P.Caputo & Del Guacchio and *Cynanchica pyrenaica* subsp. *cynanchica* (L.) P.Caputo & Del Guacchio from Bulgaria. Guyot and Malencon (1957) recorded on *Hexaphylla hirsuta* (Desf.) P.Caputo & Del Guacchio from Morocco. Additionally, there is not any record on *Asperula glomerata* and *A. orientalis* so these plants have been recorded as new host plants for this particular species.

Puccinia difformis stands out among its counterparts affecting Galium members due to its distinctive characteristics. Unlike other *Puccinia* species, *P. difformis* develops telia that are dense and firm, resembling small pitch spots, and its teliospores can cause notable swelling and deformation (Wilson & Henderson, 1966). In Türkiye, species such as *Puccinia asperulina*, *P. galii-cruciatae*, *P. nevodovskii*, *P. punctat*a, and *P. rubiae-tataricae* have already been reported (Bahçecioglu & Kabaktepe, 2012; Sesli et al., 2020). The identification of *Puccinia difformis* marks it as the fifth *Puccinia* species reported on *Galium* species within the boarder of the country.

Puccinia species that infect *Epilobium* members include *P. annulata* Ellis and Everh., *P.epilobii*, *P. epilobii-fleischeri* E. Fisch., *P. gayophyti* (Vize) Peck, *P. gigantea* P. Karst., *P. krookii* Henn., *P. oenotherae* Vize, *P. peckii* (De Toni) Kellerm., *P. pulverulenta* Grev., *P. scandica* Johanson, *P. vagans* (DC.) Arthur, and *P. veratri* Duby (Farr & Rossman, 2024). Among these, *Puccinia pulverulenta* Grev. is noteworthy for its recorded presence in Türkiye, as documented by Bahçecioglu and Kabaktepe (2012) and Sesli et al. (2020). *Puccinia epilobii* is distinguished by its dusty, reddish-brown telia and the presence of apical pores on the upper cell of its teliospores, which are marked by a tiny papilla. This sets it apart from other *Puccinia* species found on *Epilobium* species, particularly through the subtle warts on the teliospores' walls. Unlike its counterparts, this rust fungus pervades the entire plant, causing deformations in the shoots (Wilson & Henderson, 1966). Farr and Rossman (2024) documented that *Puccinia epilobii* had been reported on 14 different *Epilobium* species with the notable exception of *E. angustifolium*. However, recent findings presented in this research indicate a significant update: *Epilobium angustifolium* has now been identified as a new host for *P. epilobii*.

Twenty-three *Puccinia* species have been documented that infect *Geranium* members (Farr & Rossman 2024), including notable species such as *P. geranii-silvatici* P. Karst. and *P. polygoni-amphibii* Pers., which have been recorded in Türkiye according to a study by Bahçecioglu and Kabaktepe (2012) and Sesli et al. (2020). Among these, *P. leveillei* stands out due to its distinctive features, including a shorter pedicel and a uniquely textured outer wall of its teliospores, which is strongly verrucose and deciduous. These characteristics not only distinguish *P. leveillei* from other genus members but also underscore its specialized adaptation to *Geranium* hosts (Gäumann, 1959).

As of the most recent studies, around forty distinct species of *Puccinia* that affect *Salvia* members have been reported (Farr & Rossman, 2024). Among these, specific species such as *P. nigrescens* L.A. Kirchn., *P. salviae* Unger, and *Puccinia stipae* Arthur, which produce aecidia on *Salvia* species, in addition to *P. stipina* Tranzschel, *P. bithynica* Magnus, and *P. glechomae* DC., have been documented in Türkiye (Bahçecioglu & Kabaktepe, 2012; Sesli et al., 2020). This underscores the diverse interaction between *Puccinia* fungi and *Salvia* species within the region, showcasing a significant area of fungal biodiversity and host specificity.

Puccinia nevadensis is characterized by its powdery, dark telia and distinctive elongated, light brown pedicels that can reach lengths of up to 190 µm. It also has a unique combination of mesospores and teliospores that are light brown, aiding in its identification among the genus *Puccinia* that affects *Salvia* members (Gäumann, 1959). This species has been reported on *Salvia nutans* L., as reported by

Georghiou and Papadopoulos (1957), and on *Salvia officinalis* subsp. *lavandulifolia* (Vahl) Gams, according to Fragoso (1918). However, it has not been recorded on *Salvia tomentosa*, thus identifying this plant as a new host represents an expansion of our knowledge regarding the host range of *P. nevadensis*.

To date, several species of genus *Puccinia* have been reported on *Thesium* members. These include *P. mougeotii* Lagerh., *P. passerinii*, *P. stonemaniae* Syd., P. Syd. and Pole-Evans, *P. thesii* (Desv.) Chaillet, *P. thesii-decurrentis* Dietel, and *P. thesiicola* Jørst (Farr & Rossman, 2024). Among these, *P. thesii* has been specifically recorded in Türkiye (Bahçecioglu & Kabaktepe, 2012; Sesli et al., 2020). *Puccinia passerinii* stands out among other *Puccinia* species found on *Thesium* members due to its distinct features. Notably, it possesses verrucose teliospores (32-48 x 25-31 µm). Additionally, it is characterized by a hyaline, short, and easily detachable pedicel (Gäumann, 1959).

Puccinia tumida is unique among the genus members affecting *Conopodium majus* because it produces telia. Occasionally, one can also encounter the relatively rare aecidium of *P. bistortae* (F. Strauss) DC. on this plant (Wilson & Henderson, 1966).

The genus *Uromyces* includes several species that infect *Silene* species, namely *U. behenis* (DC.) Unger, *U. bethelii* Arthur, *U. cuenodii Maire*, *U. doricus*, *U. inaequialtus* Lasch, *U. pulchellus* Ellis and Everh., *U. silenes* (Schltdl.) Fuckel, *U. silenes-ponticae* Const., *U. suksdorfii* Dietel & Holw., and *U. verruculosus* Berk. & Broome (Farr & Rossman, 2024). Among these, *U. behenis*, *U. inaequialtus*, *U. silenes*, *U. silenes-ponticae*, and *U. verruculosus* have specifically been reported in Türkiye so far (Bahçecioglu & Kabaktepe, 2012; Sesli et al., 2020). *Uromyces doricus* is distinguishable from other *Uromyces* species reported on Silene primarily by its unique spore characteristics. Its urediniospores (25-30 x 22-25 µm) have a light brown wall (approximately 2 µm thick) and an echinulate surface. Additionally, these spores exhibit 2 to 3 equatorial pores. The teliospores of *U. doricus* (22-30 x 20-25 µm) possess brownish walls (2-2.5 µm thick) and either smooth or slightly verrucose at the ends. Moreover, the teliospores are supported by a short, hyaline, and easily detached pedicel, further setting this species apart from its relatives (Gäumann, 1959). *Uromyces doricus* has been documented to infect various species of the *Silene* members, including *Silene behen* L. (Gjaerum & Hansen, 1990), *S. caliacrae* Jordanov and Panov, *S. fabarioides* Hausskn., *S. gigantea* L., and *S. paradoxa* L. (Denchev, 1995). However, there has been no previous record of this fungus affecting *S. spergulifolia*. Therefore, the discovery of *U. doricus* on *S. spergulifolia* marks it as a novel host for this pathogen, expanding our understanding of its host range.

Uromyces scrophulariae is a unique type of the genus that specifically targets the *Scrophularia* species. This fungus is distinguished by its pale yellowish uredinia and urediniospores, which are evident on the host plant. Unlike other rust fungi, which may infect a variety of hosts, *Uromyces scrophulariae* has a specific relationship with *Scrophularia* species, showcasing these distinct fungal characteristics. *Uromyces scrophulariae* represents a distinct species of the genus, noted primarily for its specialized parasitic relationship with plants belonging to the genus *Scrophularia*. This particular species is characterized by its production of pale yellowish uredinia and urediniospores, key features that are visible on the surfaces of the infected host plants. The presence of these fungal structures is a hallmark of infection and distinguishes *U. scrophulariae* from other rust fungi, which may exhibit a broader host range and different physical manifestations (Wilson & Henderson, 1966).

Uromyces verbasci is distinguished as the sole rust fungus affecting *Verbascum* species, characterized by the presence of both uredinia and telia. Conversely, the relatively rare aecidium stage of *U. thapsi* Opiz ex Bubák can occasionally be observed on the same host plant (Gäumann, 1959).

Conclusion

The recent study has unveiled the presence of ten rust fungi species, including *Puccinia asperulae-cynanchicae*, *Puccinia difformis*, *Puccinia epilobii*, *Puccinia leveillei*, *Puccinia nevadensis*, *Puccinia passerinii*, *Puccinia tumida*, *Uromyces doricus*, *Uromyces scrophulariae* and *Uromyces verbasci* in

Türkiye for the first time at the species level. This discovery also brings to light new host-rust relationships, such as *Asperula orientalis* and *Asperula glomerata* for *Puccinia asperulae-cynanchicae*; *Epilobium angustifolium* for *Puccinia epilobii*; *Salvia tomentosa* for *Puccinia nevadensis*; and *Silene spergulifolia* for *Uromyces doricus*. These findings significantly increase the tally of known rust species in Türkiye to around 380. However, considering the wide range of potential host plants present in the country, it's highly probable that the actual number of rust fungi species is much larger. This highlights the urgent need for further comprehensive research on rust fungi in Türkiye to better understand their diversity and impact.

Ethics Committee Approval

N/A

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Author Contributions

Conceptualization: Ş.K., I.A, S.K. Investigation: Ş.K.; Material and Methodology: Ş.K., I.A, S.K.; Supervision: Ş.K.; Visualization: Ş.K., I.A.; Writing-Original Draft: Ş.K., I.A.; Writing-review & Editing Ş.K., I.A, S.K.; Other: All authors have read and agreed to the published version of manuscript.

Conflict of Interest

The Authors declare that there is no competing interests.

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