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A dynamic online documentation of Italian ascomycetes with hosts and substrates: www.italianmicrofungi.org

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Abstract

Early taxonomic studies of ascomycetous microfungi were conducted based on morphological observations. With the advent and advancement of DNA based molecular studies over the last few decades, species, genera, families and orders of Ascomycota have been subjected to rapid taxonomic changes. In the last eight years, we have introduced many novel fungal taxa with numerous new host and country records of ascomycetous microfungi from Italy. Dothideomycetes and Sordariomycetes are the major classes that we have investigated. These fungal species were collected from more than 300 host species in terrestrial habitats of different provinces in Italy. The hosts include shrubs, trees and grasses with the substrates differentiated as branches, stems and leaves. For these taxa, identification and classification were confirmed with comprehensive descriptions, colour illustrations and multi-gene phylogenetic analyses. These studies are scattered in different scientific journals. The online documentation at

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www.italianmicrofungi.org is a database for arranging all the published data together with novel updates of present and upcoming studies. Notes for species, genera and up-to-date records of Italian ascomycetes with accounts on different hosts and substrates are described here. This website provides a user-friendly and easily accessible framework to extract more information.

Keywords – Classification – Dothideomycetes – Phylogeny **–** Sordariomycetes **–** Taxonomy **–** Webpage

Introduction

Fungi are ubiquitous and a highly diverse group of eukaryotes (Hyde et al. 2018, Sun et al. 2019). Their lifestyles vary as biotrophic, endophytic, epiphytic, hemibiotrophic, saprobic or fungicolous (Hyde et al. 2018, Sun et al. 2019, Tennakoon et al. 2020). Over the last 300 years, fungal identification, classification, and speculation on the relationships among taxa were based on phenotypic characters. These phenotypic observations have been used as major tools of fungal researchers and were recorded with descriptions and line drawings (Hyde et al. 2011, Jayasiri et al. 2015, Tekpinar & Kalmer 2019, Tennakoon et al. 2020). However, morphology may not always reflect phylogenetic relationships (Judd et al. 2002). Identification of species based on morphology is challenging and highly subjective, especially among species complexes, non-sporulating fungi and cryptic species (Jeewon et al. 2002, Promputtha et al. 2005, 2007, Jayasiri et al. 2015). The initial investigations of phenotypic approaches, as well as chemical, ecological, molecular and physiological analyses, are very important in fungal taxonomy (Manawasinghe et al. 2019). The project, Assembling the Fungal Tree of Life (AFToL), provided molecular data for most of the orders and families of Ascomycota, and this was the start of the golden era of mycology (James et al. 2006, Hyde et al. 2020a). Morphology was linked to analyze the results from advanced molecular techniques, and DNA based phylogeny was developed as informative tools with better taxonomic resolution (Senanayake et al. 2017a, Hongsanan et al. 2018, Wanasinghe et al. 2018, Tennakoon et al. 2020). This combined taxonomic approach has led to the resolution of numerous taxonomic issues and has provided more reliable classification than traditional morphology-based tools (Jayasiri et al. 2015).

Earlier treatments in Italian mycology dealt with macrofungi (Venturella 1991). Alfonso Ciccarelli (1532–1585) completed the first mycological monograph for macrofungi in Italy based on morphological and organoleptic aspects of truffles (Ciccarelli 1564). However, Italian microfungal publications were concerned with only a few taxa (Venturella 1991). Giuseppe de Notaris (1805–1877), Vincenzo de Cesati (1806–1883) and Pier Andrea Saccardo (1845–1920) were significant early contributors to Italian, as well as world mycology (Onofri et al. 1999, Phukhamsakda et al. 2020). Pampaloni (1902) reported the fossil records of Italian ascomycetes related to the Miocene epoch. Saccardo (1882) provided detailed documentation for mycology and a rapid increase in microfungal studies occurred between 1931–1990 (Venturella 1991). A checklist of Sicilian fungi (Southern Italy) including hosts and substrates was published by Venturella (1991), and it is a very important resource for understanding Italian fungal diversity and ecology. Zucconi et al. (1997) studied the dematiaceous hyphomycetes microfungal communities in Mediterranean evergreen forests in central Italy. Venturella et al. (2011) reported the estimated number of regional ascomycetes and basidiomycetes up to 2010. The history of Italian mycology and the valuable contributions of great mycologists are reported by Siniscalco et al. (2013).

Ascomycota is the largest phylum, comprising Dothideomycetes and Sordariomycetes as major classes in the subphylum, Pezizomycotina (Hyde et al. 2013, 2020a, Maharachchikumbura et al. 2015, 2016, Wijayawardene et al. 2018, 2020, Hongsanan et al. 2020). PhD researchers and expert mycologists in the Center of Excellence in Fungal Research (CEFR) group have studied most of the Italian ascomycetes collected by Erio Camporesi who has promoted mycological studies as a prodigious amateur mycologist (Phukhamsakda et al. 2020). Currently, several PhD students at CEFR are studying fresh specimens from Erio Camporesi with amazing discoveries of novel taxa as well as novel host and geographical records of ascomycetes. These CEFR studies are

published regularly in different scientific journals. “Asian Journal of Mycology notes, Fungal diversity notes and Mycosphere notes” are key journal series providing more information of worldwide fungi and include many Italian ascomycetes (Ariyawansa et al. 2015, Wijayawardene et al. 2016, Hyde et al. 2017, 2019, 2020a, b, c, Senanayake et al. 2017b, Jayawardena et al. 2018, Wanasinghe et al. 2018, Phookamsak et al. 2019). Preserving scientific data through the documentation by recording fungal morphology, taxonomy and ecological information is a valuable process in mycology (Lange 2010). Mycologists have a responsibility to popularize fungal information, by inspiring and spreading informative outreach materials, and providing easily accessible websites, and openly accessed databases (Lange 2010). A strong foundation for applied biological fields such as ecology, pathology and industrial can be provided through spreading primary fungal taxonomic data.

Why Italian microfungi are very important?

Early studies of Italian microfungi were based on morphological observations, as was the case worldwide. Several mycologists in Italy contributed immensely to fungal systematics by extensive collections of fungal specimens. Notable among these were the collections and early studies by P. A. Saccardo. Italian fungal specimens are significant to study as among them are new orders, families, genera and species as well as new hosts and geographic reports. Recollecting fungal specimens can serve as epitypes and authentic herbarium materials of extant species with sequence data. The host specificity and life mode details can be updated when dealing with recollected specimens from different environments and host plants.

The need for Italian microfungi database

There is a massive collection of publications for Italian microfungi by the CEFR group. These documentations can be categorized as providing novel taxa, new host records and new geographical records from Italian sites. These publications comprise species descriptions, illustrations, and molecular phylogeny, which provides a comprehensive analysis of species delineation. However, it largely remains to reconstruct the accurate taxonomic placements for all taxa, especially for earliest studied taxa with their DNA sequence data. In our new website, we deal with the information of previously published Italian ascomycetes and will provide continuous updates from novel studies that are currently being processed by the CEFR group. The objectives of this website are to gather all information into one comprehensive source and to make it readily available to mycologists worldwide. This study provides up-to-date accounts of Italian ascomycetes on different hosts and substrates with recent taxonomic changes. In addition, we also provide notes on genera and species reported from Italy.

Importance of gathering morphological and ecological data into a single tool

The preference of modern researchers is increasingly to refer to databases rather than books and other publications to gather the scattered knowledge. A database is technically easy to handle and much less time-consuming. Therefore, gathering morphological and ecological data into a single tool is a very flexible and time-saving method for researchers. Index Fungorum (www.indexfungorum.org), MycoBank (www.mycobank.org), Facesoffungi (www.facesoffungi.org), Sordariomycetes (www.sordariomycetes.org), Dothideomycetes (www.dothideomycetes.org) and Coelomycetes (www.coelomycetes.org) are commonly used websites in studies of ascomycetes.

Italian microfungi website

In the Italian microfungi website, ascomycetous species associated with over 300 hosts from different regions in Italy have been identified. The substrates are reported mainly as branches (from shrubs and trees), stems (from herbaceous hosts and grasses) and rarely leaves (from shrubs, trees and grasses). These specimens are mainly from the provinces of Forlì-Cesena (in the region of Emilia-Romagna) and Arezzo (in the region of Tuscany) with fewer collections from the provinces

of Bologna and Ravenna (in Emilia-Romagna), Firenze (in Tuscany), Pesaro-Urbino (in Marche), Trento (in Trentino-Alto Adige) and Udine (Friuli-Venezia Giulia). This is an informative and user-friendly platform to provide in-depth knowledge of Italian ascomycetes and related host species. The host specificity and the life modes of Italian ascomycetes are evaluated. In the pursuit of discovering more fungi from Italy, this study is extending to investigate the taxonomy and phylogeny of microfungal taxa. In addition, the other websites from the CEFR group; Dothideomycetes (www.dothideomycetes.org; Pem et al. 2019), Sordariomycetes (www.sordariomycetes.org; Bundhun et al. 2020) and Coelomycetes (www.coelomycetes.org; Wijayawardene et al. 2016, Li et al. 2020) are linked to this new website for extracting relevant information of Italian ascomycetes.

Construction

Italian ascomycetes, which were identified and published by the CEFR group, are listed on the website together with their hosts and substrates. Species, which are currently being studied, will be regularly entered. For each entry of identified species, Index Fungorum, Facesoffungi, MycoBank and/or ex-type culture collection, dry culture collection, herbaria numbers and available GenBank numbers for sequence data are provided. Updated information is periodically inserted based on both previous and novel studies. Mycological experts who studied large numbers of Italian ascomycetes during the past eight years have been assigned as curators to share their knowledge and suggestions (Table 1).

Table 1 List of curators for Italian microfungi webpage

Position	**Name**	Email address
Head curator	Kevin Hyde	kdhyde3@gmail.com
Expert curator	Erio Camporesi	eriocamporesi@libero.it
Managing curator	Subodini Wijesinghe	nuwanthika.was90@gmail.com
Curators	Dhanushka Wanasinghe	dnadeeshan@gmail.com
	Indunil Senanayake	indunilchinthani@gmail.com
	Kasun Thambugala	kasunthambugala@gmail.com
	Rungtiwa Phooksamsak	jomjam.rp2@gmail.com
	Sinang Hongsanan	sinang333@gmail.com
	Sajeewa Maharachchikumbura	sajeewa83@yahoo.com
	Saowaluck Tibpromma	saowaluckfai@gmail.com

Database interface and visualization

The Italian microfungi website is functional, easy to access and navigate for searching. The overview of the homepage provides a comprehensive understanding of the website at a glance. There are several navigation bars, searching options and some informative details are visualized on the homepage (Figs 1, 2).

Details of main headings

- **Home –** The homepage provides a detailed account of our entire project (Figs 1, 2). When the user opens the webpage, the objectives are envisioned at the left top (Fig. 1a). The main headings are described as Home, Host/Substrate, Archives, Curators, History, References, News and Contact (Fig. 1b). Below the header bar, a search box is included where information on a specific fungal order, family, genus or species can be searched by entering the name (Fig. 1c). Recent news, genera and species which are updated (Fig. 1d) can be seen at the right side of the interface. The user can easily cite the webpage using the citation at the front (Fig. 1e). The contact details (Fig. 2a), publisher and copyright details are provided at the bottom (Fig. 2b).

- **Host/Substrate** – This gives the records of host occurrences on which fungal species are collected. We follow the International Plant Names Index (IPNI) for host identification. The search option is provided for easy searching of the hosts, based on user requirements (Fig. 3).
- **Archives** – Through this heading, the user can find the taxonomic classification of related taxa at order, family, genus and species level (Fig. 4). When the user opens the "Archives**"** interface, the list of orders related to Italian fungi is visualized. By clicking on relevant order, the link will navigate to "Read more about the order" or related family list of the order. Inside families, the list of associated genera and species are available.
- **Curators** – Photographs and contact details of curators are provided (Fig. 5, Table 1).
- **History** – An account of Italian mycological history, ascomycetes, host list and collecting provinces are provided (Fig. 6).
- **References** – A list of references used in the entries, history and other information related to the Italian ascomycetes are provided under this heading.
- **News** – The key events, new findings and important information regarding Italian microfungi are included here.
- **Contact** – Users can provide their comments and suggestions on this webpage.

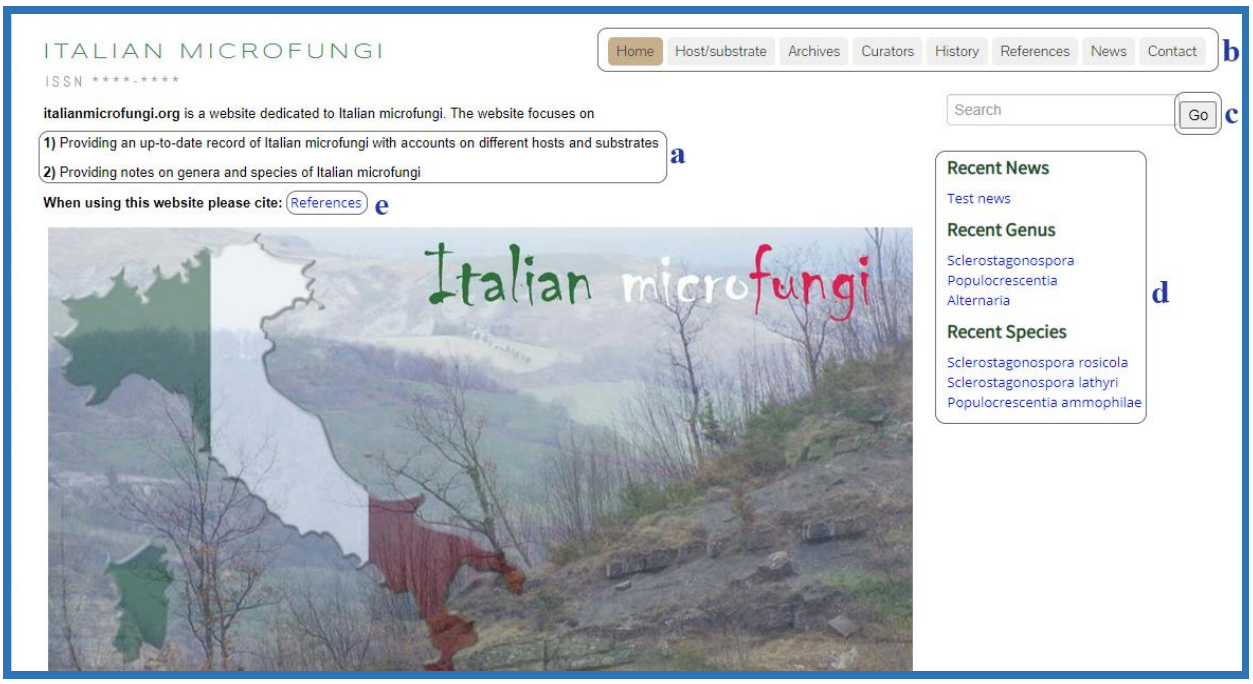

Fig. 1 – Homepage view of Italian microfungi webpage. a Objectives of the webpage. b Headers. c Search box. d Recently updated news, recent genera and species. e Citation of the webpage.

Fig. 2 – Bottom view of the homepage. a Contact details. b Publisher and copyright information.

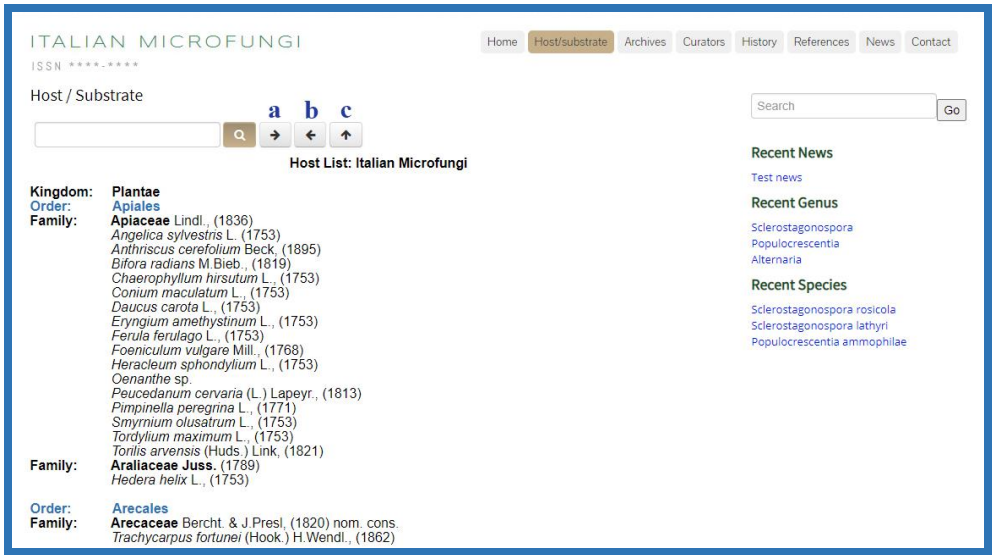

Fig. 3 – Host/substrate header of the webpage. a Find next. b Find previous. c Back to top.

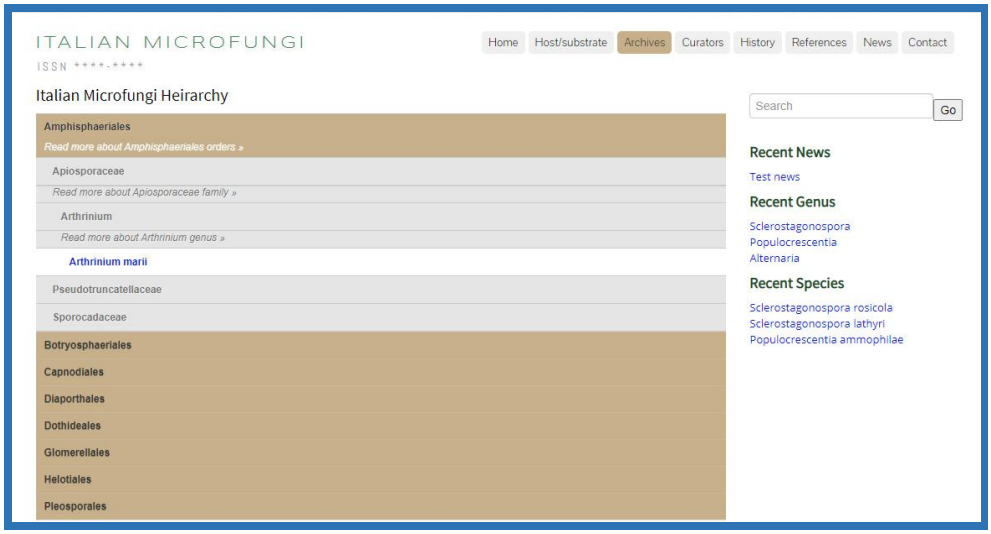

Fig. 4 – Archives header of the webpage.

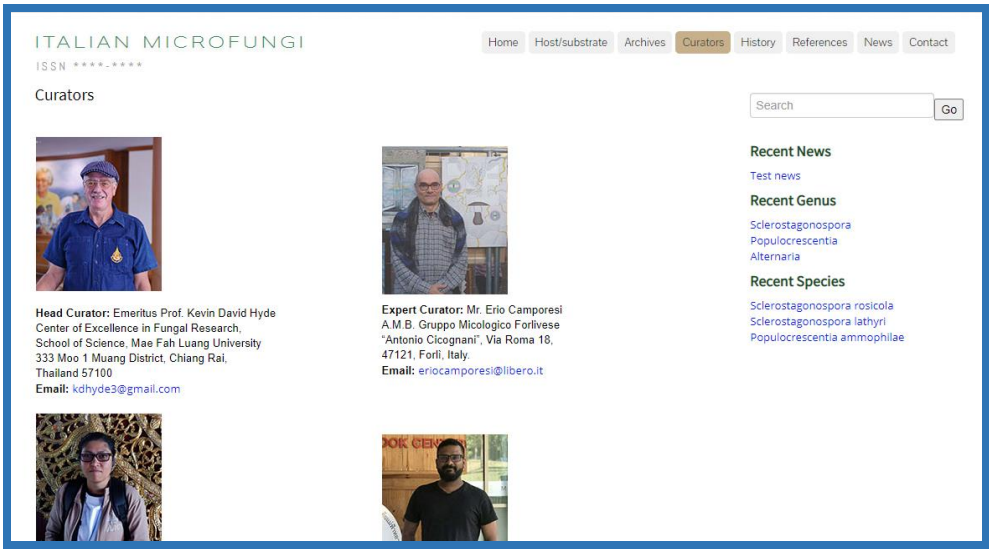

Fig. 5 – Curators header of the webpage.

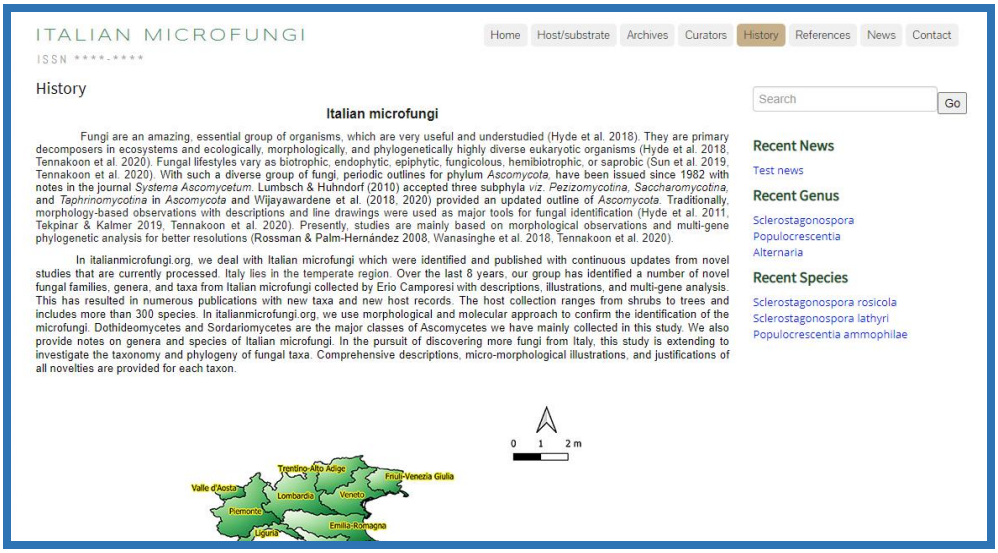

Fig. 6 – History header of the webpage.

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