Global Taxonomy and Phylogeny of Irpicaceae (Polyporales, Basidiomycota) With Descriptions of Seven New Species and Proposals of Two New Combinations

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The phylogenetic analyses of the family Irpicaceae were carried out based on a complete global sampling. The dataset that included concatenated ITS1-5.8S-ITS2 and nrLSU sequences of 67 taxa of Irpicaceae from around the world was subjected to the maximum likelihood analyses and Bayesian inference. In the phylogenetic tree, species from 14 genera were distributed in nine clades, among which five genera—Irpex, Phanerochaetella, Byssomerulius, Cytidiella, and Merulopsis, received high support values. The genus Efibula was shown to be paraphyletic and four subclades could be recognized, while Phanerochaete allantospora, Leptoporus mollis, and several species from Ceriporia and Candelabrochaete formed a large clade with relatively strong support.

Based on the molecular and morphological evidence, seven new corticioid species—Candelabrochaete guangdongensis, Efibula grandinosa, E. hainanensis, E. shenghuae, E. taiwanensis, Irpex alboflavescens, and Phanerochaetella sinensis, were revealed from the materials mostly from East Asia. The monotypic genus Flavodontia, newly described from southwestern China, is regarded as a later synonym of Irpex, and the new combination I. rosea is proposed. In addition, Phanerochaetella queletii is proposed for a taxon first described from Italy and newly recorded from China; Phanerochaete josepherreirae from Portugal is determined to be a later synonym. Descriptions and illustrations of the new species and the newly combined taxa are presented, and morphological comparisons for the known species of Efibula and Phanerochaetella are provided.

Keywords: corticioid fungi, East Asia, Phanerochaete s.l., phlebioid clade, white rot, wood-decaying fungi

INTRODUCTION

The phlebioid clade of Polyporales includes lots of wood-decaying fungi, which were distributed in the three well-supported families: Phanerochaetaceae, Irpicaceae, and Meruliciaceae (Floudas and Hibbett, 2015; Miettinen et al., 2016; Justo et al., 2017; Chen et al., 2021). Irpicaceae is a relatively new and small family with 13 corticioid and polyporoid genera accepted at present (Spirin, 2003): Byssomerulius Parmasto, Ceriporia Donk,
MATERIALS AND METHODS
Specimen Collection
Field trips for specimen collection in many kinds of Nature Reserves and Forest Parks in China and other countries were carried out by the authors. In situ photographs of the fungi were taken with a Canon camera EOS 70D (Canon Corporation, Japan). Fresh specimens were dried with a portable drier (manufactured in Finland). Dried specimens were labeled and then stored in a refrigerator at minus 40 °C for two weeks to kill the insects and their eggs before they were ready for morphological and molecular studies.

Morphological Studies
Voucher specimens are deposited at the herbaria of Beijing Forestry University, Beijing, China (BJFC), Centre for Forest Mycology Research, U.S. Forest Service, Madison, Wisconsin, USA (CFMR), and National Museum of Natural Science, Taichung, Taiwan, China (TNM). Herbarium code designations follow Index Herbariorum1 Thin, freehand sections were made from dried basidiomata and mounted in 2% (w/v) aqueous potassium hydroxide (KOH) and 1% (w/v) aqueous phloxine. Amyloidity and dextrinoidity of basidiospores were checked in Melzer's reagent (IKI). Cyanophily of hyphal and basidiospore walls was observed in 1% (weight/volume) cotton blue in 60% (w/v) lactic acid (CB). Microscopic examinations were carried out with a Nikon Eclipse 80i microscope (Nikon Corporation, Japan) at magnifications up to 1,000 ×. Drawings were made with the aid of a drawing tube. The following abbreviations are used: IKI−= neither amyloid nor dextrinoid, CB−= acyanophilous, L= mean spore length, W= mean spore width, Q= L/W ratio, n(a/b)= number of spores (a) measured from number of specimens (b). Color codes and names follow Kornerup and Wanscher (1978).

DNA Extraction and Sequencing
A CTAB plant genomic DNA extraction Kit DN14 (Aidlab Biotechnologies Co., Ltd, Beijing, China) was used to extract total genomic DNA from dried specimens and then amplified by the polymerase chain reaction (PCR), according to the manufacturer's instructions. The ITS1-5.8S-ITS2 region was amplified with the primer pair ITS5/ITS4 (White et al., 1990) using the following protocol: initial denaturation at 95 °C for 4 min, followed by 34 cycles at 94 °C for 40 s, 58 °C for 45 s and 72 °C for 1 min, and final extension at 72 °C for 10 min. The nrLSU D1-D2 region was amplified with the primer pair LR0R/LR72 employing the following procedure: initial denaturation at 94 °C for 1 min, followed by 34 cycles at 94 °C for 30 s, 50 °C for 1 min and 72 °C for 1.5 min, and final extension at 72 °C for 10 min. DNA sequencing was performed at Beijing Genomics Institute, and the sequences were deposited in GenBank3 (Table 1). BioEdit v.7.0.5.3 (Hall, 1999) and Geneious Basic v.11.1.15 (Kearse et al., 2012) were used to review the chromatograms and for contig assembly.

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1http://sweetgum.nybg.org/science/ih/
2http://www.biology.duke.edu/fungi/mycolab/primers.htm
3https://www.ncbi.nlm.nih.gov/
### TABLE 1 | Species and sequences used in the phylogenetic analyses.

| Taxa                              | Voucher       | Locality | ITS          | nrLSU        | Reference                      |
|-----------------------------------|---------------|----------|--------------|--------------|--------------------------------|
| Byssomerulius corium              | FP-102382     | USA      | KP135007     | KP135230     | Floudas and Hibbett, 2015      |
| Byssomerulius corium              | WEI 17-645    | China    | LC427006     | LC427030     | Chen et al., 2020              |
| Candelabrochaete guangdongensis   | He 5902*      | China    | MZ422527     | MZ422499     | Present study                  |
| Candelabrochaete langloisii       | FP-110343-Sp  | USA      | KY948793     | KY948886     | Justo et al., 2017             |
| Candelabrochaete septocystidia    | AS-95         | Sweden   | EU118609     | EU118609     | Larsson, 2007                  |
| Candelabrochaete septocystidia    | RLG-9759-Sp   | USA      | —            | GQ470631     | Wu et al., 2010                |
| Candelabrochaete septocystidia    | RLG119sp      | USA      | KY948783     | —            | Justo et al., 2017             |
| Ceriporia arbuscula               | GC 1708-338   | China    | LC427008     | LC427040     | Chen et al., 2020              |
| Ceriporia mellita                 | GC 1508-71    | China    | LC427022     | LC427044     | Chen et al., 2020              |
| Ceriporia mellita                 | WEI 17-024    | China    | LC427024     | LC427046     | Chen et al., 2020              |
| Ceriporia purpurea                | GC 1703-81    | China    | LC427020     | LC427037     | Chen et al., 2020              |
| Ceriporia reticulata              | RLG-11354-Sp  | USA      | KP135041     | KP135204     | Floudas and Hibbett, 2015      |
| Ceriporia reticulata              | Wu 1707-171   | China    | LC427021     | LC427038     | Chen et al., 2020              |
| Ceriporia viridans                | GC 1708-211   | China    | LC427027     | LC427049     | Chen et al., 2020              |
| Ceriporia viridans                | Mietitten 11701 | Netherlands | KX752600 | KX752600 | Mietitten et al., 2016        |
| Crystallicutis damiellensis       | UN63A         | Egypt    | KX428470     | —            | El-Gharabawy et al., 2016      |
| Crystallicutis rajchenbergii      | MR-4310       | USA      | KY948797     | KY948888     | Justo et al., 2017             |
| Crystallicutis serpens            | HHB-156692-Sp | USA      | KP135031     | KP135200     | Floudas and Hibbett, 2015      |
| Crystallicutis sp.                | FP-101245-Sp  | USA      | KP135029     | —            | Floudas and Hibbett, 2015      |
| Cytidiella albida                 | GB-1833       | Spain    | KY948748     | KY948889     | Justo et al., 2017             |
| Cytidiella abomarginata           | He 5575       | China    | MZ422526     | MZ422497     | Present study                  |
| Cytidiella abomarginata           | WEI 18-474    | China    | MZ639698     | MZ637110     | Chen et al., 2021              |
| Cytidiella albomellea             | FP-101843-sp  | USA      | AY219369     | —            | De Koker et al., 2003          |
| Cytidiella albomellea             | He 3089       | China    | MZ422525     | MZ422496     | Present study                  |
| Cytidiella nitidula               | He 5126       | China    | MZ422523     | MZ422494     | Present study                  |
| Cytidiella nitidula               | He 5135       | China    | MZ422524     | MZ422495     | Present study                  |
| Cytidiella nitidula               | Nystroem 020830 | Sweden     | EU118655     | EU118655     | Larsson, 2007                  |
| Cytidiella nitidula               | T-407         | Canada   | KY948747     | —            | Justo et al., 2017             |
| Cytidiella sp.                    | He 6198       | China    | —            | MZ4242498    | Present study                  |
| Cytidiella sp.                    | Wu 0010-171   | China    | MZ639651     | MZ637114     | Chen et al., 2021              |
| Cytidiella sp.                    | Wu 1409-168   | China    | MZ639652     | MZ637115     | Chen et al., 2021              |
| Efibula americana                 | FP-102165     | USA      | KP135016     | KP135256     | Floudas and Hibbett, 2015      |
| Efibula americana                 | HHB-10209-Sp  | USA      | KP135014     | —            | Floudas and Hibbett, 2015      |
| Efibula clarkii                   | FD-228        | USA      | KP135019     | —            | Floudas and Hibbett, 2015      |
| Efibula gracilis                  | FD-455        | USA      | KP135027     | —            | Floudas and Hibbett, 2015      |
| Efibula gracilis                  | FP-102052     | USA      | KP135028     | —            | Floudas and Hibbett, 2015      |
| Efibula grandinosa                | He 6312s*     | China    | MZ422509     | MZ422480     | Present study                  |
| Efibula hainanensis               | He 6004*      | China    | MW580949     | MW580939     | Present study                  |
| Efibula hainanensis               | Chen 1294     | China    | ON117184     | —            | Present study                  |
| Efibula intertexta                | Wu 1707-96    | China    | MZ639654     | MZ637118     | Chen et al., 2021              |
| Efibula matsuensis                | Chen 1510     | China    | MZ639655     | —            | Chen et al., 2021              |
| Efibula shenghuai                 | He 3384*      | China    | MZ422508     | MZ422479     | Present study                  |
| Efibula sp.                       | FCOUG 305     | Sweden   | MZ639659     | GQ470669     | Wu et al., 2010; Chen et al., 2021 |
| Efibula sp.                       | Wu 1707-79    | China    | MZ639661     | MZ637123     | Chen et al., 2021              |
| Taxa                | Voucher | Locality | ITS         | nrLSU        | Reference                        |
|---------------------|---------|----------|-------------|--------------|----------------------------------|
| *Efibula subglobispora* | Chen 1716 | China    | MZ636962    | MZ637124     | Chen et al., 2021               |
| *Efibula subglobispora* | He 3983  | China    | MW580944    | MW580934     | Present study                   |
| *Efibula subglobispora* | He 7032  | China    | MZ422506    | MZ422477     | Present study                   |
| *Eibula taywanensis*   | He 4582a* | China    | MZ636966    | MZ637128     | Chen et al., 2021               |
| *Eibula tropica*       | He 6008  | China    | MW580947    | MW580937     | Present study                   |
| *Eibula tropica*       | WEI 18-149 | China  | MZ636967    | MZ637129     | Chen et al., 2021               |
| *Eibula tuberculata*   | OM-6707  | Finland  | KP135017     | —             | Floudas and Hibbett, 2015       |
| *Eibula tuberculata*   | OM-11754 | Finland  | KP135018     | —             | Floudas and Hibbett, 2015       |
| *Eibula turgida*       | He 3145  | China    | MW580945    | MW580935     | Present study                   |
| *Eibula turgida*       | He 6711  | China    | MW580946    | MW580936     | Present study                   |
| *Eibula turgida*       | Wu 0910-99 | China  | MZ636973    | MZ637135     | Chen et al., 2021               |
| *Eibula yunnanensis*   | CLZhao 11641 | China | MT611529     | —             | Ma et al., 2020                 |
| *Eibula yunnanensis*   | He 4653  | China    | MZ422505    | MZ422476     | Present study                   |
| *Eibula yunnanensis*   | He 6970  | China    | MZ422502    | MZ422473     | Present study                   |
| *Eibula yunnanensis*   | He 7032  | China    | MZ636967    | MZ637129     | Present study                   |
| *Eibula yunnanensis*   | He 4582a* | China    | MZ636966    | MZ637128     | Chen et al., 2021               |
| *Eibula yunnanensis*   | He 6008  | China    | MW580947    | MW580937     | Present study                   |
| *Eibula yunnanensis*   | WEI 18-149 | China  | MW580947    | MW580938     | Present study                   |
| *Eibula yunnanensis*   | WEI 18-149 | China  | MW580947    | MW580938     | Present study                   |
| *Hapalopilus ochraceolatentus* | Miettinen 16992 | USA  | KY948741    | KY948891     | Justo et al., 2017              |
| *Irpea alboflavescens* | FP-160003 | USA      | KP135022     | —             | Zmitrovich and Malyshova, 2014  |
| *Irpea alboflavescens* | He 3933* | China    | MZ422503    | MZ422474     | Present study                   |
| *Irpea alboflavescens* | He 4719  | China    | MZ422501    | MZ422472     | Present study                   |
| *Irpea alboflavescens* | He 5783  | Sri Lanka | MZ422500    | MZ422471     | Present study                   |
| *Irpea alboflavescens* | He 5835  | Sri Lanka | MZ422504    | MZ422475     | Present study                   |
| *Irpea alboflavescens* | He 6355  | Malaysia | MZ422502    | MZ422473     | Present study                   |
| *Irpea alboflavescens* | Wu 910807-35 | China | MZ636994    | GQ470627     | Wu et al., 2010; Chen et al., 2021 |
| *Irpea flavus*         | LE295997 | Tanzania | KF856505    | KF856510     | Zmitrovich and Malyshova, 2014  |
| *Irpea flavus*         | WHC 1381 | China    | LC427029    | LC427052     | Chen et al., 2020               |
| *Irpea flavus*         | KUC20121109-01 | South Korea | KJ668510    | KJ668362     | Jang et al., 2016              |
| *Irpea hydnoides*      | Dai 22402 | China    | MZ787973    | MZ787965     | Tian et al., 2022              |
| *Irpea jinshaensis*    | Dai 13638A | China  | KX494576    | KX494580     | Yuan et al., 2017              |
| *Irpea lacteus*        | FD-9     | USA      | KP135026    | KP135224     | Floudas and Hibbett, 2015      |
| *Irpea lacteus*        | FD-93    | USA      | KP135025    | —             | Floudas and Hibbett, 2015      |
| *Irpea lacteus*        | FP-55521T | USA      | KP135024    | KP135202     | Floudas and Hibbett, 2015      |
| *Irpea lacteus*        | Platek 1997 | Poland  | KX752592    | KX752592     | Miettinen et al., 2016         |
| *Irpea lenis*          | Wu 1608-22 | China    | MZ636992    | MZ637153     | Chen et al., 2021              |
| *Irpea rosea*          | He 6277  | China    | MW580943    | MW580933     | Present study                   |
| *Irpea rosea*          | CLZhao 18491* | China  | MW377575    | MW377578     | Wang and Zhao, 2022            |
| *Irpea rosea*          | CLZhao 18489 | China  | MW377574    | MW377577     | Wang and Zhao, 2022            |
| *Irpea rosettiformis*  | LR40855  | USA      | JN649347    | JN649347     | Sjökvist et al., 2012          |
| *Irpea rosettiformis*  | Meijer3729 | Brazil  | JN649346    | JN649346     | Sjökvist et al., 2012          |
| *Irpea subulatus*      | BPI 893213 | USA      | NR_154000   | NG_060421    | Simmons et al., 2016           |
| *Irpea subulatus*      | CLZhao 3341 | China  | MH114652    | —             | Unpublished                    |
| *Irpea subulatus*      | Cui 7275 | China    | KY131836    | KY131895     | Wu et al., 2017                |
| *Irpea subulatus*      | Dai 5929 | China    | KY131837    | KY131896     | Wu et al., 2017                |
| *Irpea subulatus*      | He 3468  | China    | MW580942    | MW580932     | Present study                   |
| *Leptoporus mollis*    | RLG7163  | USA      | KY948794    | EU402510     | Justo et al., 2017             |
| *Leptoporus mollis*    | TJV-93-174T | USA     | KY948795    | —             | Lindner and Bank, 2008; Justo et al., 2017 |
### TABLE 1 | Continued

| Taxa                        | Voucher       | Locality      | ITS         | nrLSU        | Reference                  |
|-----------------------------|---------------|---------------|-------------|--------------|----------------------------|
| Merulopsis crassitunicata   | CHWC 1506-46  | China         | LC427010    | LC427034     | Chen et al., 2020          |
| Merulopsis leptocystidiata  | Wu 1708-43    | China         | LC427013    | LC427033     | Chen et al., 2020          |
| Merulopsis parvispora       | Wu 1209-58    | China         | LC427017    | LC427039     | Chen et al., 2020          |
| Merulopsis taxicola         | GC 1704-60    | China         | LC427028    | LC427050     | Chen et al., 2020          |
| Phanerochaete allantospora  | KKN-111-Sp    | USA           | KP135038    | KP135238     | Floudas and Hibbett, 2015  |
| Phanerochaete allantospora  | RLG-10478     | USA           | KP135039    | —            | Floudas and Hibbett, 2015  |
| Phanerochaetella angustocystidiata | He 4789    | China         | MZ422513    | MZ422484     | Present study              |
| Phanerochaetella angustocystidiata | He 3167    | China         | MZ422514    | MZ422485     | Present study              |
| Phanerochaetella angustocystidiata | He 2965    | China         | MZ422515    | MZ422486     | Present study              |
| Phanerochaetella angustocystidiata | CLZhao 8393 | China         | MK404428    | —            | Unpublished                |
| Phanerochaetella angustocystidiata | KUC20121102-15 | South Korea | KJ668492    | KJ668346     | Unpublished                |
| Phanerochaetella exilis     | Wu 9606-39    | China         | —           | GQ470638     | Wu et al., 2010            |
| Phanerochaetella formosana  | HHB-6988-Sp   | USA           | KP135001    | KP135236     | Floudas and Hibbett, 2015  |
| Phanerochaetella formosana  | Chen 479      | China         | —           | GQ470650     | Wu et al., 2010            |
| Phanerochaetella formosana  | He 3962       | China         | MZ422522    | MZ422493     | Present study              |
| Phanerochaetella formosana  | He 4411       | China         | MZ422521    | MZ422492     | Present study              |
| Phanerochaetella leptoderma | 103526        | India         | —           | KP715577     | Unpublished                |
| Phanerochaetella leptoderma | Chen 1362     | China         | —           | GQ470646     | Wu et al., 2010            |
| Phanerochaetella queletii   | He 3050       | China         | MZ422512    | MZ422483     | Present study              |
| Phanerochaetella queletii   | He 3284       | China         | MZ422510    | MZ422481     | Present study              |
| Phanerochaetella queletii   | He 20120917-10 | China         | MZ422511    | MZ422482     | Present study              |
| Phanerochaetella queletii   | HHB-11463     | USA           | KP134994    | KP135235     | Floudas and Hibbett, 2015  |
| Phanerochaetella sinensis   | He 3509       | China         | MZ422517    | MZ422488     | Present study              |
| Phanerochaetella sinensis   | He 4229*      | China         | MZ422518    | MZ422489     | Present study              |
| Phanerochaetella sinensis   | He 5071       | China         | MZ422519    | MZ422490     | Present study              |
| Phanerochaetella sp.        | FP-102936     | USA           | KP135000    | —            | Floudas and Hibbett, 2015  |
| Phanerochaetella sp.        | HHB-18104     | New Zealand   | KP135003    | KP135254     | Floudas and Hibbett, 2015  |
| Phanerochaetella xerophila  | HHB-8509-Sp   | USA           | KP134996    | KP135259     | Floudas and Hibbett, 2015  |
| Phanerochaetella xerophila  | KKN-172-Sp    | USA           | KP134997    | —            | Floudas and Hibbett, 2015  |
| Raduliporus anerina         | HHB-15629-Sp  | USA           | KP135023    | KP135207     | Floudas and Hibbett, 2015  |
| Resiniporus resinascens     | BRNM 710169   | Czech Republic | FJ496675    | FJ496698     | Tomášovský et al., 2010    |
| Trametopsis aborigena       | Robledo 1236  | Argentina     | KY655336    | KY655338     | Lopes et al., 2017         |
| Trametopsis cervina         | TJV-93-216T   | USA           | JN165020    | JN164796     | Justo and Hibbett, 2011    |
| Outgroup                    |               |               |             |              |                            |
| Gloeoporus dichrous         | FP-151129     | USA           | KP135058    | KP135213     | Floudas and Hibbett, 2015  |
| Gloeoporus pannocinctus     | L-15726-Sp    | USA           | KP135060    | KP135214     | Floudas and Hibbett, 2015  |

New species and new combinations are set in bold with type specimens indicated with an asterisk *. 
Phylogenetic Analyses

The molecular phylogeny was inferred from a concatenated dataset of ITS-nrLSU sequences of species in the Irpicaceae. *Gloeoporus dichrous* (Fr.) Bres. and *G. pannocinctus* (Romell) J. Erikss. were selected as the outgroup (Floudas and Hibbett, 2015; Chen et al., 2021). The ITS and nrLSU sequences were aligned separately using MAFFT v.7.4.8 (Katoh et al., 2017) with the G-INS-I iterative refinement algorithm and optimized manually in BioEdit v.7.0.5.3. The separate alignments were then concatenated using Mesquite v.3.5.1 (Maddison and Maddison, 2018). The datasets were deposited in TreeBase5 (submission ID: 29610).

Maximum likelihood (ML) analyses and Bayesian inference (BI) were carried out by using RAxML v.8.2.10 (Stamatakis, 2014) and MrBayes 3.2.6 (Ronquist et al., 2012), respectively. In ML analysis, statistical support values were obtained using rapid bootstrapping with 1000 replicates, with default settings used for other parameters. For BI, the best-fit substitution model was estimated with jModeltest v.2.17 (Darriba et al., 2012). Four Markov chains were run for 8,000,000 generations until the split deviation frequency value was lower than 0.01. Trees were sampled every 100th generation. The first quarter of the trees, which represented the burn-in phase of the analyses, were discarded, and the remaining trees were used to calculate posterior probabilities (BPP) in the majority rule consensus tree.

RESULTS

Phylogenetic Analyses

The concatenated ITS-nrLSU dataset contained 120 ITS and 101 nrLSU sequences from 126 samples representing 69 taxa of Irpicaceae (Table 1). The concatenated dataset had an aligned length of 2220 characters. jModelTest suggested that GTR+I+F was the best-fit model of nucleotide evolution for the concatenated ITS-nrLSU. The average standard deviation of split frequencies of BI was 0.007321 at the end of the run. ML analyses resulted in almost identical tree topology compared to the BI analysis. Only the BI tree is provided in Figure 1 with the likelihood bootstrap values (≥50%, before the slash) and Bayesian posterior probabilities (≥0.95, behind the slash) labeled along the branches.

The topology of the tree is similar to those in previous studies (Justo et al., 2017; Chen et al., 2021). For the ingroups, species from 14 genera were distributed in nine clades: *Irpex*, *Efibula*, *Phanerochaetella*, *Byssosporiulus*, *Cytidiella*, *Raduliporus*, *Resiniporus*, *Trametopsis*, *Crystallicitus*, *Meruliposis*, *Ceriporia* s.l./ *Leptoporus*/*Candelabrochaete* s.l./ *Phanerochaete* s.l. While *Irpex*, *Phanerochaetella*, *Byssosporiulus*, *Cytidiella*, and *Meruliposis* received high support values, and the genus *Efibula* was shown to be polyphyletic. *Raduliporus*, *Resiniporus*, and *Trametopsis* formed a strongly supported clade. The monophyly of *Crystallicitus* was not well-supported in our tree. *Phanerochaete allantospora*, *Leptoporus mollis*, and several species from *Ceriporia* and *Candelabrochaete* formed a large clade with relatively strong support. Seven new species—*Candelabrochaete guangdongensis*, *Efibula grandinosa*, *E. hainanensis*, *E. shenghuai*, *E. taiwanensis*, *Irpex alboflavescens*, and *P. sinensis*, formed distinct lineages in the tree. For *Irpex rosea*, our sample (He 6277) and the type materials of *Flavodontia rosea* (Zhao 18489 and Zhao 18491) formed a distinct lineage in the *Irpex* clade, while for *Phanerochaetella queletii*, samples from China and USA grouped together with strong support values.

Taxonomy

*Candelabrochaete guangdongensis* Y. Li and S.H. He, sp. nov.

MycoBank: MB843531

Type—China, Guangdong Province, Shixing County, Chebaling Nature Reserve, on fallen angiosperm trunk, June 14, 2019, He 5902 (BJFC 030777, holotype).

Etymology—Refers to the type locality in Guangdong Province, southern China.

Fruiting body—Basidiomata annual, resupinate, widely effused, closely adnate, inseparable from substrate, ceraceous, first as small patches, later confluent up to 9-cm long, 3-cm wide, up to 250-µm thick in section. Hymenophore smooth, orange [6B(7–8)] to reddish orange [7B(7–8)], turning reddish black in KOH, rarely cracked; margin thinning out, determinate, adnate, concolorous with or darker than hymenophore surface. Context cream.

Microscopic structures—Hyphal system monomitic; generative hyphae simple-septate. Subiculum distinct; hyphae colorless, slightly to distinctly thick-walled, smooth, usually branched at a right angle, frequently septate, loosely interwoven, 3–6-µm in diam. Subhymenium thickening, composed of collapsed hymenia; hyphae colorless, thin- to slightly thick-walled, vertically arranged, frequently branched and septate, 2–4-µm in diam. Septocystidia abundant, cylindrical, usually sinuous, frequently septate, colorless, slightly thick-walled, smooth, or sometimes slightly encrusted with yellowish granules at the apex, arising from the subiculum, mostly embedded, projecting up to 40-µm beyond hymenium, 145–190 × 6–10-µm. Basidia clavate to subcylindrical, colorless, thin-walled, smooth, with a basal simple septum and four sterigmata, 16–24 × 1.5–2 µm. Basidiospores short-cylindrical to allantoid, with an apiculus, colorless, thin-walled, smooth, IKI–, CB–, 4–5 × 1.5–2 µm, L = 4.5 µm, W = 1.7 µm, Q = 2.6 (n = 30/1).

Notes—*Candelabrochaete guangdongensis* (Figure 2) is characterized by the ceraceous basidiomata with a smooth hymenophore that turns black in KOH, large septocystidia and short-cylindrical to allantoid basidiospores. In the phylogenetic tree (Figure 1), *C. guangdongensis* is closely related to *C. septocystidia* (Burt) Burds., and morphologically both species have smooth hymenophore, large septocystidia, and allantoid basidiospores. However, *C. septocystidia* can be distinguished from *C. guangdongensis* by having a hymenophore unchanged in KOH, slightly longer basidiospores (4.5–6.5 µm), distinctly encrusted septocystidia, and a distribution in North America and Europe (Burdsall, 1984). *Candelabrochaete macaronesica* M. Dueñas, Telleria and Melo is similar to *C. guangdongensis* by sharing smooth hymenophore and large septocystidia but differs in having slightly larger ellipsoid basidiospores and a
Li et al. Taxonomy and Phylogeny of Irpicaceae
distribution in Portugal (5–6.5×2–3.5µm, Dueñas et al., 2008). Candelabrochaete neocaledonica Duham and Buyck has similar septocystidia and basidiospores with C. guangdongensis but differs in having a distinctly hydnyid hymenophore (Duham and Buyck, 2011).

Efibula grandinosa Y. Li and S.H. He, sp. nov.
MycoBank: MB843532
Type—China, Yunnan Province, Shizong County, Junzishan Forest Park, on dead angiosperm branch, November 18, 2019, He 6312 (BJFC 033256, holotype).

Etymology—Refers to the grandinioid hymenophore due to the projecting hyphal pegs.

Fruiting body—Basidiomata annual, resupinate, widely effused, closely adnate, inseparable from substrate, membranaceous, first as small patches, later confluent up to 10-cm long, 3-cm wide, up to 250-µm thick in section. Hymenophore grandinioid with projecting hyphal pegs, pale orange (6A3) to grayish orange [6B(4–5)], slightly darkening in KOH, not cracking upon drying; margin thinning out, adnate, indistinct, paler than hymenophore surface, white. Context orange white.
Microscopic structures—Hyphal system monomitic; generative hyphae simple-septate. Subiculum distinct; hyphae colorless, thin- to slightly thick-walled, smooth, moderately branched, frequently united, loosely interwoven, 2.5–3.8 μm in diam. Subhymenium thin; hyphae colorless, thin-walled, smooth, moderately branched and septate, interwoven. Cystidia absent. Hyphal pegs scattered, largely projecting beyond hymenium, composed of many vertically arranged hyphae; hyphae colorless, thin-walled, smooth or occasionally encrusted with crystals, unbranched, infrequently septate. Basidia clavate, colorless, thick-walled, smooth, with a basal simple septum and four sterigmata, 36–43 × 5–7 μm. Basidiospores ellipsoid, with an apiculus, colorless, thin-walled, smooth, IKI–, CB–, 6–6.8 (–7) × (3.5–) 3.7–4 (–4.1) μm, L = 6.4 μm, W = 3.9 μm, Q = 1.7 (n = 30/1).

Notes—Efibula grandinosa Figure 3 is characterized by having a grandinioid hymenophore and hyphal pegs. In the phylogenetic tree (Figure 1), E. grandinosa and E. shenghuae formed a strongly supported lineage sister to E. clarkii Floudas and Hibbett. Morphologically, although all the three species have grandinioid or tuberculate hymenophore, E. shenghuae and E. clarkii can be easily distinguished from E. grandinosa by lacking hyphal pegs (Floudas and Hibbett, 2015).

Efibula hainanensis Y. Li and S.H. He, sp. nov. MycoBank: MB843533
Type—China, Hainan Province, Changjiang County, Bawangling Nature Reserve, on dead liana, July 4, 2019, He 6004 (BJFC 030880, holotype).
**FIGURE 2** | Candelabraete guangdongensis (from the holotype He 5902; scale bars: a = 1 cm; b–d, f = 10 µm; e = 20 µm). (A) Basidiomata. (B) Basidiospores. (C) Basidia. (D) Basidioles. (E) Septocystidia. (F) Hyphae from subiculum.
Figure 3 | *Efibula* grandinosa (from the holotype He 6312; scale bars: a = 1 cm; b–e = 10 μm). (A) Basidiomata. (B) Basidiospores. (C) Basidia. (D) Basidioles. (E) Hyphae from subiculum.
Etymology—Refers to the type locality in Hainan Province, southern China.

Fruiting body—Basidiomata annual, resupinate, widely effused, closely adnate, inseparable from substrate, membranaceous, first as small patches, later confluent up to 8-cm long, 2.5-cm wide, up to 200-µm thick in section. Hymenophore smooth, pale orange (5A3) to brownish orange [5C(4–5)], turning black in KOH, not cracking upon drying; margin thinning out, adnate, indistinct, fimbriate, paler than hymenophore surface, white to pale yellow. Context pale yellow.

Microscopic structures—Hypothallus system monomitic; generative hyphae simple-septate. Subiculum distinct; hyphae colorless, thin- to thick-walled, usually encrusted with small crystals, straight, rarely branched, infrequently septate, loosely interwoven, 1.8–3.5 µm in diam. Subhymenium thin; hyphae colorless, thin-walled, encrusted with fine crystals, moderately septate. Cystidia rare, subfusiform to subcylindrical, colorless, thin-walled, smooth, with a basal simple septum, embedded or slightly projecting beyond the hymenium, 30–50 × 5–9 µm. Basidia clavate, colorless, thin-walled, smooth, with a basal simple septum and four sterigmata, 23–38 × 4.5–7 µm. Basidiospores oblong ellipsoid, with an apiculus, colorless, thin-walled, smooth, IKI–, CB–, (6.8–) 6.2–7 µm, L = 4.7 µm, W = 3.0 µm, Q = 1.6 (n = 30/1).

Additional specimen examined—China, Taiwan, Taitung, Orchid Island, Tienchih, on branch of angiosperm, May 16, 2003; Chen 1284 (TNM F0015135).

Notes—Efibula hainanensis Figure 4 is characterized by having a smooth hymenophore, thin-walled cystidia, and relatively small ellipsoid basidiospores. Until now, E. hainanensis is the only species in the genus with cystidia. In the phylogenetic tree (Figure 1), E. hainanensis and E. intertexta (Sheng H. Wu) C.C. Chen and Sheng H. Wu formed a relatively strongly supported lineage. Morphologically, E. intertexta differs from E. hainanensis by having distinctly thickening hymenial layer and cylindrical basidiospores (5.6–6.4 × 2.2–2.6 µm) and lacking cystidia (Chen et al., 2021).

Notes—Efibula taiwanensis Y. Li and S.H. He, sp. nov.

MycoBank: MB843535

Type—China, Taiwan, Nantou County, Lianhuachi Forest Park, on dead angiosperm branch, December 6, 2016, He 4582a (BJFC 024024, holotype).

Etymology—Refers to the type locality in Taiwan.

Fruiting body—Basidiomata annual, resupinate, widely effused, closely adnate, inseparable from substrate, membranaceous to slightly pellicular, first as small patches, later confluent up to 6-cm long, 1.5-cm wide, up to 150-µm thick in section. Hymenophore smooth, white (5A1) to orange white (5A2), unchanged in KOH, not cracking upon drying; margin thinning out, adnate, indistinct, arachnoid, paler than hymenophore surface, white. Context white.

Microscopic structures—Hypothallus system monomitic; generative hyphae simple-septate. Subiculum indistinct, thin; hyphae colorless, slightly thick-walled, smooth, rarely branched, moderately septate, more or less parallel to substrate, 3–4.5 µm in diam. Subhymenium distinct, thickening, with masses of crystals; hyphae colorless, thin-walled, smooth, densely interwoven, agglutinated, frequently septate, 1.8–3.5 µm in diam. Cystidia absent. Basidia clavate, colorless, thin-walled, smooth, with a basal simple septum and four stigmaticata, 23–38 × 4.5–7 µm. Basidiospores oblong ellipsoid, with an apiculus, colorless, thin-walled, smooth, IKI–, CB–, 6–6.5 (6.8–) × 3.5–3.8 µm, L = 6.2 µm, W = 3.2 µm, Q = 1.9 (n = 30/1).

Notes—Efibula shenghuae Figure 5 is characterized by its granidioid hymenophore, indistinct subiculum, and masses of crystals in subhymenium. In the phylogenetic tree (Figure 1), E. shenghuae and E. grandinosa formed a well-supported lineage sister to E. clarkii. However, E. grandinosa can be easily distinguished from E. shenghuae by having hypal pegs, while E. clarkii differs from E. shenghuae by having extensively cracked basidiomata and less crystals (Floudas and Hibbett, 2015).

Efibula tuberculata is similar to E. shenghuae by sharing smooth to tuberculate hymenophore but differs by having cracked basidiomata and less crystals in section (Chen et al., 2021). Moreover, the two species formed distinct lineages in the tree.

Notes—Efibula taiwanensis Figure 4 is characterized by having a smooth hymenophore, thin-walled cystidia, and relatively small ellipsoid basidiospores. Until now, E. hainanensis is the only species in the genus with cystidia. In the phylogenetic tree (Figure 1), E. hainanensis and E. intertexta (Sheng H. Wu) C.C. Chen and Sheng H. Wu formed a relatively strongly supported lineage. Morphologically, E. intertexta differs from E. hainanensis by having distinctly thickening hymenial layer and cylindrical basidiospores (5.6–6.4 × 2.2–2.6 µm) and lacking cystidia (Chen et al., 2021).

Notes—Efibula taiwanensis Y. Li and S.H. He, sp. nov.

MycoBank: MB843535

Type—China, Taiwan, Nantou County, Lianhuachi Forest Park, on dead angiosperm branch, December 6, 2016, He 4582a (BJFC 024024, holotype).

Etymology—Refers to the type locality in Taiwan.

Fruiting body—Basidiomata annual, resupinate, widely effused, closely adnate, inseparable from substrate, membranaceous to slightly pellicular, first as small patches, later confluent up to 6-cm long, 1.5-cm wide, up to 150-µm thick in section. Hymenophore smooth, white (5A1) to orange white (5A2), unchanged in KOH, not cracking upon drying; margin thinning out, adnate, indistinct, arachnoid, paler than hymenophore surface, white. Context white.

Microscopic structures—Hypothallus system monomitic; generative hyphae simple-septate. Subiculum indistinct, thick; hyphae colorless, thin- to slightly thick-walled, smooth or slightly to heavily encrusted with fine crystals, loosely interwoven, moderately branched and septate, 2.5–4.5 µm in diam. Subhymenium thin; hyphae colorless, thin-walled, smooth or slightly encrusted with fine crystals, interwoven, 2–3.5 µm in diam. Cystidia absent. Basidia clavate to subcylindrical, colorless, thin-walled, smooth, with a basal simple septum and four sterigmata, 23–38 × 4.5–7 µm. Basidiospores oblong ellipsoid, with an apiculus, colorless, thin-walled, smooth, IKI–, CB–, 6–6.5 (6.8–) × 3.5–3.8 µm, L = 6.2 µm, W = 3.2 µm, Q = 1.9 (n = 30/1).

Notes—Efibula shenghuae Figure 5 is characterized by its granidioid hymenophore, indistinct subiculum, and masses of crystals in subhymenium. In the phylogenetic tree (Figure 1), E. shenghuae and E. grandinosa formed a well-supported lineage sister to E. clarkii. However, E. grandinosa can be easily distinguished from E. shenghuae by having hypal pegs, while E. clarkii differs from E. shenghuae by having extensively cracked basidiomata and less crystals (Floudas and Hibbett, 2015).

Efibula tuberculata is similar to E. shenghuae by sharing smooth to tuberculate hymenophore but differs by having cracked basidiomata and less crystals in section (Chen et al., 2021). Moreover, the two species formed distinct lineages in the tree.

Efibula taiwanensis Y. Li and S.H. He, sp. nov.

MycoBank: MB843535

Type—China, Taiwan, Nantou County, Lianhuachi Forest Park, on dead angiosperm branch, December 6, 2016, He 4582a (BJFC 024024, holotype).

Etymology—Refers to the type locality in Taiwan.

Fruiting body—Basidiomata annual, resupinate, widely effused, closely adnate, inseparable from substrate, membranaceous, first as small patches, later confluent up to 8-cm long, 1.5-cm wide, up to 200-µm thick in section. Hymenophore smooth to granidioid with irregular and scattered granules, orange white (5A2) to pale orange (5A3), unchanged in KOH, not cracking upon drying; margin thinning out, adnate, indistinct, fimbriate, paler than hymenophore, white. Context white.

Microscopic structures—Hypothallus system monomitic; generative hyphae simple-septate. Subiculum indistinct, thin; hyphae colorless, slightly thick-walled, smooth, rarely branched, moderately septate, more or less parallel to substrate, 3–4.5 µm in diam. Subhymenium distinct, thickening, with masses of crystals; hyphae colorless, thin-walled, smooth, densely interwoven, agglutinated, frequently septate, 1.8–3.5 µm in diam. Cystidia absent. Basidia clavate, colorless, thin-walled, smooth, with a basal simple septum and four stigmaticata, 23–38 × 4.5–7 µm. Basidiospores oblong ellipsoid, with a distinct apiculus, colorless, thin-walled, smooth, IKI–, CB–, (5.5–) 5.8–6.5 (−7) × 4–4.5 µm, L = 6.2 µm, W = 4.2 µm, Q = 1.5 (n = 30/1).
FIGURE 4 | *Elibula hainanensis* (from the holotype He 6004; scale bars: a = 1 cm; b–f = 10 μm). (A) Basidiomata. (B) Basidiospores. (C) Basidia. (D) Basidioles. (E) Cystidia. (F) Hyphae from subiculum.
Notes—**Eibula taiwanensis** Figure 6 is characterized by having membranaceous to pellicular basidiomata and broadly ellipsoid to ovoid basidiospores. In the phylogenetic tree, *E. taiwanensis* is sister to *E. subglobispora* C.C. Chen and Sheng H. Wu and *E. americana* Floudas and Hibbett. Morphologically, *E. subglobispora* differs from *E. taiwanensis* by having larger basidiospores (6.4–8.1 × 4.5–5.8 μm, Chen et al., 2021), while *E. americana* can be easily distinguished from *E. taiwanensis*
by having smaller ellipsoid to cylindrical basidiospores (5.3–6.5 × 3–3.8) and a distribution in USA (Floudas and Hibbett, 2015).

*Irпex alboflavescens* Y. Li, Nakasone and S.H. He, sp. nov.
MycoBank: MB843536
FIGURE 7 | *Irpex alboflavescens* (from the holotype He 3933; scale bars: a = 1 cm; b–f = 10 µm). (A) Basidiomata. (B) Basidiospores. (C) Basidia. (D) Basidioles. (E) Lamprocystidia. (F) Hyphae from subiculum.
FIGURE 8 | Basidiomata of Irpex alboflavescens (scale bars: A–E = 1 cm). (A) He 2278; (B) He 4719; (C) He 5783; (D) He 6355; (E) He 5732.

Type—China, Hainan Province, Wuzhishan County, Wuzhishan Nature Reserve, on fallen angiosperm trunk, June 10, 2016, He 3933 (BJFC 022435, holotype).

Etymology—Refers to the color of hymenophore, “albo (Lat.)” = white; “flavescens (Lat.)” = yellow.

Fruiting body—Basidiomata annual, resupinate, widely effused, adnate, separable from substrate, coriaceous, first as small patches, becoming confluent up to 15-cm long, 5-cm wide, up to 350-μm thick in section. Hymenophore smooth or slightly tuberculate when fresh, pale orange (5A3) to grayish orange [5B(4–5)], slightly darkening in KOH, rarely cracked; margin thinning out, adnate or sometimes elevated and curved inside exposing substrate upon drying, indistinct, fimbriate, paler than hymenophore, white to orange white. Context white.

Microscopic structures—Hyphal system monomitic; generative hyphae simple-septate. Subiculum distinct; hyphae colorless, slightly thick-walled, usually encrusted with fine crystals, loosely interwoven, infrequently branched, moderately septate, 2–5 μm in diam. Subhymenium distinct, thickening; composed of lamprocystidia and hyphae; hyphae colorless, slightly thick-walled, smooth, interwoven, slightly agglutinated, moderately branched and septate, 2–4 μm in diam. Lamprocystidia numerous, metuloid, colorless, thick-walled, heavily encrusted, embedded or slightly projecting beyond the hymenium, 35–70 × 8–16 μm (crystals included). Basidia subcylindrical, colorless, thin-walled, smooth, with a basal simple septum and four sterigmata, 13–26 × 3.2–6.5 μm. Basidiospores ellipsoid to broadly ellipsoid, with a distinct apiculus, colorless, thin-walled, smooth, IKI–, CB–, (3.8–) 4.2–5.8 (−6) × (2.5–) 2.8–3.5 (−3.8) μm, L = 4.8 μm, W = 3.1 μm, Q = 1.4–1.6 (n = 120/4).

Additional specimens examined—China, Guangxi Autonomous region, Longzhou County, Nonggang Nature Reserve, on dead angiosperm branch, 22 July 2012, He 20120722–4 (BJFC 014505, CFMR); on fallen wood of rattan, June 4, 2015, Dai 15296 (BJFC 019407); Huanjiang County, Mulun Nature Reserve, on dead angiosperm branch, July 10, 2017, He 4719 (BJFC 024238) and He 4724 (BJFC 024243); Guizhou Province, Libo County, Maolan Nature Reserve, on dead angiosperm branch, June 15, 2016, He 3782 (BJFC 022281) and He 3791 (BJFC 022290); Hunan Province, Shimen County, Hupingshan Nature Reserve, on fallen angiosperm trunk, July 6, 2015, He 2278 (BJFC 020733, CFMR); Jiangxi Province, Lianping County, Jiulianshan Nature Reserve, on dead angiosperm branch, August 13, 2016, He 4311 (BJFC 023753). Malaysia, Sembilan, Semenyih, Broga Hill, on dead angiosperm branch, 3 December 2019, He 6355 (BJFC 033299). Sri Lanka, Central Province, Kandy, Udawattakele Royal Forest Park, on dead angiosperm branch, March 2, 2019, He 5767 (BJFC 030634);
Irpex rosea (C.L. Zhao) Y. Li and S.H. He, comb. nov.
MycoBank: MB844001

= Flavodontia rosea C.L. Zhao, Mycotaxon 136: 762, 2022 [2021]. [MB# 838323]

Fruiting body—Basidiomata annual, resupinate to effused–reflexed with slightly elevated margin, adnate, easily separated from substrate, coriaceous, first as small patches, later confluent up to 10-cm long, 3-cm wide, up to 700-µm thick in section. Hymenophore smooth, odontioid or irpicoid, grayish orange [5C(3–4)], unchanged in KOH, slightly cracked to densely and deeply cracked; margin thinning out or abrupt, adnate or slightly elevated with age, paler than or concorolous with hymenophore surface. Context cream.

Microscopic structures—Hyphal system monomitic; generative hyphae simple-septate. Subiculum indistinct, thin; hyphae colorless, thick-walled, smooth, rarely branched, infrequently septate, more or less agglutinated, parallel to substrate, 3–5-µm in diam. Subhymenium thickening; hyphae colorless, thin- to thick-walled, smooth, moderately branched and septate, agglutinated, densely interwoven, 2.5–4.5-µm in diam. Lamprocystidia arising from subhymenium, narrowly clavate, colorless, thick-walled, heavily encrusted, mostly embedded, 30–70 × 5–10-µm. Basidial clavate to subcylindrical, colorless, thin-walled, smooth, with a basal simple septum and four sterguita, 20–35 × 4–6-µm. Basidiospores cylindrical, with an apiculus, colorless, thin-walled, smooth, IKI–, CB–, (5.8–) 6–7.2 (–7.8) × 2–3 (–3.2) µm. L = 6.6 µm, W = 2.5 µm, Q = 2.3–2.9 (n = 120/4).

Additional specimens examined—China, Gansu Province, Tianshui County, Maijishan Forest Park, On dead liana, August 8, 2015, He 2484 (BJFC 020937, CFMR); Hubei Province, Chaibuxi Forest Park, On dead angiosperm branch, August 15, 2017, He 5071 (BJFC 024589) and He 5073 (BJFC 024591); Yunnan Province, Luquan County, Zhuanlong Town, On dead angiosperm branch, December 4, 2015, He 3509 (BJFC 024591); Yunnan Province, Luquan County, Zhuanlong Town, On dead angiosperm branch, December 4, 2015, He 6277 (BJFC 033221).

Notes—Wang and Zhao (2022) built a new monotypic genus Flavodontia Figures 9, 10 C.L. Zhao for the species F. rosea collected from Yunnan Province, southwestern China, mainly based on molecular evidence; however, our phylogenetic analyses using an expanded dataset of Irpicaceae demonstrated that the species was nested within the Irpex clade, which has been shown to include taxa from Emmia, Flavodon, and Hydnopolyporus (Chen et al., 2021). Morphologically, I. rosea has effused-reflexed coriaceous basidiomata with smooth, odontiod, or irpicoid hymenophores, simple-septate generative hyphae, broadly ellipsoid basidiospores and lacks cystidia, which fits well with the characters of Irpex. Thus, we propose the new combination and treat Flavodontia as a later synonym of Irpex.

Specimen examined—China, Yunnan Province, Xichou County, Xiaoaqiaogou Forest Park, on dead angiosperm stump, November 16, 2019, He 6277 (BJFC 033221).

Phanerochaetella sinensis Y. Li and S.H. He, sp. nov.
MycoBank: MB843539

Type—China, Jiangxi Province, Yifeng County, Guanshan Nature Reserve, on dead angiosperm branch, August 9, 2016, He 4229 (BJFC 023671, holotype).

Etymology—Refers to the type locality in China.

Fruiting body—Basidiomata annual, resupinate, widely effused, closely adnate, inseparable from substrate, membranaceous to coriaceous, first as small patches, later confluent up to 10-cm long, 2-cm wide, up to 300-µm thick in section. Hymenophore smooth, orange white [5A2] to brownish orange [5C(3–4)], unchanged in KOH, slightly cracked to densely and deeply cracked; margin thinning out or abrupt, adnate or slightly elevated with age, paler than or concorolous with hymenophore surface. Context white.

Microscopic structures—Hyphal system monomitic; generative hyphae simple-septate. Subiculum indistinct, thin; hyphae colorless, thick-walled, smooth, rarely branched, infrequently septate, more or less agglutinated, parallel to substrate, 3–5-µm in diam. Subhymenium thickening; hyphae colorless, thin- to thick-walled, smooth, moderately branched and septate, agglutinated, densely interwoven, 2.5–4.5-µm in diam. Lamprocystidia arising from subhymenium, narrowly clavate, colorless, thick-walled, heavily encrusted, mostly embedded, 30–70 × 5–10-µm. Basidial clavate to subcylindrical, colorless, thin-walled, smooth, with a basal simple septum and four sterguita, 20–35 × 4–6-µm. Basidiospores cylindrical, with an apiculus, colorless, thin-walled, smooth, IKI–, CB–, (5.8–) 6–7.2 (–7.8) × 2–3 (–3.2) µm. L = 6.6 µm, W = 2.5 µm, Q = 2.3–2.9 (n = 120/4).

Additional specimens examined—China, Gansu Province, Tianshui County, Majishan Forest Park, On dead liana, August 8, 2015, He 2484 (BJFC 020937, CFMR); Hubei Province, Chaibuxi Forest Park, On dead angiosperm branch, August 15, 2017, He 5071 (BJFC 024589) and He 5073 (BJFC 024591); Yunnan Province, Luquan County, Zhuanlong Town, On dead angiosperm branch, December 4, 2015, He 3509 (BJFC 021907, CFMR).

Notes—Phanerochaetella sinensis Figure 11 is characterized having a cracked hymenophore, lamprocystidia, and cylindrical basidiospores. In the phylogenetic tree (Figure 1), three samples of P. sinensis formed a distinct lineage sister to P. exilis (Burt) C.C. Chen and Sheng H. Wu, which differs
in having smaller lamprocystidia (30–50 × 5–6 µm) and ellipsoid basidiospores (5.5–6.5 × 3–3.5 µm, Burdsall, 1985). *Phanerochaetella angustocystidiata* and *P. sinensis* are almost inseparable in micromorphology, but differing in color (ivory or light cream in the former) and thickness (up to 200-µm thick in the former). Meanwhile, they formed distinct lineages in the tree (Wu, 2000).

**Phanerochaetella queletii** (Bres.) Y. Li, Nakasone and S.H. He, comb. nov.

MycoBank: MB844002

= *Corticium queletii* Bres., Nuovo Giornale Boanico Italiano 8: 10, 1901. [MB# 183260]

= *Phanerochaete queletii* (Bres.) Nakasone, Cryptogamie Mycologie 29(3): 237, 2008. [MB# 512577]

= *Phanerochaete jose-ferreirae* (D.A. Reid) D.A. Reid, Acta Botanica Croatica 34: 135, 1975. [MB# 319714]

= *Corticium jose-ferreirae* D.A. Ried, Revista Biolgia 5: 140, 1965. [MB# 311853]

Fruiting body—Basidiomata annual, resupinate, widely effused, adnate, separable from substrate, membranaceous to coriaceous, first as small patches, later confluent up to 8-cm long, 4-cm wide, up to 350-µm thick in section. Hymenophore
FIGURE 10 | Irpex rosea (from He 6277; scale bars: a–c = 10 µm). (A) Basidiospores, (B) Basidia and basidioles. (C) Hyphae from subiculum.
Phanerochaetella sinensis (from the holotype He 4229; scale bars: a = 1 cm; b–f = 10 µm). (A) Basidiomata. (B) Basidiospores. (C) Basidia. (D) Basidioles. (E) Lamprocystidia. (F) Hyphae from subiculum.

smooth, pale orange (5A3) to grayish orange [5B(4–5)], unchanged in KOH, not cracking or slightly cracked with age; margin thinning out, adnate or loose and slightly elevated with age, fimbriate and paler than hymenophore surface when juvenile, becoming indistinct and concolorous when mature. Context white.
Microscopic structures—Hyphal system monomitic; generative hyphae simple-septate. Subiculum distinct, up to 250-µm thick; hyphae colorless, thin- to slightly thick-walled, slightly encrusted with fine crystals, infrequently branched, moderately septate, loosely interwoven, 2.5–5 µm in diam. Subhymenium indistinct, thin; hyphae colorless, thin-walled, smooth, infrequently branched, moderately septate, loosely interwoven, 2–4.5 µm in diam. Cystidia absent. Basidia clavate to subcylindrical, colorless, thin-walled, smooth, with a basal simple septum and four sterigmata, 28–42 × 4.5–7 µm. Basidiospores cylindrical, with an apiculus, colorless, thin-walled, smooth, IKI–, CB–, (6.8–) 7–8 (–8.2) × 2–2.8 (–3) µm, L = 7.6 µm, W = 2.4 µm, Q = 3.2–3.3 (n = 90/3).

Type specimens examined—Italy, Vallombrosa, ad ramos corticates Abietis pectinate, Nov 1899, Martielli (BPI 0282568, K(M) 146494 (holotype of Corticium jose-ferriei); BPI 282568 (holotype of C. queletii); F11364 (isotype of C. queletii); He 3284; He 20120917-10; He 7467.)
holotype of *C. queletii*). Portugal, Serra da Arrabida, on (bark of) fallen branch, 10 May 1964, D.A. Reid (K(M) 146449, holotype of *C. jose-ferrieriae*).

Additional specimens examined—China, Beijing, Mentougou District, Lingshan Scenic Spot, on dead angiosperm branch, April 10, 2022, He 7467 (BJFC 038602); Inner Mongolia Autonomous Region, Genhe County, Greater Khingan Nature Reserve, on dead *Salix* branch, October 17, 2015, He 3050 (BJFC 021440, CFMR); Yakeshi County, Tulih Forest Park, on dead *Salix* branch, October 18, 2015, He 3065 (BJFC 021455, CFMR); Sichuan Province, Xiaoqin County, Jiajin Mountains, on dead angiosperm branch, September 17, 2012, He 20120917-10 (BJFC 014601); Yunnan Province, Baoshan County, Gaoligongshan Nature Reserve, On dead branch of *Alniphyllum*, November 28, 2015, He 3284 (BJFC 021679, CFMR).

Notes—*Phanerochaetella queletii* **Figures 12, 13** is characterized by basidiomata with smooth to tuberculate hymenophores that often are rimose to reveal the white context and margins that are typically distinct and abrupt that often are slightly detached and incurved, cylindrical basidiospores, and lacking cystidia. Its preferred habitat is small, corticate branches of woody angiosperms, rarely on gymnosperms. This widely distributed species was first described from Italy but is known throughout Europe and is frequently collected in the upper Midwest in the USA. This is the first record this species in China. There is variability in the hymenophore ranging from smooth to distinctly tuberculate, sparsely to highly rimose, and nearly white and cream to brownish orange. Similarly, the margin may be narrowly adnate, white, and fimbriate to abrupt, slightly detached and incurved. Variability in basidiospore length and width was also observed. The description above is based on the Chinese specimens only that appear to have slightly narrower basidiospores than reported earlier. Despite the basidiospore size difference between the type specimens of *C. queletii* and *C. jose-ferrieriae*, their overwhelming similarities in basidiomata texture and color, hymenophore configuration, and other microscopic features indicate that they are conspecific. For additional descriptions and illustrations, see Eriksson et al. (1978), Nakasone (2008), and Bernicchia and Gorjón (2010).

In the phylogenetic tree (**Figure 1**), three samples of *P. queletii* from China and one sample from USA (HHB-11463) formed a strongly support lineage, which is sister to *P.
### TABLE 2 | Diagnostic characters for species of *Elbula*.

| Species                  | Hymenophore           | Color change in KOH | Cystidia            | Basidia size (µm) | Spores                              | Known distribution | Reference                        |
|--------------------------|-----------------------|---------------------|---------------------|-------------------|--------------------------------------|-------------------|----------------------------------|
|                          |                       |                     |                     |                   |                                      |                   |                                  |
| *E. americana*           | Smooth to reticulate  | Not mentioned       | Absent              | 20–32 x 5–8       | Ellipsoid to Cylindrical             | 5.3–6.5 x 3–3.8    | USA                              |
| *E. clarkii*             | Slightly tuberculate  | Not mentioned       | Absent              | 25–39 x 5–7.5     | Oblong to ellipsoid                 | 6–7 x 3–3.5       | USA                              |
| *E. gracilis*            | Smooth                | Not mentioned       | Absent              | 17–30 x 5–6.5     | Ellipsoid to oblong                 | 5.5–7 x 3.3–4     | USA                              |
| *E. grandinosa*          | grandinioid           | Slightly darkening  | Absent              | 36–43 x 5–7       | Ellipsoid                           | 6–6.8 x 3.7–4     | China                            |
| *E. hainanensis*         | Smooth                | turning black       | rare                | 15–26 x 4–6       | Ellipsoid to broadly ellipsoid      | 4.2–5.5 x 2.8–3.2 | China                            |
| *E. intertexta*          | Smooth                | No                  | Absent              | 30–35 x 4.5–5     | Cylindrical                         | 5.6–6.4 x 2.2–2.6 | China                            |
| *E. matsuensis*          | Smooth                | darkening           | Absent              | 18–25 x 6.5–8     | Ellipsoid to Cylindrical            | 7.4–8.6 x 3.8–4.4 | China                            |
| *E. rodriguezarmasiae*   | Smooth to tuberculate | Not mentioned       | Absent              | 35–48 x 6–8       | Ellipsoid                           | 6–7 x 4–5         | Micronesia                       |
| *E. shenghuae*           | Smooth to grandinioid | No                  | Absent              | 23–38 x 4.5–7     | Oblong ellipsoid                    | 6–6.5 x 3–3.5     | China                            |
| *E. subglobispora*       | Smooth                | No                  | Absent              | 30–40 x 6.5–8     | Broadly ellipsoid to subglobebose   | 6.4–8.1 x 4.5–5.8 | China                            |
| *E. taiwanensis*         | Smooth                | No                  | Absent              | 24–44 x 6–8       | Broadly ellipsoid to ovoid          | 5.8–6.5 x 4–4.5   | China                            |
| *E. tropica*             | Smooth                | No                  | Absent              | 20–40 x 5.5–8     | Broadly ellipsoid                   | 6.4–7.7 x 3.7–4.4 | China and Japan                  |
| *E. tuberculata*         | Smooth to slightly    | No                  | Absent              | 18–35 x 5–6       | Ellipsoid                           | 5.3–6.4 x 3.4–4.3 | East Asia, Europe and North America |
| *E. turgida*             | Smooth                | No                  | Absent              | 26–30 x 6.5–7     | Cylindrical                         | 6.6–8.2 x 3.3–3.9 | China                            |
| *E. yunnanensis*         | mainly Smooth, sometimes slightly tuberculate | No | Absent | 27–38 x 6–7 | Broadly ellipsoid | 6.6–8 x 3.9–4.7 | China and Japan |

**xerophila** (Burds.) C.C. Chen and Sheng H. Wu from the Sonoran Desert on southwestern USA, and *P. angustocystidiata* (Sheng H. Wu) C.C. Chen and Sheng H. Wu from East Asia. Morphologically, both *P. xerophila* and *P. queletti* lack cystidia, but the former species has broadly ellipsoid basidiospores (6–9 x 3.5–4.5 µm, Burdsall, 1985). *Phanerochaetella angustocystidiata* has cylindrical basidiospores that are slightly smaller than in *P. queletti* and develops lamprocystidia (Wu, 2000).

**DISCUSSION**

The species diversity, taxonomy, and phylogeny of the phlebioid clade in Polyporales were intensively studied recently by many authors, and a large number of new taxa from East Asia were described (Floudas and Hibbett, 2015; Miettinen et al., 2016; Justo et al., 2017; Ma and Zhao, 2019; Chen et al., 2020, 2021; Xu et al., 2020; Wang and Zhao, 2021; Zhao et al., 2021; Tian et al., 2022). This study furthers our knowledge of this group with the addition of seven new corticioid species in the Irpicaceae. There is no doubt that more new taxa will be revealed as more surveys are carried out in areas of Asia with the aid of molecular evidence. Our phylogenetic analysis results supported to place the newly described monotypic genus, *Flavodontia*, in synonymy under *Irpex*. We also demonstrated that one species, namely, *P. queletti*, has a wide distribution throughout the north temperate region from China to Europe and North America.
TABLE 3 | Diagnostic characters for species of Phanerochaetella.

| Species            | Hymenophore               | Lamprocystidia (μm) | Basidia size (μm) | Spores       | Known distribution | Reference |
|--------------------|---------------------------|---------------------|-------------------|--------------|--------------------|-----------|
| P. angustocystidiata | Smooth                    | Yes; 30–70 × 5–9    | 18–28 × 4.5–5.5  | Cylindrical  | 6.3–8 × 2.3–3     | China and Japan | Wu, 2000 |
| P. exilis           | Smooth to finely pubescent | Yes; 30–50 × 5–6   | 12–15 × 5–6      | Ellipsoid    | 5.5–6.5 × 3–3.5   | Mexico and USA | Burdsall, 1985 |
| P. formosana        | Smooth                    | Yes; 20–35 × 7–10  | 18–24 × 5–6      | Cylindrical  | 7.5–8.7 × 2.9–3.5 | China     | Chen et al., 2021 |
| P. leptoderrma      | Smooth                    | Yes; 35–65 × 4–6   | 21–28 × 4.7–6   | Cylindrical  | 6.4–7.6 × 2.9–3.3 | China, India and Japan | Wu, 1990 |
| P. quetelii         | Smooth                    | No                  | 28–42 × 4.5–7   | Cylindrical  | 7–8 × 2–2.8       | China and USA | Present study |
| P. sinensis         | Smooth                    | Yes; 30–70 × 5–10  | 20–35 × 4–6     | Cylindrical  | 6–7.2 × 2–3       | China     | Present study |
| P. xerophila        | Smooth to tuberculate     | No                  | 30–40 × 6–7     | Broadly ellipsoid | 6–9 × 3.5–4.5 | USA      | Burdsall, 1985 |

The results of our phylogenetic analyses of Irpicaceae are consistent with that presented by Chen et al. (2021). In both studies, clades of the five genera—Irpet, Phanerochaetella, Byssomerulius, Cytidiella, and Meruliopsis, received strong support values, whereas Efibula was shown to be paraphyletic with species distributed in four subclades. According to the phylogenetic results, Irpet now includes species with smooth, poroid, labyrinthine, irpicoid, hydnoid to irregular hymenophore configurations. However, there are still many old names in Irpet that need to be studied by using modern taxonomic methods and systems. For Efibula, there are no distinct morphological characters to divide it into small genera at present (Table 2). The newly erected genus, Phanerochaetella, contains several species with diverse micromorphology: lamprocystidia present or absent and basidiospores from broadly ellipsoid to cylindrical (Table 3). Three species of Candelabrochaete formed two distinct lineages in the Ceriporia/Candelabrochaete s.l./Leptoporus/Phanerochaete allantospora clade, but their generic position remains unresolved since the type species, C. africana Boidin, was not nested within the phlebioid clade (Justo et al., 2017; Chen et al., 2021).

The molecular evidence has brought significant changes and increased our understanding in the taxonomy of Irpicaceae. The morphological circumscriptions of some genera became broader, for example, Irpet now contains species with poroid, labyrinthine, irpicoid, hydnoid to irregular hymenophore, and Efibula is shown to contain species with or without horizontally arranged subicular hyphae. Species with simple-septate hyphae and without cystidia can be found in Efibula, Irpet, and Phanerochaetella. To determine important and useful morphological characters for distinguishing those genera and resolve infra-generic phylogeny, additional taxa from these genera from other regions should be included in the future phylogenetic studies. In addition, comparative morphological analyses of fruitbody features such as subicum and subhymenium thickness, construction, and texture in addition to basidia, cystidia, and basidiospore shape and size are important areas of consideration in future studies. Information on habitat and distribution may be useful for understanding species delimitation and phylogeny of species within a genus.

DATA AVAILABILITY STATEMENT

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found below: https://www.ncbi.nlm.nih.gov/genbank/, see the Table 1 included in article.

AUTHOR CONTRIBUTIONS

YL performed the phylogenetic analyses and did most of the measurements, descriptions, and illustrations. S-HH designed the research, collected most of the specimens, and wrote the text. C-CC provided with some measurements, descriptions, and illustrations. KN examined materials from USA and revised the text. H-XM helped in field trips. All authors contributed to the article and approved the submitted version.

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