



# *Phaeoacremonium* species diversity on woody hosts in the Western Cape Province of South Africa

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## Key words

brown wood streaking  
decline disease  
phylogeny  
systematics  
*Togninia*

**Abstract** Nineteen *Phaeoacremonium* species are currently known in South Africa. These have been reported from grapevines, fruit trees, fynbos twig litter and arthropods. In other countries some of these *Phaeoacremonium* species are also known from hosts such as European olive, quince and willow that commonly occur in the Western Cape Province of South Africa, where most South African records of *Phaeoacremonium* have been made. The aim of this study was to investigate the species diversity and host-range of *Phaeoacremonium* in the Western Cape Province of South Africa by characterising 156 isolates collected from 29 woody hosts. Phylogenetic analyses of combined actin and beta-tubulin datasets allowed for the identification of 31 species among the 156 isolates, including 13 new species and 3 known species that had not been recorded in South Africa previously. The new *Phaeoacremonium* species include *P. album*, *P. aureum*, *P. bibendum*, *P. gamsii*, *P. geminum*, *P. junior*, *P. longicollarum*, *P. meliae*, *P. oleae*, *P. paululum*, *P. proliferatum*, *P. rosicola* and *P. spadicum*. All previous records of *P. alvesii* in South Africa were re-identified as *P. italicum*, but both species were recovered during this survey. A total of 35 described *Phaeoacremonium* species are now known from South Africa, more than double the number reported from any other country. This high diversity reflects the high diversity of indigenous flora of the Cape Floral Region, a biodiversity hotspot mainly situated in the Western Cape Province. Paraphyly and incongruence between individual phylogenies of the actin and beta-tubulin regions complicated species delimitation in some cases indicating that additional phylogenetic markers should be investigated for use in *Phaeoacremonium* phylogenies to prevent misidentifications and the introduction of vague species boundaries.

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## INTRODUCTION

The genus *Phaeoacremonium* (*Togniniales*, *Togniniaceae*) was originally described in 1996 during a re-evaluation of isolates similar to what was considered at that stage to be *Phialophora parasitica* (Crous et al. 1996). The newly described genus contained six species: *Phaeoacremonium angustius*, *P. chlamydosporum* ( $\equiv$  *Phaeomoniella chlamydospora*), *P. inflatipes*, *P. aleophilum* ( $\equiv$  *P. minimum*), *P. parasiticum* (type species) and *P. rubrigenum* (Crous et al. 1996). Some landmark publications regarding the taxonomy of the genus include the identification of *Togninia* as the sexual morph of *Phaeoacremonium* (Mostert et al. 2003), the monograph by Mostert et al. (2006) that standardised the taxonomy of 22 *Phaeoacremonium* and 10 *Togninia* species known at the time, and the recent review by Gramaje et al. (2015) in which *Togninia* species are formally included in *Phaeoacremonium* according to the change to single nomenclature for fungi (Hawksworth et al. 2011). Gramaje et al. (2015) included a total of 46 species in *Phaeoacremonium*, but failed to consider the synonymy of *P. novae-zealandiae* with *P. leptorrhynchum* (Réblová 2011) so the actual total taxa known at that time should have been 45. With the recently described *P. tectonae* (Ariyawansa et al. 2015), *P. pseudopanacis* (Crous et al. 2016) and *P. nordesticola* (Da Silva et al. 2017), the total number of species in *Phaeoacremonium* currently stands at 48. *Phaeoacremonium* has a global distribution, with species being reported from South, Central and North America, Europe,

Scandinavia, Ukraine, the Middle East, Far East, Oceania and Africa (Gramaje et al. 2015). Most *Phaeoacremonium* species are associated with wood diseases of plants, e.g., Petri and esca diseases of grapevines (Crous et al. 1996, Essakhi et al. 2008, Gramaje et al. 2009a, b, White et al. 2011, Raimondo et al. 2014) and dieback and cankers on other fruit trees and woody hosts (Damm et al. 2008b, Gramaje et al. 2012, Mohammadi et al. 2014, Sami et al. 2014, Carlucci et al. 2015, Hashemi & Mohammadi 2016, Kazemzadeh Chakusary et al. 2017). Eleven *Phaeoacremonium* species are also known from human infections (Mostert et al. 2005, Gramaje et al. 2015). Other hosts and substrates have also been reported, including non-woody plants such as *Lactuca canadensis* and *Dactylis glomerata* (Sánchez Márquez et al. 2007), arthropods (Kubátová et al. 2004, Mostert et al. 2006, Moyo et al. 2014), soil and once from another fungus (Mostert et al. 2005). Several *Phaeoacremonium* species are known only from grapevine, and more *Phaeoacremonium* species have been reported from this host than any other host (Gramaje et al. 2015). This is likely to reflect the higher priority given to trunk disease research on grapevines than to fungi from comparable sites on other hosts. It does not imply host preference or specificity. In fact, species like *P. minimum* and *P. parasiticum* have been recorded from more than 10 hosts each, and most species that have been reported from more than one country have also been reported from more than one host (Gramaje et al. 2015).

A total of 19 *Phaeoacremonium* species are currently known in South Africa. Twelve species have been reported on grapevines; two of these have not been associated with other hosts in South Africa (Groenewald et al. 2001, Mostert et al. 2005, 2006, White et al. 2011). The remaining 10 species known from grapevines and seven species not known from grapevines have

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been reported from fruit trees (*Diospyros kaki*, *Malus domestica*, *Prunus* spp. and *Pyrus communis*), fynbos twig litter (*Brabejum stellatifolium* and *Leucadendron* sp.) and arthropods (Damm et al. 2008b, Marincowitz et al. 2008, Cloete et al. 2011, Moyo et al. 2014, 2016). In other parts of the world, some of these *Phaeoacremonium* species, such as *P. alvesii*, *P. iranianum* and *P. minimum*, are also known from hosts such as European olive (*Olea europaea* subsp. *europaea*), quince (*Cydonia oblonga*) and willow (*Salix* spp.) (Crous & Gams 2000, Nigro et al. 2013, Sami et al. 2014, Carlucci et al. 2015, Hashemi & Mohammadi 2016, Kazemzadeh Chakusary et al. 2017). These hosts also occur in the Western Cape Province of South Africa where viticulture is one of the main agricultural enterprises. Other woody plants that might harbour *Phaeoacremonium* infections are often found growing near vineyards including not just commercial crops or trees and shrubs cultivated for diverse purposes in gardens, but also naturally occurring trees. Many of these plants have not been reported as hosts for *Phaeoacremonium* species anywhere else in the world. The aim of the present study was to assess the species diversity and host range of *Phaeoacremonium* in the Western Cape Province of South Africa by characterising isolates obtained from 29 different woody hosts often found in close proximity to vineyards.

## MATERIALS AND METHODS

### Isolates

Samples of 29 woody hosts exhibiting dieback or decline symptoms were collected in the Western Cape (South Africa). Two additional samples of 10-yr-old grapevines from Limpopo that exhibited symptoms of slow dieback were also included. Isolations were made from various internal wood symptoms (including wedge-shaped or irregular black/brown discolouration, vascular streaking and white rot) as described by Moyo et al. (2016). All isolates were stored as colonised potato dextrose agar (PDA; Biolab) plugs in sterile water at 4 °C or in 10 % glycerol at -80 °C at the Plant Protection Division of the ARC Infruitec-Nietvoorbij in Stellenbosch, South Africa. Isolates of new species were also deposited in the fungal collection of the University of Stellenbosch Department Plant Pathology (STE-U) and in the Westerdijk Fungal Biodiversity Institute (CBS), in Utrecht, the Netherlands.

### DNA extraction, PCR and sequencing

DNA was extracted using a CTAB protocol as described by Damm et al. (2008b) and quantified using a NanoDrop ND-1000 spectrophotometer (NanoDrop Technologies, Wilmington, DE, USA). DNA samples were diluted to a range of 5–15 ng/μL prior to PCR amplification.

The beta-tubulin region was amplified in 10 μL reactions with 1 × KAPA Taq ReadyMix, primers T1 (O'Donnell & Cigelnik 1997) and Bt2b (Glass & Donaldson 1995) at 0.08 μM each, and 1 μL DNA under cycling conditions entailing initial denaturation for 3 min at 94 °C, 30 cycles of denaturation at 94 °C for 30 s, annealing for 30 s at 58 °C, and extension for 30 s at 72 °C, and a final extension for 7 min at 72 °C. The actin region was amplified using the primers ACT-512F and ACT-783R from Carbone & Kohn (1999) with conditions as described for beta-tubulin, but annealing at 52 °C. In some cases where these conditions failed to produce usable PCR product for sequencing DNA samples were re-amplified in 20 μL reactions containing primers at 0.8 μM each, and 2 μL DNA with other reagents and conditions as above. A touch-down PCR entailing annealing temperatures decreasing with 2 °C every 5 cycles from 66 °C to 58 °C and a final set of 20 cycles annealing at 55 °C was also used for some actin amplifications.

All PCR products were visualised on 1 % agarose gels and successful amplifications were sequenced in both directions. Successful amplifications from 10 μL reactions were sequenced directly, but those performed in 20 μL volumes were purified using a MSB® Spin PCRapace kit (Invitex, Germany) prior to sequencing using the BigDye Terminator v. 3.1 Cycle Sequencing Kit (PE Biosystems, Foster City, CA, USA). Sequencing product was analysed on an ABI PRISM 3130XL DNA sequencer (Perkin-Elmer, Norwalk, CT, USA) at the Central Analytical Facility of Stellenbosch University.

### Sequence editing and preliminary species identification

Sequences were trimmed and edited using Geneious R8 (Kearse et al. 2012). Preliminary identifications were obtained by BLAST analyses of single strand beta-tubulin or actin sequences against a curated database containing only sequences used by Gramaje et al. (2015) and those of *P. tectonae* that was described later in the same year (Ariyawansa et al. 2015). Putative novel species identified in these analyses were also subjected to a BLAST search against the NCBI nucleotide database. BLAST identifications were confirmed and refined with preliminary maximum likelihood phylogenies inferred under the GTR+I+G model using PhyML (Guindon et al. 2010) in Geneious R8 without calculation of bootstrap support. Based on these preliminary identifications, strains representing putative new species, first reports for various hosts in South Africa, and intraspecific phylogenetic variants of known species were selected. For these strains both forward and reverse sequences of the beta-tubulin and actin regions were generated, edited and assembled in Geneious R8 and double strand consensus sequences were extracted for alignment and phylogenetic analyses.

### Phylogenetic analyses

Sequences used by Gramaje et al. (2015), sequences from the published descriptions of *P. nordesticola*, *P. pseudopanacis* and *P. tectonae*, and representative sequences from previous reports of *Phaeoacremonium* species in South Africa were included as reference sequences (Appendix 1). *Calosphaeria africana* STE-U 6182, *Jattaea algeriensis* STE-U 6201 and *Pleurostoma richardsiae* CBS 270.33 were included as outgroups. Reference and *de novo*-generated sequences of the two gene regions were aligned separately using the E-INS-i algorithm in the MAFFT plugin of Geneious R9 (Katoh & Standley 2013), visually inspected for obvious alignment errors, and concatenated in Geneious R9. Both maximum likelihood and Bayesian analyses were performed on the concatenated alignment, while individual gene alignments were only subjected to maximum likelihood analyses.

Maximum likelihood analysis was performed in PhyML-mpi (Guindon et al. 2010) under the best fit model (HKY+I+G) as estimated with the Bayesian information criterion in jModeltest2 (Darriba et al. 2012). Branch support was calculated from 100 bootstrap replicates for the concatenated dataset only. Bayesian analyses were performed using PhyloBayes-MPI v. 1.7 (Lartillot et al. 2013) under CAT-GTR settings. Two independent chains were run for 20 000 cycles of which every 10th point was saved. Of the 2 000 saved points, the first 100 were discarded as burn-in prior to assessing convergence using the bpcomp and tracecomp commands. The effective population sizes after running these commands were larger than 300 and maxdiff values were less than 0.3, indicating sufficient convergence as per the guidelines set out in the PhyloBayes-MPI manual.

**Table 1** Host data and GenBank accession numbers of actin (*ACT*) and beta-tubulin (*TUB2*) sequences for 156 South African strains of *Phaeoacremonium* reported in this study.

Species	Strain <sup>a</sup>	Host	<i>ACT</i>	<i>TUB2</i>	
<i>Phaeoacremonium africanum</i>	CSN871	<i>Eriobotrya japonica</i>	KY906754	KY906755	
	CSN946	<i>Olea europaea</i> subsp. <i>europaea</i>	KY906772	KY906773	
<i>Phaeoacremonium album</i>	PMM2276	<i>Cydonia oblonga</i>	KY906926	KY906927	
	CBS 142688 <sup>T</sup> = STE-U 8379 = PMM1938	<i>Pyrus communis</i>	KY906884	KY906885	
	CBS 142689 = STE-U 8378 = PMM2275	<i>Cydonia oblonga</i>	KY906924	KY906925	
	CBS 142716 = STE-U 8380 = CSN1256	<i>Vitis vinifera</i>	KY906794	KY906795	
<i>Phaeoacremonium alvesii</i>	STE-U 8377 = CSN660	<i>Cydonia oblonga</i>	KY906736	KY906737	
	CSN1239	<i>Prunus persica</i>	KY906784	KY906785	
	CSN1335	<i>Psidium guajava</i>	KY906800	KY906801	
	PMM744	<i>Ficus carica</i>	KY906822	KY906823	
<i>Phaeoacremonium aureum</i>	PMM1817	<i>Rosa</i> sp.	KY906844	KY906845	
	PMM2222	<i>Melia azedarach</i>	KY906898	KY906899	
	CBS 142690 = STE-U 8374 = CSN1322	<i>Psidium guajava</i>	KY906798	KY906799	
	CBS 142691 <sup>T</sup> = STE-U 8372 = CSN23	<i>Melia azedarach</i>	KY906656	KY906657	
	CBS 142692 = STE-U 8375 = PMM1019	<i>Psidium guajava</i>	KY906832	KY906833	
	CBS 142693 = STE-U 8376 = PMM2252	<i>Rosa</i> sp.	KY906916	KY906917	
	STE-U 8371 = CSN20	<i>Melia azedarach</i>	KY906654	KY906655	
<i>Phaeoacremonium australiense</i>	STE-U 8373 = CSN124	<i>Melia azedarach</i>	KY906692	KY906693	
	CSN490	<i>Psidium guajava</i>	KY906728	KY906729	
	CSN657	<i>Cydonia oblonga</i>	KY906734	KY906735	
	CSN904	<i>Punica granatum</i>	KY906760	KY906761	
	CSN914	<i>Psidium guajava</i>	KY906764	KY906765	
	CSN1024	<i>Ficus carica</i>	KY906774	KY906775	
	CSN1244	<i>Eriobotrya japonica</i>	KY906792	KY906793	
	PMM1826	<i>Vitis vinifera</i>	KY906848	KY906849	
	PMM1843	<i>Rosa</i> sp.	KY906856	KY906857	
	PMM2277	<i>Cydonia oblonga</i>	KY906928	KY906929	
	PMM2439	<i>Malus domestica</i>	KY906934	KY906935	
<i>Phaeoacremonium bibendum</i>	CBS 142694 <sup>T</sup> = STE-U 8365 = CSN894	<i>Schinus molle</i>	KY906758	KY906759	
<i>Phaeoacremonium fraxinopennsylvanicum</i>	CSN66	<i>Malus domestica</i>	KY906680	KY906681	
<i>Phaeoacremonium gamsii</i>	CBS 142712 <sup>T</sup> = STE-U 8366 = CSN670	<i>Callistemon</i> sp.	KY906740	KY906741	
<i>Phaeoacremonium geminum</i>	CBS 142713 <sup>T</sup> = STE-U 8402 = C741 = CSN1944	<i>Malus domestica</i>	KY906648	KY906649	
	CBS 142717 = STE-U 8367 = C631 = CSN1945	<i>Malus domestica</i>	KY906646	KY906647	
<i>Phaeoacremonium globosum</i>	CSN471	<i>Cydonia oblonga</i>	KY906724	KY906725	
	CSN1258	<i>Vitis vinifera</i>	KY906796	KY906797	
	PMM1829	<i>Vitis vinifera</i>	KY906852	KY906853	
<i>Phaeoacremonium griseo-olivaceum</i>	PMM1828	<i>Vitis vinifera</i>	KY906850	KY906851	
	PMM1895	<i>Psidium guajava</i>	KY906874	KY906875	
	PMM2220	<i>Melia azedarach</i>	KY906896	KY906897	
	PMM2267	<i>Rosa</i> sp.	KY906920	KY906921	
	PMM2444	<i>Prunus persica</i>	KY906940	KY906941	
<i>Phaeoacremonium inflatipes</i>	CSN47	<i>Morus</i> sp.	KY906664	KY906665	
	CSN57	<i>Prunus armeniaca</i>	KY906674	KY906675	
	CSN247	<i>Prunus persica</i>	KY906700	KY906701	
	CSN389	<i>Cydonia oblonga</i>	KY906714	KY906715	
	PMM739	<i>Psidium guajava</i>	KY906820	KY906821	
	PMM1849	<i>Ficus carica</i>	KY906858	KY906859	
	PMM1864	<i>Eriobotrya japonica</i>	KY906864	KY906865	
	PMM1866	<i>Salix</i> sp.	KY906866	KY906867	
	PMM1987	<i>Cinnamomum camphora</i>	KY906892	KY906893	
	PMM2230	<i>Malus domestica</i>	KY906900	KY906901	
	PMM2608	<i>Quercus robur</i>	KY906956	KY906957	
	<i>Phaeoacremonium iranianum</i>	CSN170	<i>Prunus persica</i> var. <i>nucipersica</i>	KY906694	KY906695
		CSN267	<i>Cydonia oblonga</i>	KY906706	KY906707
		CSN689	<i>Cinnamomum camphora</i>	KY906746	KY906747
PMM2248		<i>Prunus salicina</i>	KY906912	KY906913	
<i>Phaeoacremonium italicum</i>	CSN59	<i>Melia azedarach</i>	KY906676	KY906677	
	CSN119	<i>Morus</i> sp.	KY906690	KY906691	
	CSN206	<i>Ficus carica</i>	KY906696	KY906697	
	CSN254	<i>Punica granatum</i>	KY906702	KY906703	
	CSN277	<i>Prunus persica</i>	KY906710	KY906711	
	PMM731	<i>Psidium guajava</i>	KY906818	KY906819	
	PMM2238	<i>Malus domestica</i>	KY906908	KY906909	
	PMM2291	<i>Cydonia oblonga</i>	KY906930	KY906931	
<i>Phaeoacremonium junior</i>	CBS 142695 = STE-U 8398 = CSN13	<i>Vitis vinifera</i>	KY906650	KY906651	
	CBS 142696 = STE-U 8399 = CSN16	<i>Vitis vinifera</i>	KY906652	KY906653	
	CBS 142697 <sup>T</sup> = STE-U 8397 = CSN273	<i>Schinus molle</i>	KY906708	KY906709	
	CBS 142698 = STE-U 8396 = PMM2445	<i>Prunus armeniaca</i>	KY906942	KY906943	
<i>Phaeoacremonium longicollarum</i>	CBS 142699 <sup>T</sup> = STE-U 8393 = CSN84	<i>Prunus armeniaca</i>	KY906688	KY906689	
	CBS 142700 = STE-U 8395 = PMM1900	<i>Psidium guajava</i>	KY906878	KY906879	
	STE-U 8394 = CSN655	<i>Psidium guajava</i>	KY906732	KY906733	
<i>Phaeoacremonium meliae</i>	CBS 142709 = STE-U 8391 = CSN256	<i>Melia azedarach</i>	KY906704	KY906705	
	CBS 142710 <sup>T</sup> = STE-U 8392 = PMM975	<i>Melia azedarach</i>	KY906824	KY906825	
<i>Phaeoacremonium minimum</i>	CSN668	<i>Cydonia oblonga</i>	KY906738	KY906739	
	CSN893	<i>Schinus molle</i>	KY906756	KY906757	
	CSN1910	<i>Prunus dulcis</i>	KY906812	KY906813	
	PMM1305	<i>Punica granatum</i>	KY906836	KY906837	
	PMM1323	<i>Morus</i> sp.	KY906842	KY906843	
	PMM1822	<i>Rosa</i> sp.	KY906846	KY906847	
	PMM1967	<i>Salix</i> sp.	KY906886	KY906887	

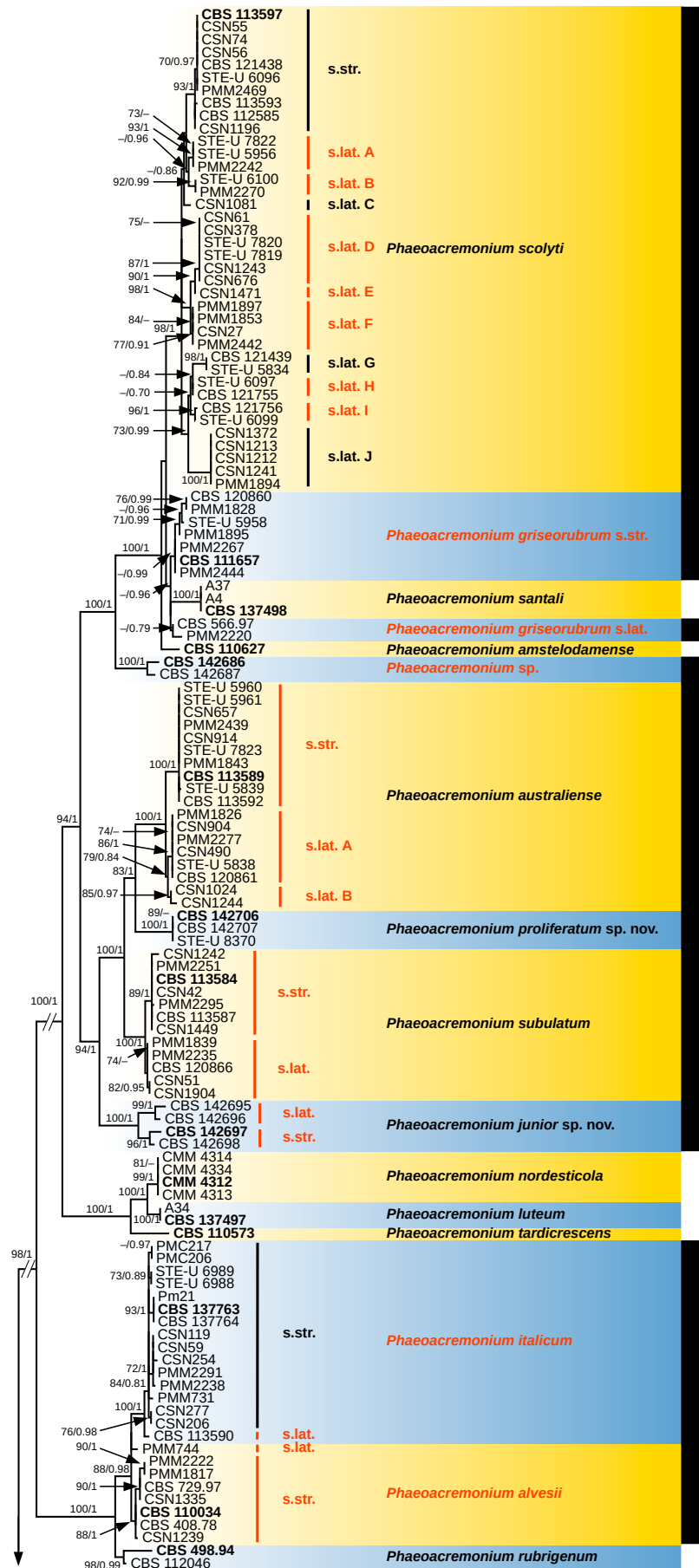


Table 1 (cont.)

Species	Strain <sup>a</sup>	Host	ACT	TUB2	
<i>Phaeoacremonium minimum</i> (cont.)	PMM2073	<i>Olea europaea</i> subsp. <i>europaea</i>	KY906894	KY906895	
	PMM2470	<i>Psidium guajava</i>	KY906946	KY906947	
	PMM2602	<i>Eriobotrya japonica</i>	KY906948	KY906949	
<i>Phaeoacremonium oleae</i>	CBS 142701 = STE-U 8381 = CSN403	<i>Olea europaea</i> subsp. <i>cuspidata</i>	KY906718	KY906719	
	CBS 142702 = STE-U 8382 = CSN945	<i>Olea europaea</i> subsp. <i>cuspidata</i>	KY906770	KY906771	
	CBS 142703 = STE-U 8384 = PMM1981	<i>Olea europaea</i> subsp. <i>cuspidata</i>	KY906890	KY906891	
	CBS 142704 <sup>†</sup> = STE-U 8385 = PMM2440	<i>Olea europaea</i> subsp. <i>cuspidata</i>	KY906936	KY906937	
	STE-U 8383 = CSN703	<i>Olea europaea</i> subsp. <i>cuspidata</i>	KY906750	KY906751	
<i>Phaeoacremonium parasiticum</i>	CSN24	<i>Ficus carica</i>	KY906658	KY906659	
	CSN72	<i>Eriobotrya japonica</i>	KY906682	KY906683	
	CSN79	<i>Psidium guajava</i>	KY906686	KY906687	
	CSN210	<i>Cydonia oblonga</i>	KY906698	KY906699	
	CSN464	<i>Punica granatum</i>	KY906720	KY906721	
	CSN465	<i>Erythrina</i> sp.	KY906722	KY906723	
	CSN624	<i>Olea europaea</i> subsp. <i>europaea</i>	KY906730	KY906731	
	CSN912	<i>Melia azedarach</i>	KY906762	KY906763	
	PMM1978	<i>Salix</i> sp.	KY906888	KY906889	
	PMM2237	<i>Malus domestica</i>	KY906906	KY906907	
	PMM2260	<i>Rosa</i> sp.	KY906918	KY906919	
	PMM2604	<i>Afrocarpus falcatus</i>	KY906952	KY906953	
	<i>Phaeoacremonium paululum</i>	CBS 142705 <sup>†</sup> = STE-U 8389 = PMM1914	<i>Psidium guajava</i>	KY906880	KY906881
		<i>Phaeoacremonium proliferatum</i>	CBS 142706 <sup>†</sup> = STE-U 8368 = PMM2231	<i>Malus domestica</i>	KY906902
CBS 142707 = STE-U 8369 = PMM990	<i>Rosa</i> sp.		KY906826	KY906827	
<i>Phaeoacremonium prunicola</i>	STE-U 8370 = PMM991	<i>Rosa</i> sp.	KY906828	KY906829	
	CSN398	<i>Cydonia oblonga</i>	KY906716	KY906717	
	CSN719	<i>Schinus molle</i>	KY906752	KY906753	
	CSN1425	<i>Vitis vinifera</i>	KY906804	KY906805	
	ID230	<i>Olea europaea</i> subsp. <i>cuspidata</i>	KY906816	KY906817	
	PMM1318	<i>Eriobotrya japonica</i>	KY906840	KY906841	
	PMM1870	<i>Pyrus communis</i>	KY906868	KY906869	
	PMM1892	<i>Psidium guajava</i>	KY906870	KY906871	
	PMM1932	<i>Cinnamomum camphora</i>	KY906882	KY906883	
	PMM2603	<i>Afrocarpus falcatus</i>	KY906950	KY906951	
	<i>Phaeoacremonium rosicola</i>	CBS 142708 <sup>†</sup> = STE-U 8390 = PMM1002	<i>Rosa</i> sp.	KY906830	KY906831
	<i>Phaeoacremonium scolyti</i>	CSN27	<i>Melia azedarach</i>	KY906660	KY906661
		CSN55	<i>Prunus domestica</i>	KY906670	KY906671
		CSN56	<i>Psidium guajava</i>	KY906672	KY906673
		CSN61	<i>Prunus dulcis</i>	KY906678	KY906679
		CSN74	<i>Pyrus communis</i>	KY906684	KY906685
		CSN378	<i>Salix</i> sp.	KY906712	KY906713
		CSN676	<i>Olea europaea</i> subsp. <i>europaea</i>	KY906742	KY906743
		CSN1081	<i>Cydonia oblonga</i>	KY906776	KY906777
CSN1196		<i>Olea europaea</i> subsp. <i>europaea</i>	KY906778	KY906779	
CSN1212		<i>Olea europaea</i> subsp. <i>cuspidata</i>	KY906780	KY906781	
CSN1213		<i>Olea europaea</i> subsp. <i>europaea</i>	KY906782	KY906783	
CSN1241		<i>Quercus suber</i>	KY906786	KY906787	
CSN1243		<i>Melia azedarach</i>	KY906790	KY906791	
CSN1372		<i>Psidium guajava</i>	KY906802	KY906803	
CSN1471		<i>Psidium guajava</i>	KY906808	KY906809	
PMM1853		<i>Rosa</i> sp.	KY906860	KY906861	
PMM1894		<i>Malus domestica</i>	KY906872	KY906873	
PMM1897		<i>Psidium guajava</i>	KY906876	KY906877	
PMM2242		<i>Punica granatum</i>	KY906910	KY906911	
PMM2270		<i>Rosa</i> sp.	KY906922	KY906923	
PMM2442		<i>Eriobotrya japonica</i>	KY906938	KY906939	
PMM2469		<i>Melia azedarach</i>	KY906944	KY906945	
<i>Phaeoacremonium sicilianum</i>		CSN482	<i>Ficus carica</i>	KY906726	KY906727
<i>Phaeoacremonium spadicum</i>		CSN930	<i>Juglans</i> sp.	KY906768	KY906769
		CBS 142711 <sup>†</sup> = STE-U 8386 = PMM1315	<i>Eriobotrya japonica</i>	KY906838	KY906839
		CBS 142714 = STE-U 8388 = CSN49	<i>Rhoicissus tomentosa</i>	KY906666	KY906667
<i>Phaeoacremonium subulatum</i>		CBS 142715 = STE-U 8387 = ID208	<i>Olea europaea</i> subsp. <i>cuspidata</i>	KY906814	KY906815
		CSN42	<i>Pyrus communis</i>	KY906662	KY906663
		CSN51	<i>Punica granatum</i>	KY906668	KY906669
		CSN1242	<i>Prunus armeniaca</i>	KY906788	KY906789
		CSN1449	<i>Psidium guajava</i>	KY906806	KY906807
	CSN1904	<i>Schinus molle</i>	KY906810	KY906811	
	PMM1839	<i>Rosa</i> sp.	KY906854	KY906855	
	PMM2235	<i>Malus domestica</i>	KY906904	KY906905	
	PMM2251	<i>Prunus salicina</i>	KY906914	KY906915	
	PMM2295	<i>Cydonia oblonga</i>	KY906932	KY906933	
	<i>Phaeoacremonium venezuelense</i>	PMM1138	<i>Rosa</i> sp.	KY906834	KY906835
	<i>Phaeoacremonium viticola</i>	CSN678	<i>Cydonia oblonga</i>	KY906744	KY906745
		CSN701	<i>Psidium guajava</i>	KY906748	KY906749
		CSN926	<i>Salix</i> sp.	KY906766	KY906767
		PMM1863	<i>Eriobotrya japonica</i>	KY906862	KY906863
PMM2605		<i>Quercus robur</i>	KY906954	KY906955	

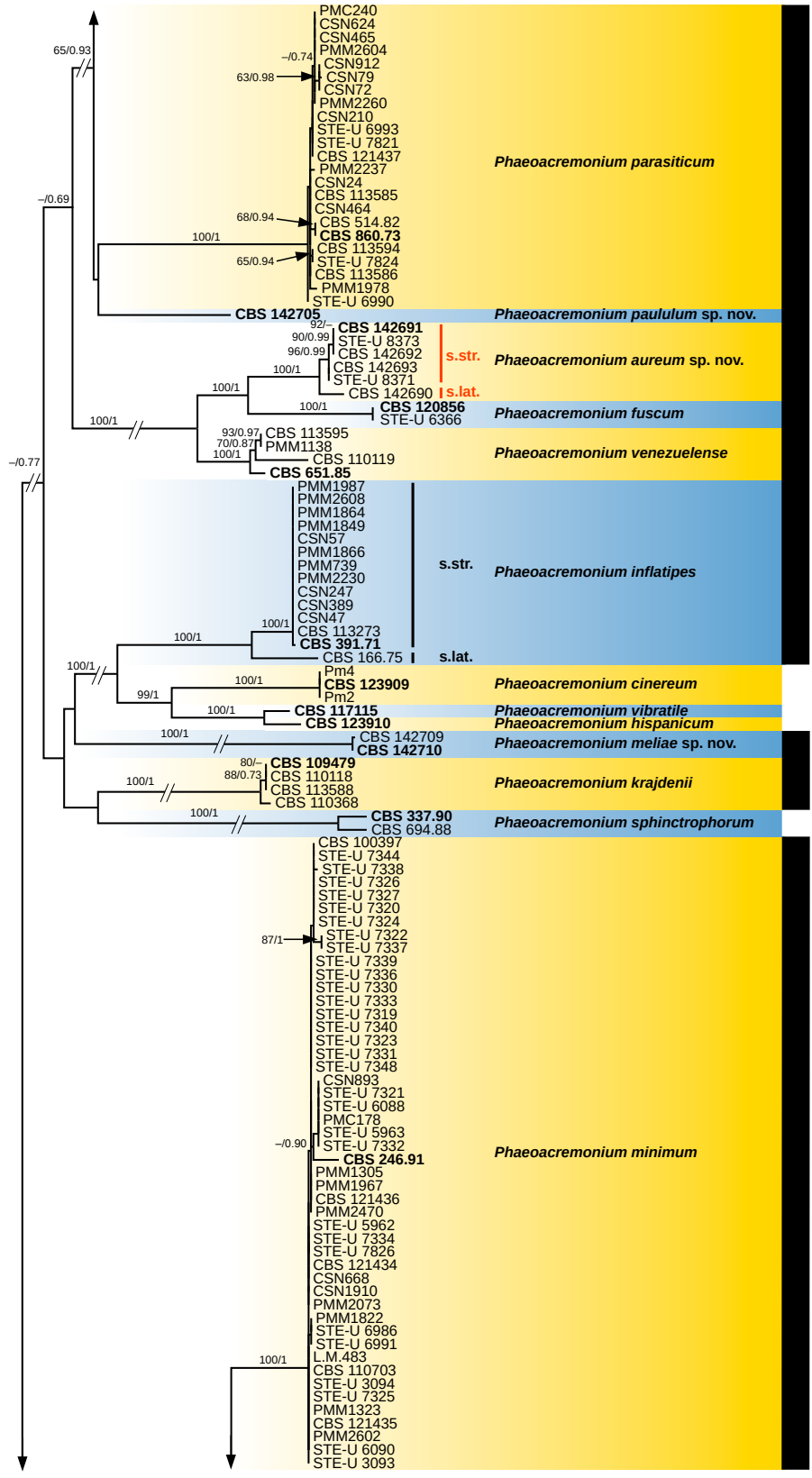
<sup>a</sup> CBS, Westerdijk Fungal Biodiversity Institute, Utrecht, the Netherlands; CSN, collection of Chris Spies at ARC-Nietvoorbij, Stellenbosch, South Africa; ID, collection of Ihan du Plessis at ARC-Nietvoorbij; PMM, collection of Providence Moyo at the University of Stellenbosch Department of Plant Pathology, Stellenbosch, South Africa; STE-U, fungal collection of the University of Stellenbosch Department of Plant Pathology.

<sup>†</sup> Ex-type strain.



**Fig. 1** Maximum likelihood phylogeny of the genus *Phaeoacremonium* as estimated from concatenated alignments of the actin (*ACT*) and beta-tubulin (*TUB2*) regions. Maximum likelihood bootstrap percentages and Bayesian posterior probability values are indicated at the nodes. Support values less than 70 % bootstrap or 0.80 posterior probability are omitted or indicated with ‘-’. Ex-type strains are indicated in **bold** typeface. In species where considerable intraspecific variation was observed sub-clades that included the ex-type strain were designated *sensu stricto* (s.str.) while the remaining sub-clade(s) were designated *sensu lato* (s.lat.). Clade and sub-clade designations in orange indicate paraphyletic species or incongruence between the combined *ACT-TUB2* phylogeny and individual *ACT/TUB2* phylogenies (see Appendix 2). Vertical black bars on the right of the figure indicate species that have been reported in South Africa.

Fig. 1 (cont.)



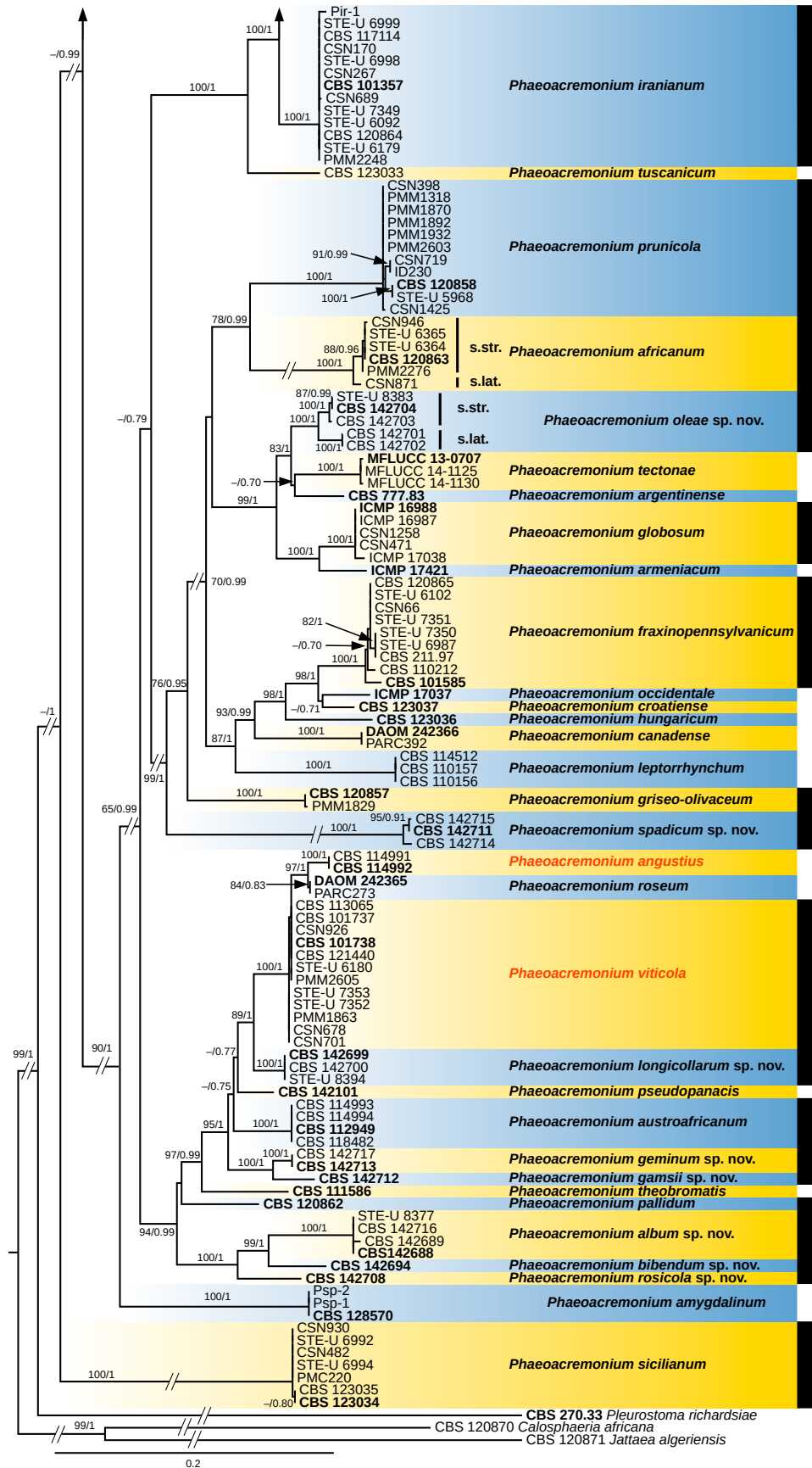
**Morphological characterisation**

Slide cultures for micromorphological characterisation were prepared following a similar protocol as Arzanlou et al. (2007). Isolates of new species were grown on malt extract agar (MEA; Oxoid) for two weeks. Agar blocks (~1 cm x 1 cm) from actively growing regions of the cultures were placed on autoclaved microscope slides in 9 cm Petri dishes containing two autoclaved discs of filter paper that had been moistened with 1.5 mL sterile water. An autoclaved cover slip was placed on each agar block, Petri dishes were sealed with cling wrap and

incubated at 25 °C. After 5 d, both colonised cover slips and colonised microscope slides were used to prepare slides by transferring colonised cover slips to clean microscope slides with 70 % lactic acid, and by placing 70 % lactic acid and clean cover slips on colonised parts of the microscope slides after removing the agar blocks. Slides were pressed under stacks of heavy books for times ranging from several hours to overnight, and sealed with nail polish.

Fungal growth on slides were inspected using a light microscope (Nikon Y-TV55). Images of vegetative hyphae, conidia,

Fig. 1 (cont.)



phialides (types I, II and III), collarettes, and conidiophores were captured at 1000× magnification using a Nikon DS-Ri2 camera on a Nikon Eclipse Ni light microscope. Except where noted otherwise, thirty individual structures of each type were viewed and measured using the NIS-Elements Viewer software (Nikon Instruments Inc.).

Colony morphology was evaluated on MEA, PDA and oatmeal agar (OA; Biolab) after 16 d. Plates of the different media were

inoculated with 4 mm diam plugs taken from actively growing PDA cultures and incubated at 25 °C in the dark for 16 d. Colony colours were evaluated using the colour charts of Rayner (1970). Cardinal temperatures for growth were determined by incubating MEA plates in the dark at temperatures ranging from 5–40 °C in intervals of 5 °C, as well as 37 °C and measuring radial growth after 8 d.



## RESULTS

### Isolates

Isolates of *Phaeoacremonium* were recovered from 29 different woody hosts. Based on preliminary identifications 156 isolates representing putative new species, phylogenetic variants of known species or first reports for various hosts in South Africa were selected for inclusion in this study. A full list of these strains with host information is given in Table 1.

### Phylogenetic analyses

Maximum likelihood and Bayesian analyses of the combined *ACT-TUB2* regions yielded a phylogeny with high support (98–100 % maximum likelihood bootstrap and 1.00 Bayesian posterior probability) for all species-level clades except *P. alvesii* (paraphyletic, 88 % bootstrap support and 1.00 posterior probability for *P. alvesii* s.str.), *P. griseorubrum* (paraphyletic, 61 % bootstrap support and 0.99 posterior probability for *P. griseorubrum* s.str.), *P. roseum* (84 % bootstrap support and 0.83 posterior probability) and *P. viticola* (paraphyletic with regards to *P. angustius* and *P. roseum*) (Fig. 1). The 267 South African strains clustered in 33 clades and 5 unique or unresolved positions representing 36 *Phaeoacremonium* species. Of the 156 strains reported here for the first time, 152 strains clustered in 28 clades, and 4 additional strains occupied unique or unresolved positions. In total, these 156 strains represent 31 species, 13 of which are new species described below. *Phaeoacremonium alvesii* strain CBS 113590 and four South African strains (PMC206, PMC217, STE-U 6988, STE-U 6989) previously reported as *P. alvesii* (White et al. 2011, Moyo et al. 2014) clustered in the *P. italicum* clade with good support (100 % bootstrap, 1.00 posterior probability). The phylogenetic positions of all other previously reported South African *Phaeoacremonium* strains confirmed their reported identifications.

The combined *ACT-TUB2* phylogeny revealed sub-clades suggestive of significant intraspecific genetic variation within several species-level clades, including *P. africanum*, *P. aureum* sp. nov., *P. australiense*, *P. inflatipes*, *P. junior* sp. nov., *P. oleae* sp. nov., *P. scolyti* and *P. subulatum*. For each of these species, the sub-clade containing the ex-type strain has been designated the *sensu stricto* (s.str.) clade and the remaining *sensu lato* (s.lat.) sub-clades have been numbered alphabetically where more than one is present (Fig. 1). Individual gene maximum likelihood phylogenies of *ACT* and *TUB2* (no support calculated) resolved identical sub-clades within *P. africanum*, *P. inflatipes*, and *P. oleae* sp. nov., but suggested conflicting or unresolved placement of some isolates within *P. aureum* sp. nov., *P. australiense*, *P. junior* sp. nov., *P. scolyti* and *P. subulatum* (Appendix 2).

The combined phylogeny (Fig. 1) and individual gene phylogenies (Appendix 2) revealed paraphyly, incongruence or a lack of resolution for some species. In the *P. alvesii*/*P. italicum* group the phylogenetic positions of strains PMM744 (*P. alvesii* s.lat.) and CBS 113590 (*P. italicum* s.lat.) were incongruent between the combined and individual phylogenies. The combined and *TUB2* phylogenies suggest that *P. italicum* s.lat. strain CBS 113590 should be included in *P. italicum*; however, in the *ACT* phylogeny this strain clustered with *P. alvesii*. Similarly, *P. alvesii* s.lat. strain PMM744 held unique positions in the combined and *TUB2* phylogenies, but in the *ACT* phylogeny this strain clustered in the clade otherwise consisting of *P. alvesii* s.str. and *P. italicum* s.lat. CBS 113590. *Phaeoacremonium griseorubrum* was paraphyletic in both the *TUB2* and combined phylogenies, with *P. griseorubrum* s.lat. containing strains CBS 566.97 and PMM2220, and *P. griseorubrum* s.str. containing all other strains of this species, including the ex-type (CBS 111657). In the *ACT* phylogeny, however, this species was monophyletic, although

strain CBS 566.97 clustered separately from the remaining strains. Strain PMM2220, on the other hand, clustered within the *P. griseorubrum* s.str. clade. Paraphyly and a lack of resolution was also observed in the *P. angustius*/*P. roseum*/*P. viticola* group. In the combined and *TUB2* phylogenies *P. viticola* was paraphyletic with regards to *P. angustius* or *P. roseum*. In the *ACT* phylogeny this species was monophyletic; however, *P. angustius* was paraphyletic with regards to *P. roseum*.

## TAXONOMY

***Phaeoacremonium album*** C.F.J. Spies, Moyo, Halleen & L. Mostert, sp. nov. — MycoBank MB820852; Fig. 2

*Etymology.* Latin, *album*, meaning white. In reference to the white colour of colonies on MEA, PDA and OA.

*Type specimen.* SOUTH AFRICA, Western Cape, Durbanville, from internal wood necrosis of pear (*Pyrus communis*), 6 May 2014, P. Moyo (holotype CBS-H 23159, culture ex-type CBS 142688 = STE-U 8379 = PMM1938).

MEA slide culture micromorphology — *Mycelium* septate, hyaline to very pale brown, smooth to coarsely verruculose, 1.5–2.5 (av. 2)  $\mu\text{m}$  wide, in bundles of up to 5 strands; no warts observed. *Conidiophores* (only 9 characterised) smooth to verruculose, mainly branched, hyaline, with up to 5 septa, 16–52  $\times$  2–2.5 (av. 25  $\times$  2.5)  $\mu\text{m}$ ; basal cells sometimes inflated. *Phialides* terminal or lateral, monophialidic, predominantly type I, smooth, hyaline; collarettes usually short 0.5–1.5  $\times$  0.5–2(–2.5) (av. 1  $\times$  1)  $\mu\text{m}$ . Type I phialides subcylindrical to elongate-ampulliform, sometimes very short (0.5–)1–11(–16)  $\times$  1–2(–2.5) (av. 4.5  $\times$  1)  $\mu\text{m}$ ; type II elongate-ampulliform to navicular, sometimes subcylindrical with tapering apex, (7.5–)8–13(–13.5)  $\times$  1.5–3 (av. 10.5  $\times$  2.5)  $\mu\text{m}$ ; type III elongate-ampulliform to navicular to subcylindrical with tapering apex, sometimes subulate, 13–21.5(–22)  $\times$  (1–)1.5–2 (av. 15.5  $\times$  2)  $\mu\text{m}$ . *Conidia* allantoid to subcylindrical or oblong-ellipsoidal, 3.5–5(–5.5)  $\times$  1–1.5 (av. 4  $\times$  1.5)  $\mu\text{m}$ .

Colony morphology — Colonies reaching a radius of 9–10 mm in 8 d at 25 °C. Minimum temperature for growth 10 °C, optimum 25 °C, maximum 30 °C. Colonies on MEA and PDA smooth, flat, with entire edge; after 16 d white above, white to pale buff in reverse. Colonies on OA woolly, with entire edge; after 16 d white.

Markers used for identification — *TUB2* = KY906885, *ACT* = KY906884.

*Additional strains examined.* SOUTH AFRICA, Western Cape, Stellenbosch, from internal wood necrosis of quince (*Cydonia oblonga*), 19 June 2014, P. Moyo (CBS 142689 = STE-U 8378 = PMM2275).

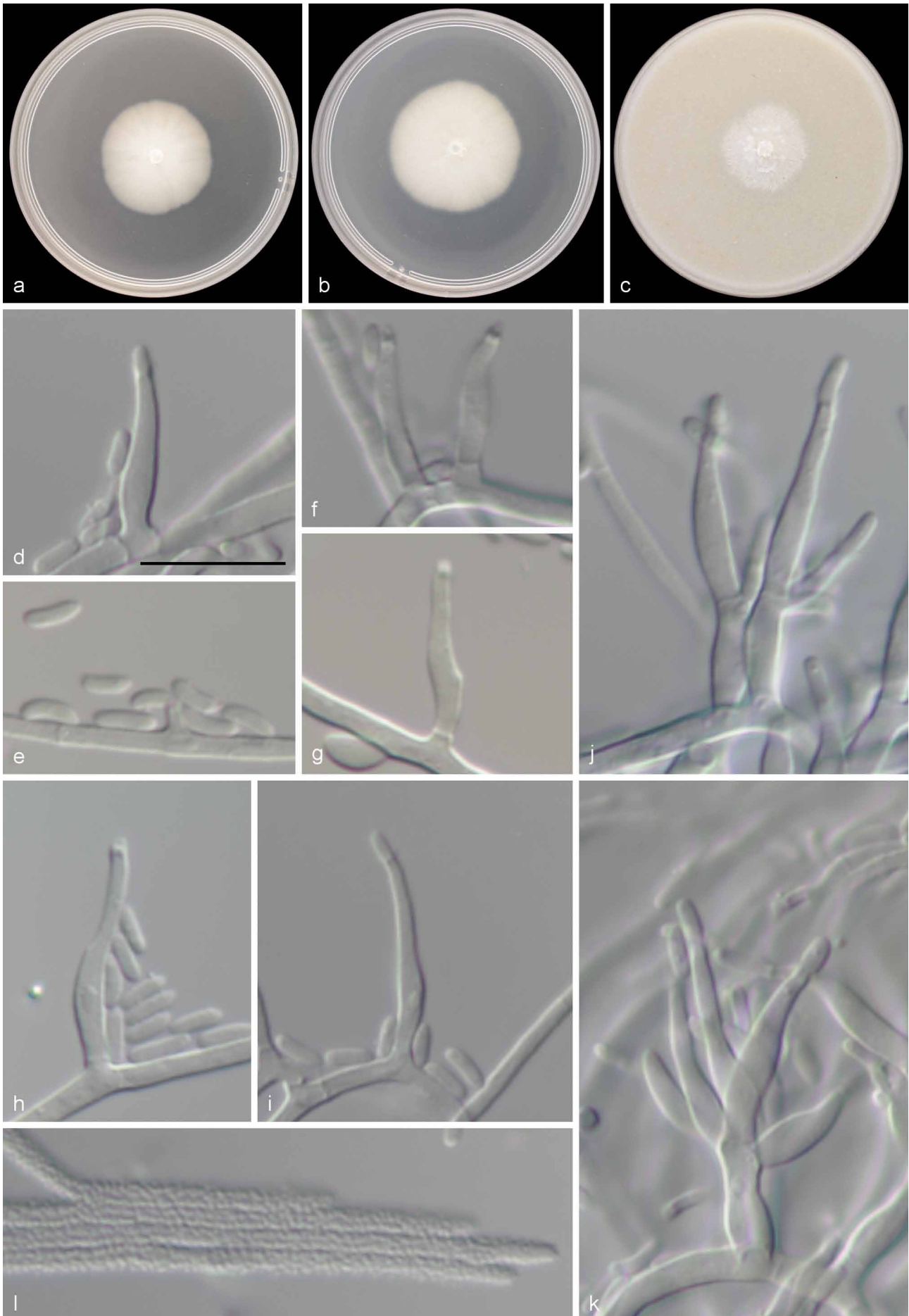
Notes — *Phaeoacremonium album* is related to *P. bibendum* and *P. rosicola* within the larger clade that also includes *P. angustius*, *P. austroafricanum*, *P. geminum*, *P. gamsii*, *P. longicollarum*, *P. pallidum*, *P. roseum*, *P. theobromatis* and *P. viticola*. Very little or no phylogenetic variation was observed among the four isolates included in the *ACT-TUB2* phylogeny. In addition to the ex-type, only strain CBS 142689 was characterised morphologically. The type I phialides of the ex-type strain were generally shorter than those observed for strain CBS 142689, which had type I phialides 2.5–12.5(–15.5) (av. 6.5)  $\mu\text{m}$  in length. Other measured characters as well as colony morphology were similar for these two isolates.

***Phaeoacremonium aureum*** C.F.J. Spies, Moyo, Halleen & L. Mostert, sp. nov. — MycoBank MB821005; Fig. 3

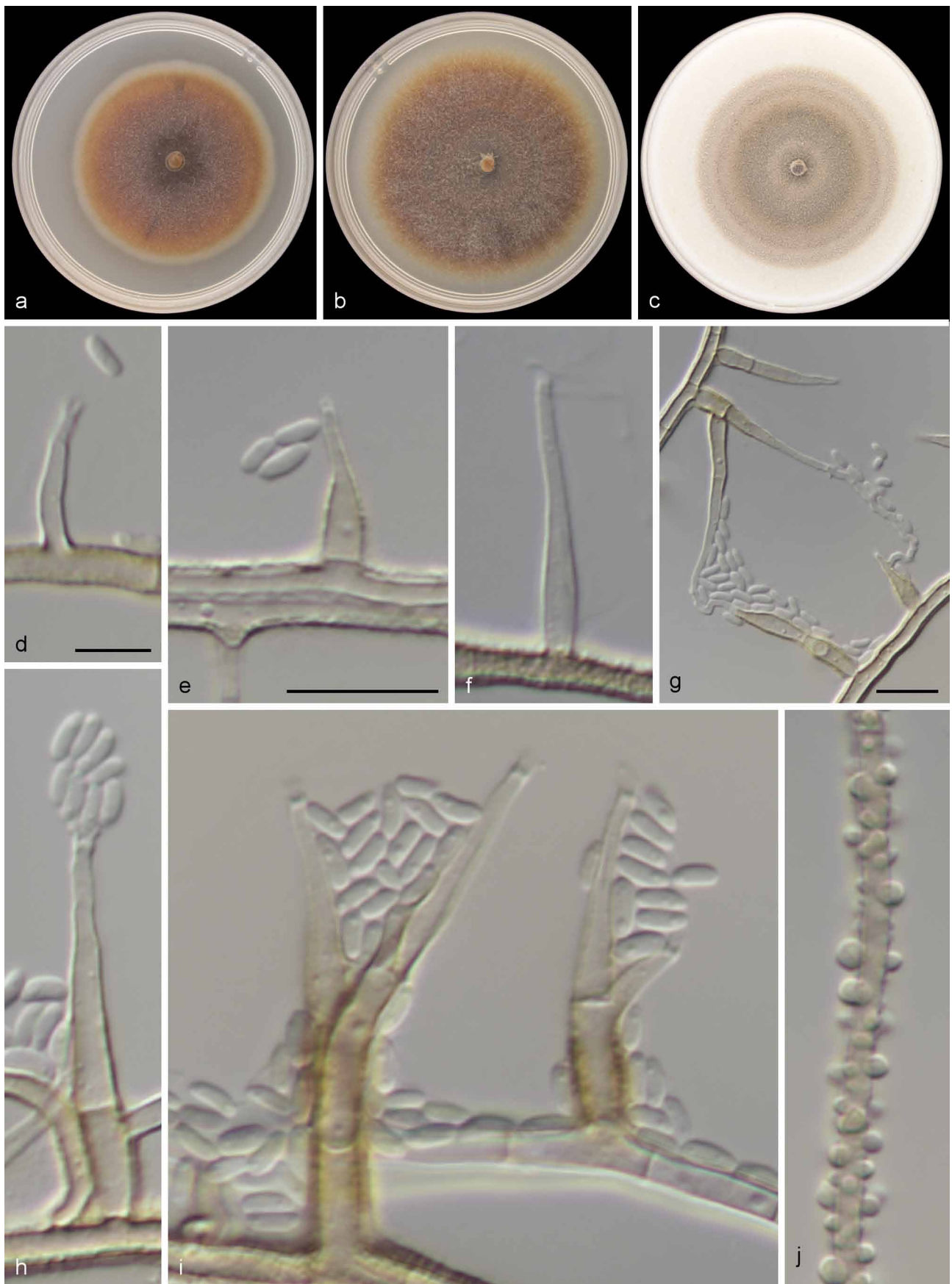
*Etymology.* Latin, *aureum* (from *aurea*), meaning golden. In reference to the golden pigmentation of some hyphae.

*Type specimen.* SOUTH AFRICA, Western Cape, Wellington, from internal wood necrosis of syringa (*Melia azedarach*), 6 Oct. 2014, P. Moyo (holotype CBS-H 23160, culture ex-type CBS 142691 = STE-U 8372 = CSN23).





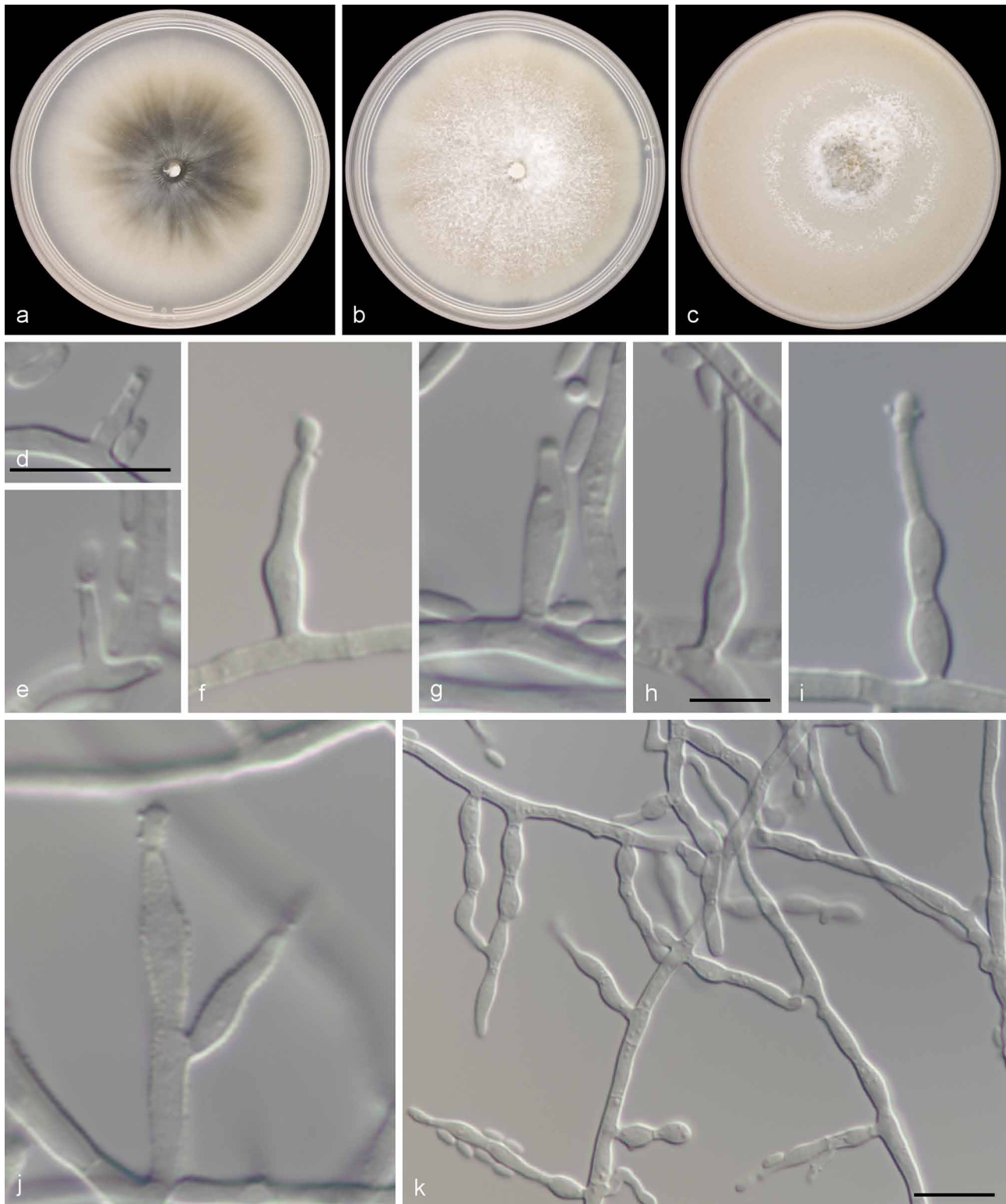
**Fig. 2** *Phaeoacremonium album* (CBS 142688 – ex-type culture STE-U 8379 = PMM1938). a–c. Sixteen-day-old colonies incubated at 25 °C on MEA (a), PDA (b) and OA (c); d–e. type I phialides, elongate ampulliform (d) and short, subcylindrical, with allantoid conidia (e); f–g. subcylindrical (f) and elongate ampulliform (g) type II phialides; h–i. elongate ampulliform type III phialides; j–k. branched conidiophores; l. bundle of four verruculose hyphal strands. — Scale bar: d = 10 µm, applies to e–l.



**Fig. 3** *Phaeoacremonium aureum* (CBS 142691 – ex-type culture STE-U 8372 = CSN23). a–c. Sixteen-day-old colonies incubated at 25 °C on MEA (a), PDA (b) and OA (c); d. subcylindrical type I phialide; e. basally pigmented elongate ampulliform type II phialide; f. elongate ampulliform type III phialide; g. branched conidiophores and a type II phialide showing terminal and lateral vegetative proliferation; h–i. branched conidiophores with a slimy head of conidia (h) and golden-brown verruculose texture on basal parts (i); j. hyphal exudate observed as warts. — Scale bars: d = 5 µm, applies to h, j; e, g = 10 µm, e applies to f, i.

MEA slide culture micromorphology — *Mycelium* hyaline to golden brown, smooth to tuberculate, 1.5–2.5(–3.5) (av. 2)  $\mu\text{m}$  wide, in bundles of up to 5 strands, with warts up to 8  $\mu\text{m}$ . *Conidiophores* smooth to verruculose, branched or unbranched, hyaline to golden brown, with up to 4 septa, (18–)18.5–38(–45)  $\times$  2.5–4(–4.5) (av. 27.5  $\times$  3)  $\mu\text{m}$ . *Phialides* terminal or lateral, monopialidic, with types II and III dominant, generally smooth to verruculose, hyaline to pale brown; with collarettes 0.5–2  $\times$  1–2.5 (av. 1.5  $\times$  1.5)  $\mu\text{m}$ ; and with lateral and terminal pro-

liferation occurring frequently. Type I phialides subcylindrical to elongate-ampulliform, (3–)4–17(–18.5)  $\times$  1–2.5(–3) (av. 8.5  $\times$  2)  $\mu\text{m}$ ; type II elongate-ampulliform to subcylindrical with tapering apex, (8–)9–13.5  $\times$  2–3(–3.5) (av. 11.5  $\times$  2.5)  $\mu\text{m}$ ; type III subcylindrical with tapering apex, sometimes elongate-ampulliform or navicular, (14–)14.5–21.5(–23)  $\times$  2–2.5(–3) (av. 17  $\times$  2.5)  $\mu\text{m}$ . *Conidia* borne in slimy heads, oblong ellipsoidal to subcylindrical, 3–5(–5.5)  $\times$  1.5–2(–2.5) (av. 4  $\times$  1.5)  $\mu\text{m}$ .



**Fig. 4** *Phaeoacremonium bibendum* (CBS 142694 – ex-type culture STE-U 8365 = CSN894). a–c. Sixteen-day-old colonies incubated at 25 °C on MEA (a), PDA (b) and OA (c); d–e. subcylindrical type I phialides; f–g. elongate ampulliform (f) and navicular (g) type II phialides; h. elongate ampulliform type III phialide with slightly inflated neck; i–j. conidiophores, unbranched with inflated basal cell and basally inflated conidiogenous cell (i) and branched (j); k. vegetative hyphae, conidiophores and phialides with inflated segments. — Scale bars: d, k = 10  $\mu\text{m}$ , d applies to e–g, i–j; h = 5  $\mu\text{m}$ .



Colony morphology — Colonies reaching a radius of 13–14 mm in 8 d at 25 °C. Minimum temperature for growth 15 °C, optimum 30 °C, maximum 37 °C. Colonies on MEA flat, felty, with entire edge; after 16 d luteous sienna with dark brick centre and white margin above, luteous umber with dark brick centre and ochreous buff margin in reverse. Colonies on PDA flat, felty, with entire edge; after 16 d dark brick fading to luteous sienna at the margins above, dark brick fading to luteous umber at the margins in reverse. Colonies on OA flat, felty, with entire edge; after 16 d dark mouse grey to greyish sepia.

Markers used for identification — *TUB2* = KY906657, *ACT* = KY906656.

*Additional strains examined.* SOUTH AFRICA, Western Cape, Franschhoek, from internal wood necrosis of syringa (*Melia azedarach*), 25 Sept. 2014, *P. Moyo* (STE-U 8371 = CSN20); Western Cape, Calitzdorp, from internal wood necrosis of syringa (*Melia azedarach*), 31 Oct. 2014, *P. Moyo* (STE-U 8373 = CSN124); Western Cape, Porterville, from internal wood necrosis of guava (*Psidium guajava*), 19 Aug. 2015, C.F.J. Spies (CBS 142690 = STE-U 8374 = CSN1322); Western Cape, Klawer, from internal wood necrosis of guava (*Psidium guajava*), 12 Aug. 2013, *P. Moyo* (CBS 142692 = STE-U 8375 = PMM1019); Western Cape, Stellenbosch, from internal wood necrosis of rose (*Rosa* sp.), 11 Apr. 2014, *P. Moyo* (CBS 142693 = STE-U 8376 = PMM2252).

Notes — *Phaeoacremonium aureum* is phylogenetically related to *P. fuscum* and *P. venezuelense*. Some intraspecific phylogenetic variation is apparent in this species. With the exception of strain CBS 142690, all strains had identical *TUB2* sequences, while in the *ACT* region, strains STE-U 8371 and CBS 142693 differed from strains CBS 142691 (ex-type), STE-U 8373 and CBS 142692 at two nucleotide positions. In strain CBS 142690, the *TUB2* sequence showed 13 SNPs and one six-nucleotide indel distinct from the other sequences, while, contrastingly, the *ACT* sequence was identical to that of strains STE-U 8371 and CBS 142693. All isolates exhibited similar morphological characteristics. Microcyclic conidiation was observed in strain CBS 142690. This strain did not have hyphal warts and its phialides did not proliferate as in other strains.

***Phaeoacremonium bibendum*** C.F.J. Spies, Moyo, Halleen & L. Mostert, *sp. nov.* — MycoBank MB821006; Fig. 4

*Etymology.* In reference to the inflated segments frequently observed in the hyphae and conidiophores calling to mind Bibendum (also known as the Michelin Man) who consists of inflated segments.

*Type specimen.* SOUTH AFRICA, Western Cape, Durbanville, from internal wood necrosis of Peruvian pepper (*Schinus molle*), 27 Feb. 2015, *P. Moyo* (holotype CBS-H 23161, culture ex-type CBS 142694 = STE-U 8365 = CSN894).

MEA slide culture micromorphology — Dense growth on slide culture. *Mycelium* with individual segments sometimes inflated, hyaline to very pale brown, smooth to finely verruculose, 1.5–2.5 (av. 2)  $\mu\text{m}$  wide, in bundles of up to 6 strands, with individual strands in bundles often forming direct hyphal connections. *Conidiophores* smooth, often unbranched, hyaline, with up to 6 septa, constricted at septa; individual segments often prominently inflated, (10–)11.5–34(–43.5)  $\times$  (2–)2.5–3.5 (av. 20.5  $\times$  3)  $\mu\text{m}$ . *Phialides* solitary, terminal; monophialidic, with type II dominant, generally smooth to finely verruculose, hyaline; with short collarettes 0.5–1  $\times$  0.5–1.5(–2) (av. 0.5  $\times$  1)  $\mu\text{m}$ . Type I phialides subcylindrical to elongate-ampulliform, (1–)2–9(–10)  $\times$  1–2.5(–3) (av. 4.5  $\times$  1.5)  $\mu\text{m}$ ; type II mainly elongate-ampulliform and constricted at the base as well as often constricted below the neck; in some cases, lageniform with subcylindrical or tapering neck, navicular, with neck sometimes slightly inflated, (6–)7–13  $\times$  2–3 (av. 10  $\times$  2.5)  $\mu\text{m}$ ; type III (only 14 characterised) subcylindrical with tapering apex to elongate-

ampulliform, lageniform or navicular, 13–19.5  $\times$  1.5–2.5 (av. 16  $\times$  2)  $\mu\text{m}$ . *Conidia* oblong ellipsoidal, 3–4.5(–5)  $\times$  (1–)1.5–2 (av. 3.5  $\times$  1.5)  $\mu\text{m}$ .

Colony morphology — Colonies reaching a radius of 8 mm in 8 d at 25 °C. Minimum temperature for growth 5 °C, optimum 20 °C, maximum 30 °C. Colonies on MEA flat, smooth, with entire edge; after 16 d greenish black with white to pale buff margin above and in reverse. Colonies on PDA felty to woolly, with entire edge; after 16 d white to dark olivaceous buff above, pale buff to dark olivaceous buff with olivaceous grey specks at centre on the reverse. Colonies on OA felty to woolly, with entire edge; after 16 d white with smoky grey centre.

Markers used for identification — *TUB2* = KY906759, *ACT* = KY906758.

Notes — *Phaeoacremonium bibendum* is phylogenetically related to two new species, *P. album* and *P. rosicola*. The inflated segments of hyphae and conidiophores for which *P. bibendum* is named bear some similarity to the swollen phialide bases and conidiophore segments of *P. globosum* (Graham et al. 2009); however, such swollen segments were not reported in vegetative hyphae of *P. globosum*, as is the case for *P. bibendum*, and the two species are clearly phylogenetically distinct.

***Phaeoacremonium gamsii*** C.F.J. Spies, Moyo, Halleen & L. Mostert, *sp. nov.* — MycoBank MB821008; Fig. 5

*Etymology.* In honour of Walter Gams, one of the co-authors of the genus *Phaeoacremonium*.

*Type specimen.* SOUTH AFRICA, Western Cape, Constantia, from internal wood necrosis of bottlebrush tree (*Callistemon* sp.), 25 Nov. 2014, *P. Moyo* (holotype CBS-H 23170, culture ex-type CBS 142712 = STE-U 8366 = CSN670).

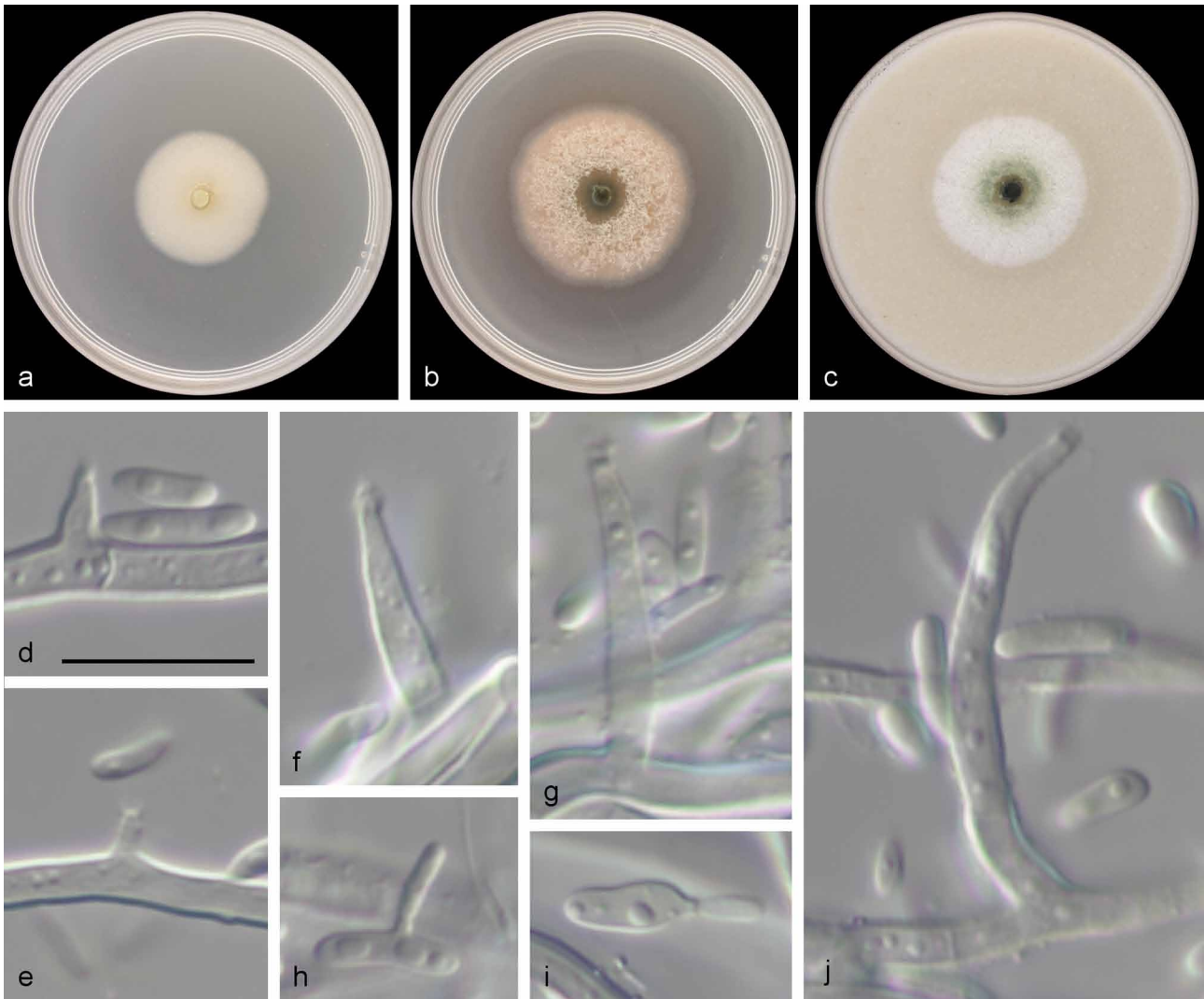
MEA slide culture micromorphology — *Mycelium* hyaline, smooth, 1.5–3 (av. 2.5)  $\mu\text{m}$  wide, in bundles of up to 10. *Conidiophores* uncommon (only 12 characterised), smooth, branched or unbranched, hyaline, with up to 3 septa, 17.5–45.5  $\times$  2–4 (av. 31  $\times$  3)  $\mu\text{m}$ . *Phialides* terminal or lateral, monophialidic, with types I and III dominant; generally smooth, hyaline; with collarettes cylindrical to slightly flaring (0.5–)1–2  $\times$  1–2(–2.5) (av. 1.5  $\times$  1.5)  $\mu\text{m}$ . Type I phialides cylindrical to subcylindrical, sometimes tapering toward the apex, (0.5–)1.5–7.5(–9)  $\times$  1–2(–2.5) (av. 3  $\times$  1.5)  $\mu\text{m}$ ; type II uncommon (only 10 characterised), elongate-ampulliform, sometimes subcylindrical tapering toward the apex, 8–13  $\times$  2–3 (av. 11  $\times$  2.5)  $\mu\text{m}$ ; type III elongate-ampulliform to subcylindrical tapering toward the apex, sometimes navicular, (13.5–)14.5–23.5(–28.5)  $\times$  2–3(–3.5) (av. 18.5  $\times$  2.5)  $\mu\text{m}$ . *Conidia* oblong-ellipsoidal to reniform, ob-ovoid or subcylindrical, 4–6.5(–7)  $\times$  1.5–2(–2.5) (av. 5  $\times$  1.5)  $\mu\text{m}$ ; microcyclic conidiation frequently observed.

Colony morphology — Colonies reaching a radius of 10 mm in 8 d at 25 °C. Minimum temperature for growth 5 °C, optimum 25 °C, maximum 30 °C. Colonies on MEA smooth, flat, with entire edge; after 16 d white with honey centre above and in reverse. Colonies on PDA flat, felty to woolly, with entire edge; after 16 d fulvous to ochreous with fuscous black centre and buff margin above, umber to pale orange with fuscous black centre and buff margin in reverse. Colonies on OA woolly, with entire edge; after 16 d white with dull green centre.

Markers used for identification — *TUB2* = KY906741, *ACT* = KY906740.

Notes — *Phaeoacremonium gamsii* is currently only known from a single isolate that is phylogenetically closely related to *P. geminum*. It differs from *P. geminum* in several aspects that are outlined in the notes under *P. geminum* below.





**Fig. 5** *Phaeoacremonium gamsii* (CBS 142712 – ex-type culture STE-U 8366 = CSN670). a–c. Sixteen-day-old colonies incubated at 25 °C on MEA (a), PDA (b) and OA (c); d–e. conical (d) and sub-cylindrical (e) type I phialides; f. elongate ampulliform type II phialide; g. type III phialide; h–i. microcyclic conidiation; j. unbranched conidiophore. — Scale bar: d = 10 µm, applies to e–j.

***Phaeoacremonium geminum*** C.F.J. Spies, Havenga & L. Mostert, *sp. nov.* — MycoBank MB821007; Fig. 6

*Etymology.* Latin, *geminum*, meaning twins. Referring to the two morphologically similar isolates examined for the description.

*Type specimen.* SOUTH AFRICA, Western Cape, Riviersonderend, from pruning wound of nursery apple tree (*Malus domestica*), 17 Aug. 2015, *M. Havenga* (holotype CBS-H 23171, culture ex-type CBS 142713 = STE-U 8402 = C741 = CSN1944).

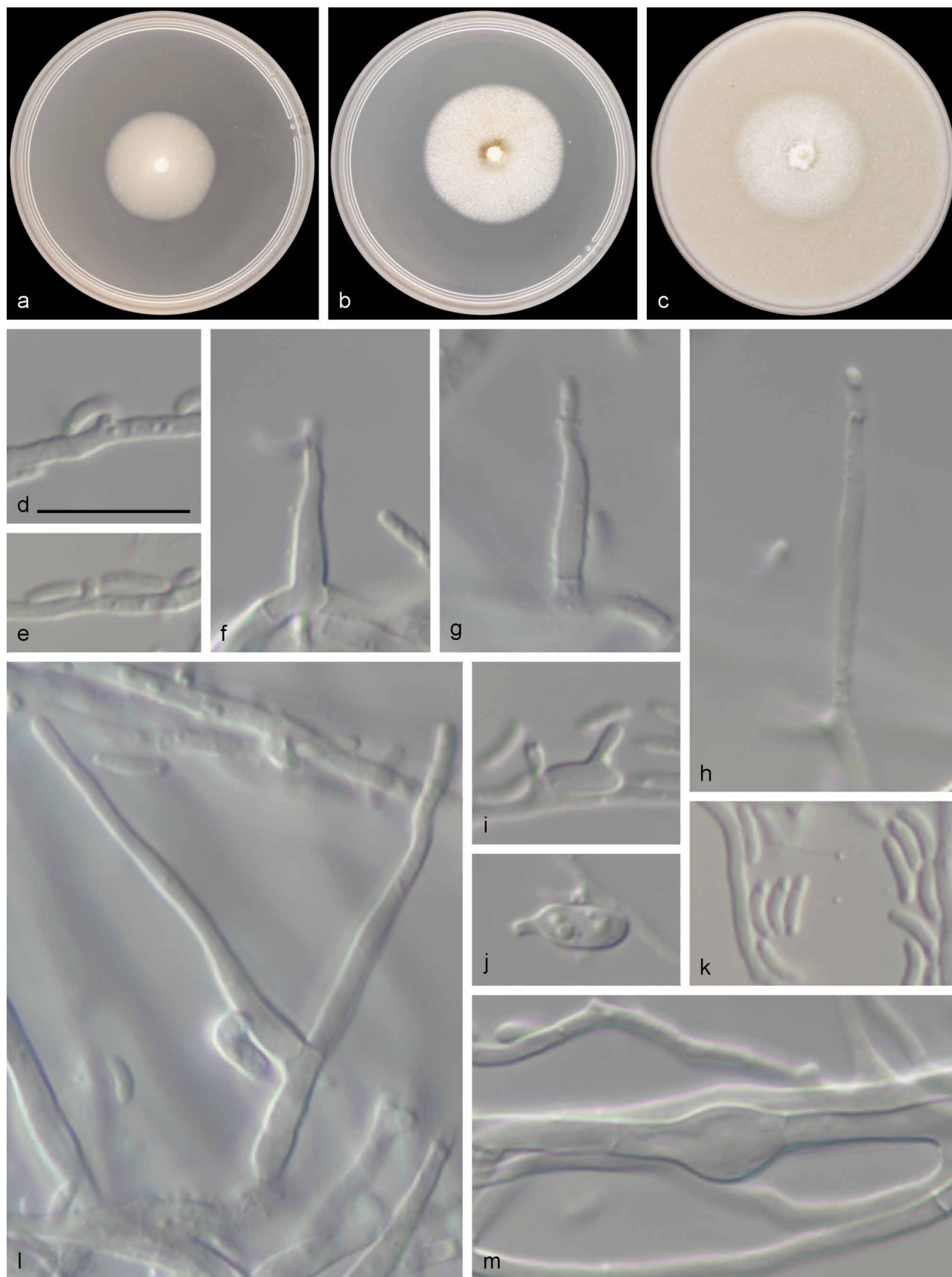
**MEA slide culture micromorphology** — *Mycelium* hyaline to pale brown, smooth to verruculose, 1.5–2.5(–3) (av. 2) µm wide, in bundles of up to 12, with individual segments occasionally swollen. *Conidiophores* uncommon (only 14 characterised), smooth to verruculose, branched or unbranched, hyaline to pale brown, with up to 4 septa, 12.5–43.5 × 2–4 (av. 28 × 2.5) µm. *Phialides* terminal or lateral, monopodialic, predominantly type I, smooth to finely verruculose, hyaline to pale brown; with collarettes cylindrical to slightly flaring (0.5–)1–1.5 × 1–2 (av. 1 × 1.5) µm. Type I phialides cylindrical to subcylindrical, tapering, or elongate-ampulliform, often reduced to an almost sessile lateral collarette on a hyphal segment, (0–)0.5–8.5(–11.5) × 1–2 (av. 3 × 1.5) µm; type II elongate-ampulliform to navicular, sometimes subcylindrical, (6–)6.5–13 × 1.5–3 (av. 10 × 2) µm; type III subulate to elongate-ampulliform or subcylindrical, (12.5–)13.5–32(–35.5) × 1.5–2.5(–3) (av. 18.5 × 2) µm. *Conidia* reniform to allantoid, oblong-ellipsoidal, (3–)4–5 × 1–1.5 (av. 4.5 × 1) µm; microcyclic conidiation frequently observed.

**Colony morphology** — Colonies reaching a radius of 8–9 mm in 8 d at 25 °C. Minimum temperature for growth 5 °C, optimum 25 °C, maximum 30 °C. Colonies on MEA smooth, flat, with entire edge; after 16 d buff above and in reverse. Colonies on PDA felty, with entire edge; after 16 d white to pale hazel with amber centre above and in reverse. Colonies on OA woolly, with entire edge; after 16 d white. Yellow pigment produced on OA.

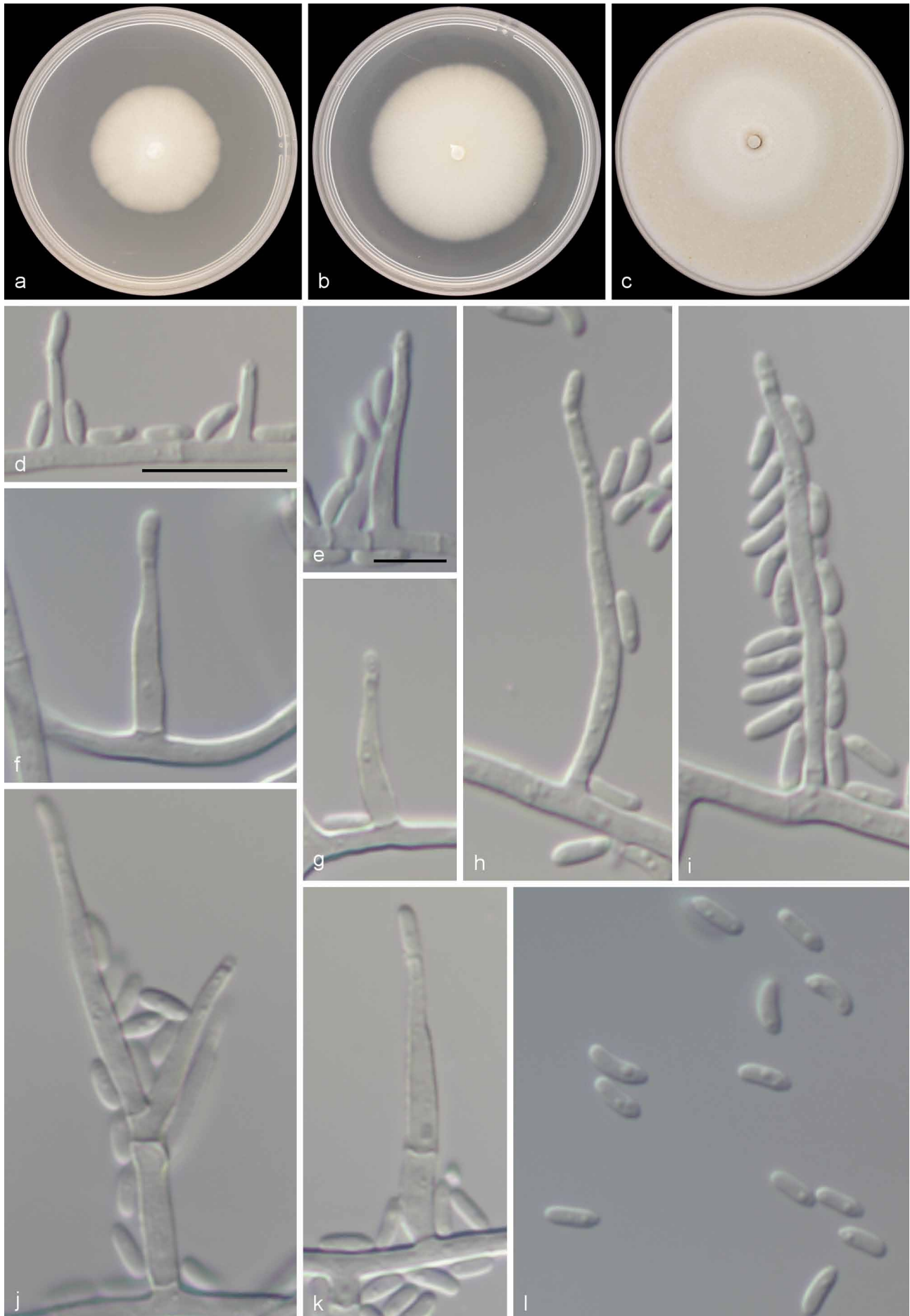
Markers used for identification — *TUB2* = KY906649, *ACT* = KY906648.

*Additional strains examined.* SOUTH AFRICA, Western Cape, Ceres, from graft union of a nursery apple tree (*Malus domestica* cv. Gale Gala grafted on CG4204), 15 Aug. 2015, *M. Havenga* (CBS 142717 = STE-U 8367 = C631 = CSN1945).

**Notes** — The two strains of *P. geminum* that were evaluated here exhibited very similar morphological characteristics. Strain C631 had slightly longer type I phialides and also equally predominant type I and II phialides; however, the short, almost sessile type I phialides are inconspicuous. It is possible that some of these were overlooked during the characterisation of strain C631, and that if more had been measured, higher type I phialide lengths would have been observed. *Phaeoacremonium geminum* differed from the closely related *P. gamsii* in the occurrence of reduced, almost sessile type I phialides and occasional swollen hyphal segments, as well as in the abundance of type II phialides, and in its colony pigmentation on MEA, PDA and OA. Similar, extremely reduced type I phialides were also



**Fig. 6** *Phaeoacremonium geminum* (CBS 142713 – ex-type culture STE-U 8402 = C741 = CSN1944). a–c. Sixteen-day-old colonies incubated at 25 °C on MEA (a), PDA (b) and OA (c); d–f. reduced (d–e) and elongate ampulliform (f) type I phialides; g. type II phialide; h. type III phialide; i–j. microcyclic conidiation; k. conidia; l. branched conidiophore; m. swollen hyphal segment. — Scale bar: d = 10 μm, applies to e–m.



**Fig. 7** *Phaeoacremonium junior* (CBS 142697 – ex-type culture STE-U 8397 = CSN273). a–c. Sixteen-day-old colonies incubated at 25 °C on MEA (a), PDA (b) and OA (c); d–e. type I phialides, subcylindrical widening at the bases (d), and elongate ampulliform (e); f–g. elongate ampulliform type II phialides; h–i. subcylindrical (h) and slender navicular (i) type III phialides; j–k. branched (j) and unbranched (k) conidiophores; l. oblong ellipsoidal and allantoid conidia. — Scale bars: d = 10 µm, applies to f, h–l; e = 5 µm, applies to g.



observed in *P. paululum*; however, the two species are clearly phylogenetically distinct.

***Phaeoacremonium junior*** C.F.J. Spies, Moyo, Halleen & L. Mostert, *sp. nov.* — MycoBank MB821009; Fig. 7

*Etymology.* ‘Junior’ was the most common name given to baby boys in South Africa in 2014, the year when this species was recovered from two provinces in this country.

*Type specimen.* SOUTH AFRICA, Western Cape, Robinson Pass, from internal wood necrosis of Peruvian pepper (*Schinus molle*), 7 Nov. 2014, *P. Moyo* (holotype CBS-H 23162, culture ex-type CBS 142697 = STE-U 8397 = CSN273).

MEA slide culture micromorphology — *Mycelium* hyaline to pale brown, smooth, 1.5–2.5 (av. 2)  $\mu\text{m}$  wide, in bundles of up to 6 strands. *Conidiophores* smooth to verruculose or sparsely tuberculate, branched or unbranched, hyaline to pale brown, with up to 5 septa, (14–)15.5–59.5(–62)  $\times$  1.5–2.5(–3) (av. 33.5  $\times$  2)  $\mu\text{m}$ . *Phialides* terminal or lateral, monophialidic, all three types equally prevalent, smooth to verruculose, hyaline to pale brown; collarettes (only 15 characterised) short, often inconspicuous 0.5–1.5  $\times$  0.5–2 (av. 1  $\times$  1)  $\mu\text{m}$ . Type I phialides subcylindrical, sometimes elongate-ampulliform or subulate, (2–)3.5–13(–25)  $\times$  1–2.5 (av. 9  $\times$  1.5)  $\mu\text{m}$ ; type II elongate-ampulliform to subulate, rarely subcylindrical, (9–)9.5–15(–15.5)  $\times$  1.5–2.5 (av. 12.5  $\times$  2)  $\mu\text{m}$ ; type III subulate or navicular to subcylindrical, (14–)14.5–26(–28.5)  $\times$  1.5–2 (av. 19  $\times$  1.5)  $\mu\text{m}$ . *Conidia* borne in slimy heads, oblong ellipsoidal to reniform, (3–)3.5–5.5(–6)  $\times$  1–1.5(–2) (av. 4  $\times$  1.5)  $\mu\text{m}$ .

Colony morphology — Colonies reaching a radius of 10–11 mm in 8 d at 25 °C. Minimum temperature for growth 5 °C, optimum 25 °C, maximum 37 °C. Colonies on MEA flat, smooth, with entire edge; after 16 d white to pale buff above and in reverse. Colonies on PDA flat, smooth, with entire edge; after 16 d white to pale buff with pale luteous buff centre above and in reverse. Colonies on OA felty, with entire edge; after 16 d white to pale buff.

Markers used for identification — *TUB2* = KY906709, *ACT* = KY906708.

*Additional strains examined.* SOUTH AFRICA, Western Cape, Bonnievale, from internal wood necrosis of apricot (*Prunus armeniaca*) associated with an old wound, 24 June 2014, *P. Moyo* (CBS 142698 = STE-U 8396 = PMM2445); Limpopo, Marble Hall, from cordon of grapevine cv. Early Sweet (*Vitis vinifera*), 18 Sept. 2014, *A. Bredell* (CBS 142695 = STE-U 8398 = CSN13); Limpopo, Marble Hall, from cordon of grapevine cv. Crimson (*Vitis vinifera*), 18 Sept. 2014, *A. Bredell* (CBS 142696 = STE-U 8399 = CSN16).

*Notes* — *Phaeoacremonium junior* is related to *P. australiense*, *P. subulatum* and the new species *P. proliferatum* that is described below. Phylogenetically, *P. junior* comprises two well-supported clades. This sub-clade clustering reflects 10 nucleotide substitutions and one indel along a 602 bp length of the *TUB2* region that consistently distinguish the isolates of the two clades. Ten nucleotide substitutions and one indel were also observed along a 208 bp length of the *ACT* region in these four isolates; however, none of these differences corresponded to the sub-clades observed in the concatenated phylogeny. Colonies of the four isolates had generally similar characteristics on MEA, PDA and OA, although strains CBS 142695 and CBS 142696 had some mouse-grey pigmentation on OA that was not observed for the two strains from the sub-clade containing the ex-type strain. Some variation was observed in the micromorphological characteristics, but these differences were not conspicuous enough to be deemed relevant, nor did they support the phylogenetic sub-clade clustering of this species in the combined *ACT-TUB2* tree.

***Phaeoacremonium longicollarum*** C.F.J. Spies, Moyo, Halleen & L. Mostert, *sp. nov.* — MycoBank MB821010; Fig. 8

*Etymology.* Latin, *longi-*, meaning long, and *collarum* (from *collare*), meaning collar. In reference to the long collarettes.

*Type specimen.* SOUTH AFRICA, Western Cape, Kruispad, from internal wood necrosis of apricot (*Prunus armeniaca*), 30 Oct. 2014, *P. Moyo* (holotype CBS-H 23163, culture ex-type CBS 142699 = STE-U 8393 = CSN84).

MEA slide culture micromorphology — *Mycelium* hyaline, 1.5–3 (av. 2)  $\mu\text{m}$  wide, smooth to verruculose, in bundles of up to 13 or more strands, no warts observed. *Conidiophores* smooth to finely verruculose, branched or unbranched, often associated with mycelial bundles or hyphal whorls; basal cells sometimes slightly inflated, hyaline to pale brown, with up to 3 septa, (21.5–)22.5–41.5(–71)  $\times$  2.5–3.5(–4) (av. 30.5  $\times$  3)  $\mu\text{m}$ . *Phialides* terminal or lateral, monophialidic, type I and III dominant, smooth to verruculose, hyaline; collarettes quite long 1–2  $\times$  1–3 (av. 1.5  $\times$  1.5)  $\mu\text{m}$ . Type I phialides subcylindrical to elongate-ampulliform to subulate, (1.5–)2–12(–17)  $\times$  1–2(–2.5) (av. 7  $\times$  1.5)  $\mu\text{m}$ ; type II mainly elongate-ampulliform, sometimes subcylindrical, navicular, or subulate 9.5–14  $\times$  (1.5–)2–3.5 (av. 12  $\times$  2.5)  $\mu\text{m}$ ; type III mainly subulate to elongate-ampulliform or navicular, (14.5–)16–27.5(–28)  $\times$  (1.5–)2–3(–3.5) (av. 20.5  $\times$  2.5)  $\mu\text{m}$ . *Conidia* shape variable, mostly oblong-ellipsoidal, 3.5–7  $\times$  1.5–2(–2.5) (av. 4.5  $\times$  2)  $\mu\text{m}$ .

Colony morphology — Colonies reaching a radius of 9–10 mm in 8 d at 25 °C. Minimum temperature for growth 5 °C, optimum 25 °C, maximum 30 °C. Colonies on MEA sparsely felty, with entire edge; after 16 d white to pale buff above and in reverse. Colonies on PDA felty to short woolly, with entire edge; after 16 d white to pale buff with ochreous amber centre above and in reverse. Colonies on OA woolly, with entire edge; after 16 d olivaceous grey with white margins.

Markers used for identification — *TUB2* = KY906689, *ACT* = KY906688.

*Additional strains examined.* SOUTH AFRICA, Western Cape, Wellington, from internal wood necrosis of guava (*Psidium guajava*), 30 Oct. 2014, *F. Halleen* (STE-U 8394 = CSN655); Western Cape, Constantia, from internal wood necrosis of guava (*Psidium guajava*) associated with an old pruning wound, 23 Apr. 2014, *P. Moyo* (CBS 142700 = STE-U 8395 = PMM1900).

*Notes* — Phylogenetically, *P. longicollarum* occupies a distinct position in the larger clade containing *P. angustus*, *P. austroafricanum*, *P. pallidum*, *P. roseum*, *P. santali*, *P. viticola*, and the five other new species described in this study. The three strains of *P. longicollarum* included in the phylogeny had identical *TUB2* and *ACT* sequences, but morphologically there were some differences. In terms of size, almost all measured structures of strain STE-U 8394 were on average longer than those of the ex-type, while those of CBS 142700 were shorter. CBS 142700 also had noticeably more subcylindrical type II and III phialides, while this shape was scarcer among type II and III phialides of the ex-type and strain STE-U 8394.

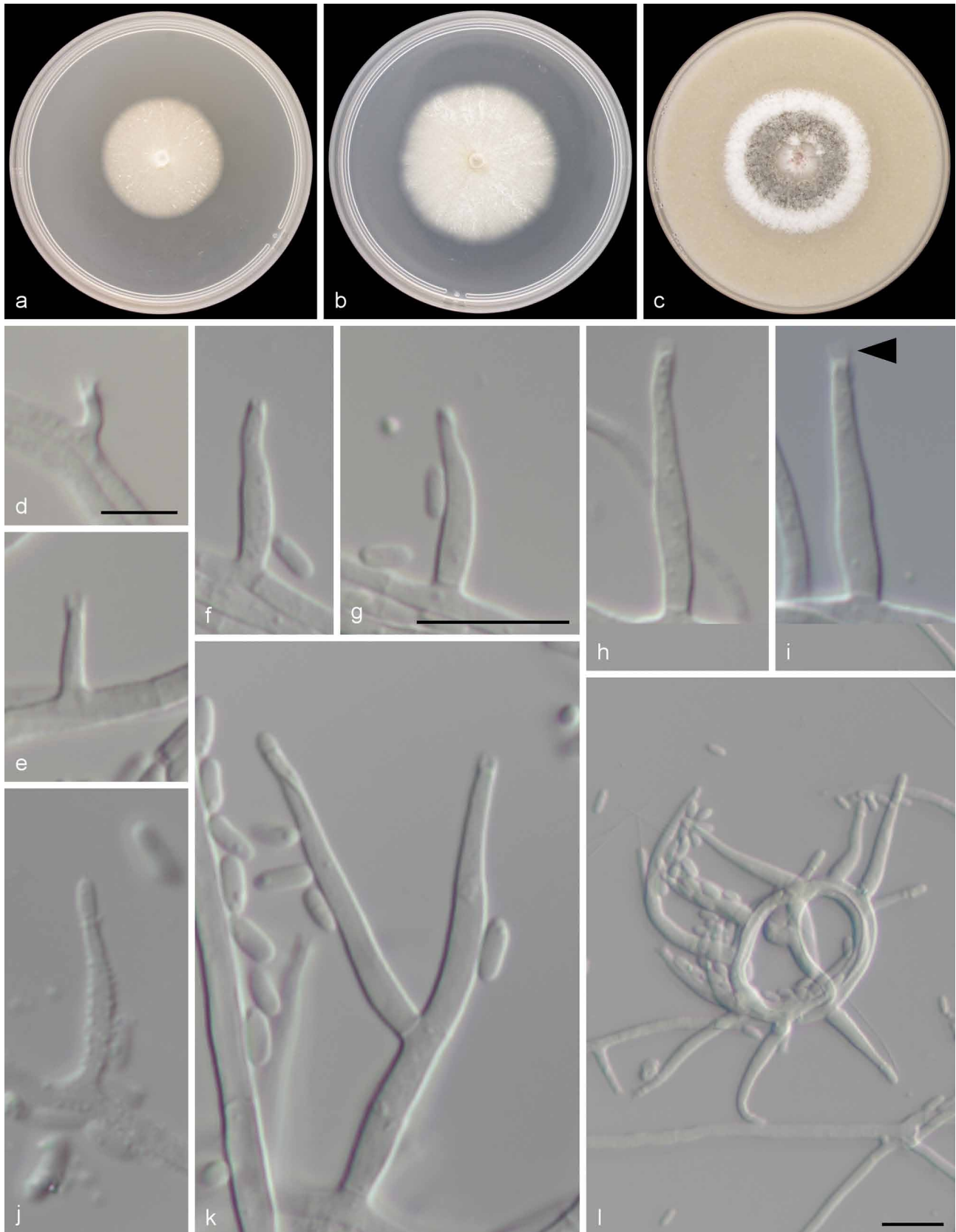
***Phaeoacremonium meliae*** C.F.J. Spies, Moyo, Halleen & L. Mostert, *sp. nov.* — MycoBank MB821016; Fig. 9

*Etymology.* In reference to the host (*Melia azedarach*) from which both strains of this species have been recovered.

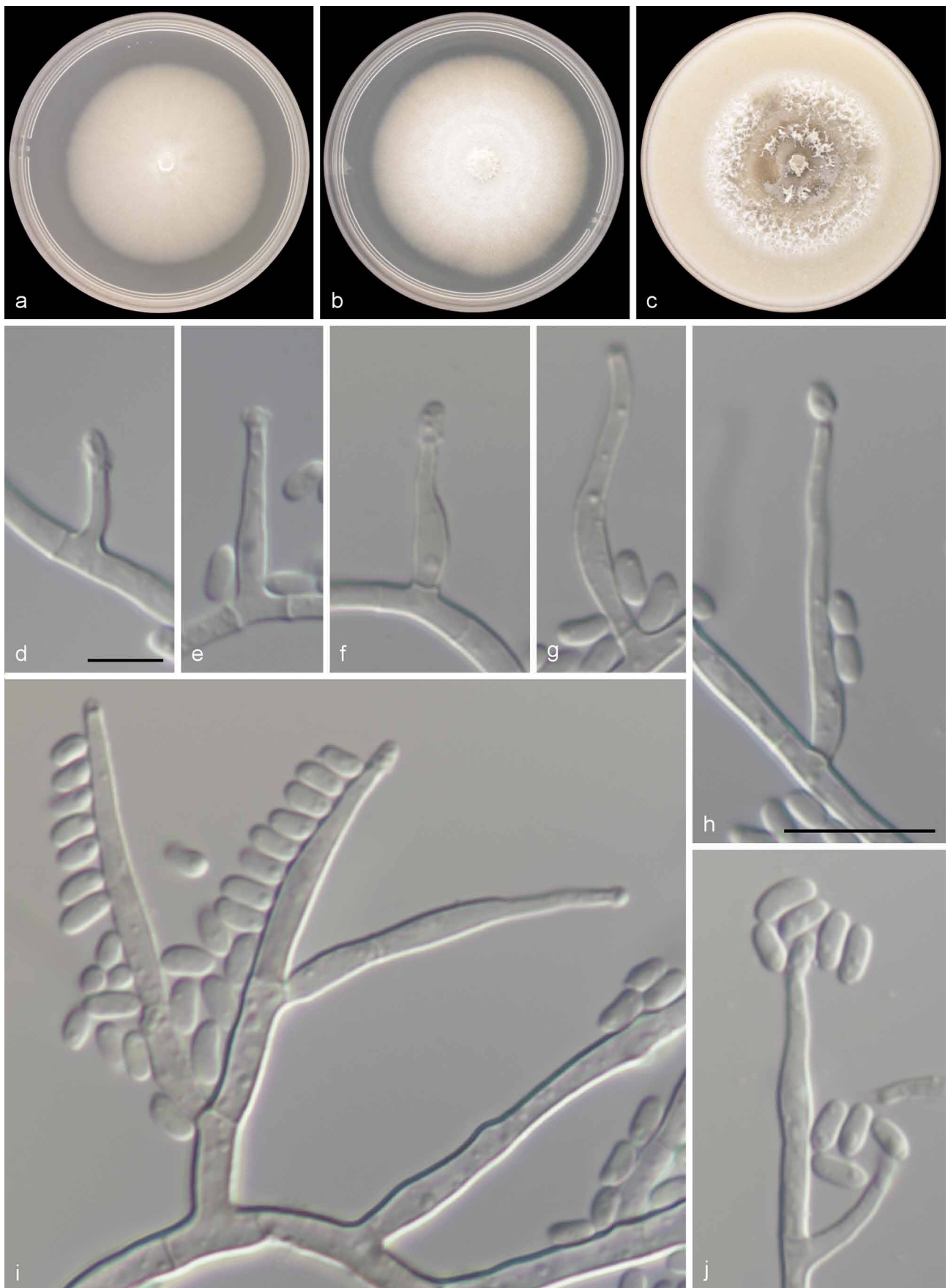
*Type specimen.* SOUTH AFRICA, Western Cape, Vredendal, from internal wood necrosis of syringa (*Melia azedarach*), 12 Aug. 2013, *P. Moyo* (holotype CBS-H 23168, culture ex-type CBS 142710 = STE-U 8392 = PMM975).

MEA slide culture micromorphology — *Mycelium* hyaline to pale brown, smooth to finely verruculose, 2–3(–3.5) (av. 2)  $\mu\text{m}$  wide, in bundles of up to 4 strands. *Conidiophores* smooth, usually branched, hyaline to pale brown, with up to 6 septa, (21.5–)23–59.5(–64)  $\times$  2–3 (av. 35  $\times$  2.5)  $\mu\text{m}$ . *Phialides* terminal or lateral, monophialidic with occasional polyphialides, smooth, hyaline to





**Fig. 8** *Phaeoacremonium longicollarum* (CBS 142699 – ex-type culture STE-U 8398 = CSN84). a–c. Sixteen-day-old colonies incubated at 25 °C on MEA (a), PDA (b) and OA (c); d–f. sub-cylindrical (d–e) and elongate ampulliform (f) type I phialides; g. elongate ampulliform type II phialide; h–i. elongate ampulliform type III phialides, long collarette indicated with a black arrowhead in i; j. verruculose phialide; k. branched conidiophore; l. hyphal whorl with conidiophores and phialides. — Scale bars: d = 5 μm, applies to e–f, h–j; g, l = 10 μm, g applies to k.

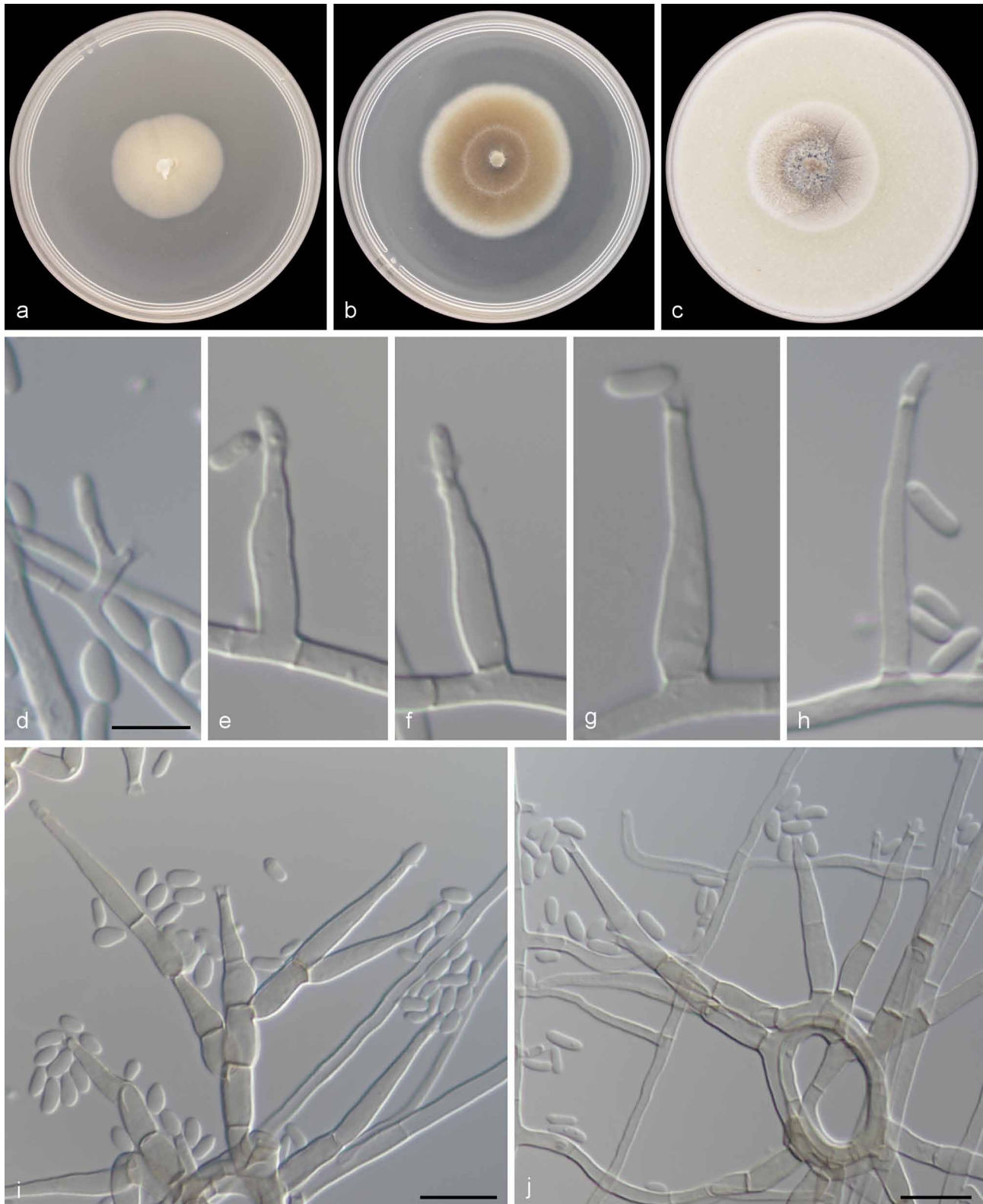


**Fig. 9** *Phaeoacremonium meliae* (CBS 142710 – ex-type culture STE-U 8392 = PMM975). a–c. Sixteen-day-old colonies incubated at 25 °C on MEA (a), PDA (b) and OA (c); d–e. subcylindrical (d) and elongate ampulliform (e) type I phialides; f. elongate ampulliform type II phialide; g–h. elongate ampulliform type III phialides; i. branched conidiophore with oblong-ellipsoidal conidia; j. oblong-ellipsoidal conidia borne in a slimy head. — Scale bars: d = 5 µm, applies to e–g; h = 10 µm, applies to i–j.

sub-hyaline; with collarettes usually prominent  $0.5\text{--}2 \times 0.5\text{--}2$  (av.  $1 \times 1.5$ )  $\mu\text{m}$ , type III phialides dominant, and with occasional lateral proliferation occurring. Type I phialides subcylindrical, sometimes tapering at the apex to elongate-ampulliform,  $(4\text{--})4.5\text{--}17(21) \times 1\text{--}2$  (av.  $8.5 \times 1.5$ )  $\mu\text{m}$ ; type II elongate-ampulliform, sometimes lageniform, navicular or subcylindrical tapering towards the apex,  $(7.5\text{--})9.5\text{--}13.5 \times 1.5\text{--}3$  (av.  $11.5 \times 2.5$ )  $\mu\text{m}$ ; type III elongate-ampulliform to navicular to subcylindrical taper-

ing towards the apex,  $(14\text{--})15\text{--}24.5(25.5) \times (1.5\text{--})2\text{--}2.5$  (av.  $19.5 \times 2$ )  $\mu\text{m}$ . *Conidia* borne in slimy heads, oblong-ellipsoidal to reniform,  $3\text{--}4(4.5) \times 1.5\text{--}2$  (av.  $3.5 \times 1.5$ )  $\mu\text{m}$ .

Colony morphology — Colonies reaching a radius of 15 mm in 8 d at 25 °C. Minimum temperature for growth 5 °C, optimum 30 °C, maximum 37 °C. Colonies on MEA flat, smooth, with entire edge; after 16 d white to buff above and in reverse. Colonies on PDA flat, felty with woolly centre, with entire edge; after 16 d



**Fig. 10** *Phaeoacremonium oleae* (CBS 142704 – ex-type culture STE-U 8385 = PMM2440). a–c. Sixteen-day-old colonies incubated at 25 °C on MEA (a), PDA (b) and OA (c); d–e. type I phialides, subcylindrical polyphialide (d) and elongate ampulliform (e); f. elongate ampulliform type II phialide; g–h. type III phialides, elongate ampulliform (g) and subcylindrical with a tapering apex (h); i. branched conidiophore showing percurrent rejuvenation; j. hyphal whorl with basally pigmented conidiophores and a type III phialide bearing conidia in a slimy head. — Scale bars: d = 5  $\mu\text{m}$ , applies to e–h; i, j = 10  $\mu\text{m}$ .



white to buff above, buff to ochreous in reverse. Colonies on OA woolly with sparsely woolly centre, with entire edge; after 16 d pale mouse grey with white woolly sections.

Markers used for identification — *TUB2* = KY906825, *ACT* = KY906824.

*Additional strains examined.* SOUTH AFRICA, Western Cape, Calitzdorp, from internal wood necrosis of chinaberry (*Melia azedarach*; also called syringa), 31 Oct. 2014, *P. Moyo* (CBS 142709 = STE-U 8391 = CSN256).

*Notes* — The two strains examined were highly similar with regards to colony morphology and micromorphology, with the exception of type I and type III phialides, which were slightly shorter in strain CBS 142709 (av. 6.30  $\mu\text{m}$  and 17.26  $\mu\text{m}$ , respectively) than those observed in the ex-type strain.

***Phaeoacremonium oleae*** C.F.J. Spies, Moyo, Halleen & L. Mostert, *sp. nov.* — MycoBank MB821011; Fig. 10

*Etymology.* In reference to the host (*Olea europaea* subsp. *cuspidata*) it was isolated from.

*Type specimen.* SOUTH AFRICA, Western Cape, Bonnievale, Merwesfont, from internal wood necrosis of wild olive (*Olea europaea* subsp. *cuspidata*), 24 June 2014, *P. Moyo* (holotype CBS-H 23264, culture ex-type CBS 142704 = STE-U 8385 = PMM2440).

MEA slide culture micromorphology — *Mycelium* hyaline to pale brown, smooth to verruculose, (1–)1.5–3 (av. 2)  $\mu\text{m}$  wide, in bundles of up to 4 strands. *Conidiophores* smooth to verruculose, branched or unbranched, hyaline to medium brown especially near base, with up to 6 septa, sometimes slightly constricted at septa, (19.5–)22.5–56.5(–66.5)  $\times$  (3–)3.5–4.5(–5) (av. 39  $\times$  4)  $\mu\text{m}$ . *Phialides* terminal or lateral, monophialidic with occasional polyphialides, with type III dominant, smooth to verruculose, hyaline to pale brown; collarettes quite long 1–2  $\times$  (1–)1.5–3 (av. 1.5  $\times$  2)  $\mu\text{m}$ ; percurrent rejuvenation observed. Type I phialides subcylindrical, sometimes with tapering apex, or elongate-ampulliform, (1.5–)2–12(–16.5)  $\times$  1–2.5(–3) (av. 7  $\times$  1.5)  $\mu\text{m}$ ; type II elongate-ampulliform, sometimes navicular, subcylindrical, or tapering toward the apex, (6–)8.5–14.5  $\times$  (1.5–)2–4(–4.5) (av. 11.5  $\times$  3)  $\mu\text{m}$ ; type III elongate-ampulliform or subcylindrical with tapering apex, sometimes navicular, (13.5–)15–21(–22)  $\times$  2.5–3.5 (av. 17.5  $\times$  3)  $\mu\text{m}$ . *Conidia* borne in slimy heads, oblong-ellipsoidal to obovoid or subcylindrical, (3.5–)4–5(–5.5)  $\times$  1.5–2.5 (av. 4.5  $\times$  2)  $\mu\text{m}$ .

Colony morphology — Colonies reaching a radius of 8 mm in 8 d at 25 °C. Minimum temperature for growth 5 °C, optimum 25 °C, maximum 30 °C. Colonies on MEA smooth, flat, with entire margin; after 16 d honey to buff with white margin above and in reverse. Colonies on PDA smooth, flat, with entire edge; after 16 d dark amber fading to amber with white margin above and in reverse. Colonies on OA felty to woolly, creased, with entire edge; after 16 d pale purplish grey or pale amber with white and mouse grey centre. Yellow pigment produced on OA.

Markers used for identification — *TUB2* = KY906937, *ACT* = KY906936.

*Additional strains examined.* SOUTH AFRICA, Western Cape, Paarl, from internal wood necrosis of wild olive (*Olea europaea* subsp. *cuspidata*), 4 Feb. 2015, *C.F.J. Spies* (CBS 142701 = STE-U 8381 = CSN403); Western Cape, Durbanville, from internal wood necrosis of wild olive (*Olea europaea* subsp. *cuspidata*) associated with a branch canker, 3 Mar. 2015, *W.J. van Jaarsveld* (CBS 142702 = STE-U 8382 = CSN945); Western Cape, Stellenbosch, from internal wood necrosis of wild olive (*Olea europaea* subsp. *cuspidata*), 12 Feb. 2015, *C.F.J. Spies* (STE-U 8383 = CSN703); ditto, from internal wood necrosis of wild olive (*Olea europaea* subsp. *cuspidata*) associated with dieback, 30 Apr. 2015, *P. Moyo* (CBS 142703 = STE-U 8384 = PMM1981).

*Notes* — This species is related to *P. argentinense*, *P. armeniacum*, *P. globosum* and the more recently described *P. tectonae*. Phylogenetically, *P. oleae* can be divided into two sub-

clades (s.str. and s.lat.) with good support (100 % bootstrap, 1.00 posterior probability). This clustering reflects 9 SNPs and a single nucleotide indel over 578 bp of the *TUB2* region and 5 SNPs over 204 bp of the *ACT* region that consistently differentiate between the two sub-clades. The *TUB2* sequence of strain CBS 142703 (s.str. sub-clade) had one unique SNP and corresponded to strains from the s.lat. sub-clade in an additional SNP that is not mentioned above. Some variation was observed among phialides and conidia of the five isolates characterised, but these differences did not reflect the sub-clade clustering. Strains CBS 142701, CBS 142703 and STE-U 8383 sometimes produced lageniform type II phialides. Cardinal temperatures and growth rate was only determined for strain CBS 142702 in addition to the ex-type strain. This strain had optimum and maximum growth temperatures of 20 °C and 35 °C, respectively, and exhibited slightly slower growth than the ex-type at 25 °C, reaching a radius of 7 mm on MEA after 8 d.

***Phaeoacremonium paululum*** C.F.J. Spies, Moyo, Halleen & L. Mostert, *sp. nov.* — MycoBank MB821012; Fig. 11

*Etymology.* Latin, *paululum*, meaning tiny. In reference to the short type I phialides.

*Type specimen.* SOUTH AFRICA, Western Cape, Constantia, from internal wood necrosis of guava (*Psidium guajava*), 23 Apr. 2014, *P. Moyo* (holotype CBS-H 23165, culture ex-type CBS 142705 = STE-U 8389 = PMM1914).

MEA slide culture micromorphology — *Mycelium* sometimes slightly constricted at septa, hyaline to pale brown, smooth to finely verruculose, 1.5–3 (av. 2)  $\mu\text{m}$  wide, in bundles of up to 7 strands. *Conidiophores* smooth to finely verruculose, branched or unbranched, hyaline to pale brown, with up to 4 septa, sometimes constricted at septa, (18.5–)19.5–46(–48)  $\times$  2–3.5(–4) (av. 31  $\times$  2.5)  $\mu\text{m}$ . *Phialides* terminal or lateral, monophialidic with occasional polyphialides, with type I dominant, smooth to finely verruculose, hyaline to pale brown; collarettes 0.5–2(–2.5)  $\times$  1–2.5 (av. 1.5  $\times$  1.5)  $\mu\text{m}$ . Type I phialides subcylindrical, sometimes reduced to almost sessile lateral collarettes on hyphal segments, 0.5–11(–13)  $\times$  1–1.5(–2) (av. 4  $\times$  1)  $\mu\text{m}$ ; type II elongate-ampulliform, sometimes subcylindrical or navicular, (7–)9–13.5  $\times$  (1.5–)2–3.5(–4) (av. 11.5  $\times$  2.5)  $\mu\text{m}$ ; type III elongate-ampulliform to navicular or subcylindrical tapering toward the apex to subulate, sometimes constricted at the base, 14–22.5(–23)  $\times$  1.5–3(–3.5) (av. 17.5  $\times$  2.5)  $\mu\text{m}$ . *Conidia* reniform to oblong-ellipsoidal, (2.5–)3–4  $\times$  1–1.5 (av. 3  $\times$  1.5)  $\mu\text{m}$ .

Colony morphology — Colonies reaching a radius of 9–10 mm in 8 d at 25 °C. Minimum temperature for growth 10 °C, optimum 25 °C, maximum 35 °C. Colonies on MEA smooth, flat, with entire edge; after 16 d white with stellate amber pigmentation above and in reverse. Colonies on PDA sparsely woolly, with entire edge; after 16 d pale buff with radial streaks of honey above, white to pale buff with radial streaks of honey in reverse. Colonies on OA felty, creased centrally, with entire edge; after 16 d hazel to dark greyish sepia with white margin.

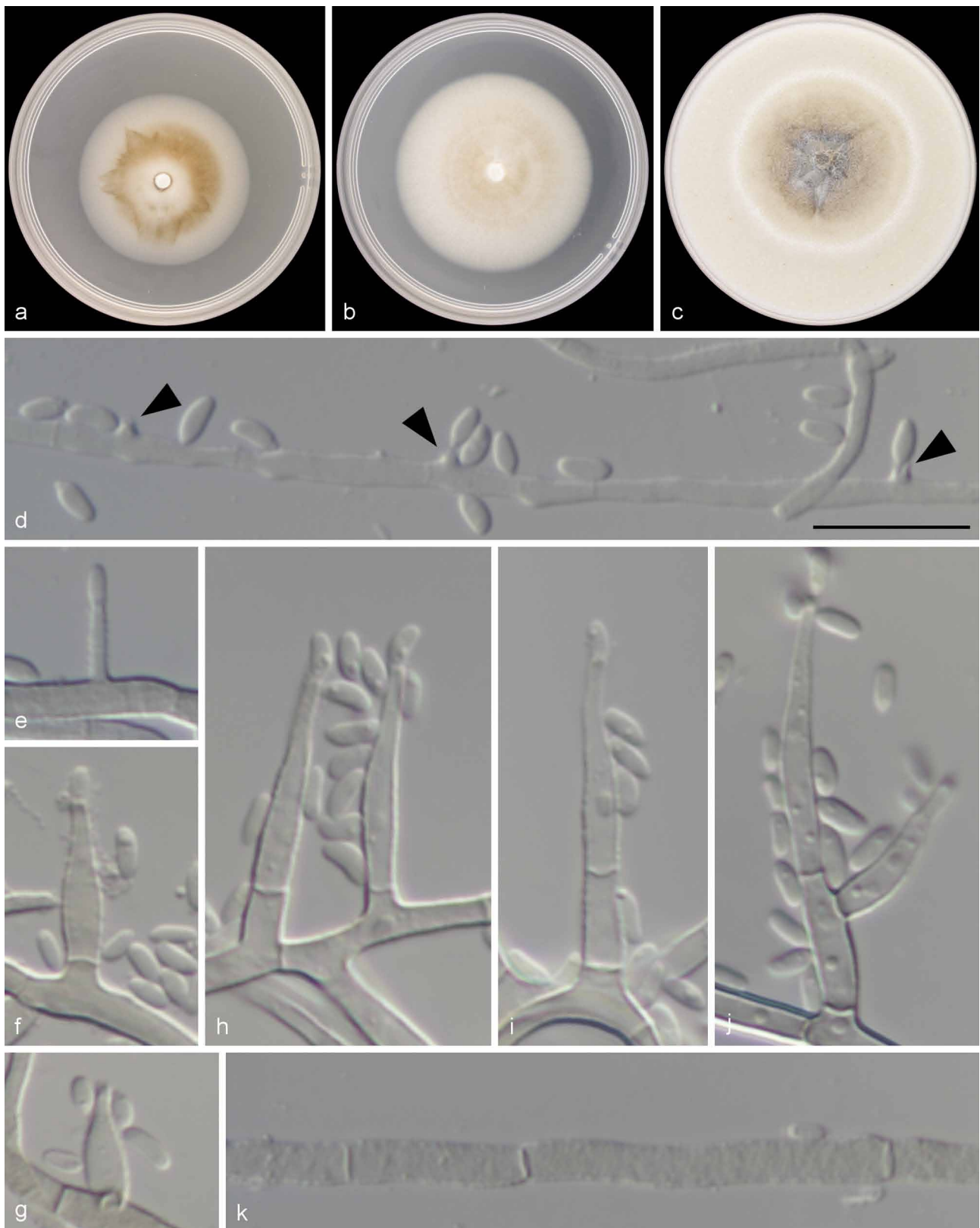
Markers used for identification — *TUB2* = KY906881, *ACT* = KY906880.

*Note* — *Phaeoacremonium paululum* occupies a unique phylogenetic position within the larger *Phaeoacremonium* clade including species such as *P. inflatipes*, *P. parasiticum* and *P. scolyti*.

***Phaeoacremonium proliferatum*** C.F.J. Spies, Moyo, Halleen & L. Mostert, *sp. nov.* — MycoBank MB821013; Fig. 12

*Etymology.* In reference to the frequent phialidic and vegetative proliferation of phialides observed in the type strain.

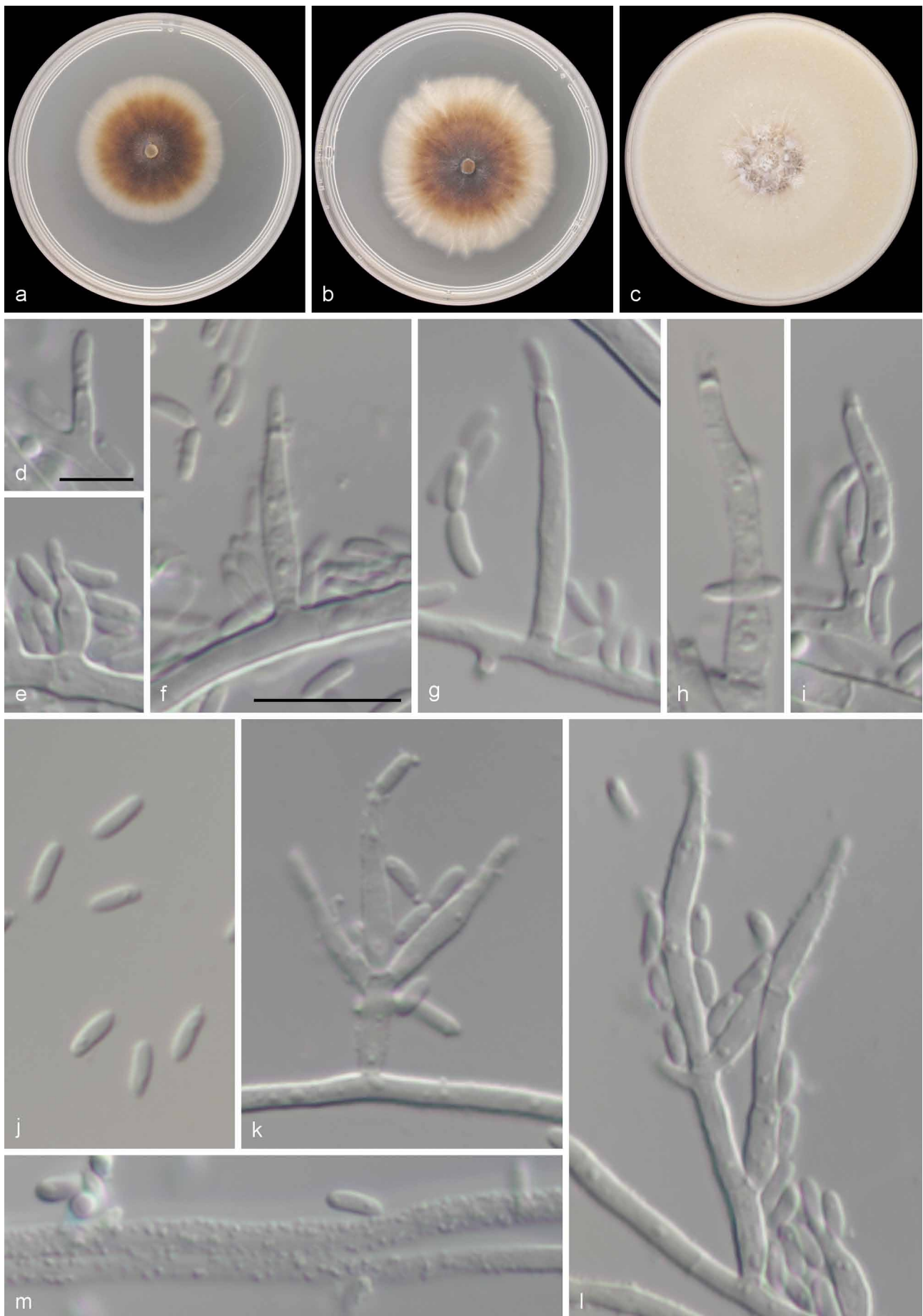




**Fig. 11** *Phaeoacremonium paululum* (CBS 142705 – ex-type culture STE-U 8389 = PMM1914). a–c. Sixteen-day-old colonies incubated at 25 °C on MEA (a), PDA (b) and OA (c); d–e. reduced (d, indicated with black arrowheads) and subcylindrical (e) type I phialides with oblong-ellipsoidal conidia; f–g. elongate ampulliform type II phialides; h. elongate ampulliform type III phialides; i–j. unbranched (i) and branched (j) conidiophores; k. finely verruculose hypha with constrictions at septa. — Scale bar: d = 10 μm, applies to e–k.



**Fig. 12** *Phaeoacremonium proliferatum* (CBS 142706 – ex-type culture STE-U 8368 = PMM2231). a–c. Sixteen-day-old colonies incubated at 25 °C on MEA (a), PDA (b) and OA (c); d. subcylindrical to slightly tapering type I phialides on a tuberculate hypha; e. elongate ampulliform type II phialide with a verruculose base and slimy head of conidia; f. subcylindrical type II polyphialide with tapering apex; g. elongate ampulliform type III phialide; h. unbranched conidiophore with percurrent rejuvenation; i. branched conidiophore; j. lateral vegetative proliferation of a type III phialide; k. microcyclic conidiation; l. hyphal whorl with unbranched conidiophores. — Scale bars: d, l = 10  $\mu$ m, d applies to f–g, i–k; e = 5  $\mu$ m, applies to h.



**Fig. 13** *Phaeoacremonium rosicola* (CBS 142708 – ex-type culture STE-U 8390 = PMM1002). a–c. Sixteen-day-old colonies incubated at 25 °C on MEA (a), PDA (b) and OA (c); d. subcylindrical type I phialide; e–f. elongate ampulliform (e) and navicular (f) type II phialides; g–h. subcylindrical (g) and elongate ampulliform (h) type III phialides; i. percurrent rejuvenation; j. oblong-ellipsoidal conidia; k–l. branched conidiophores; m. verruculose hyphae. — Scale bar: d = 5 µm, applies to e, h–i; f = 10 µm, applies to g, j–m.



*Type specimen.* SOUTH AFRICA, Western Cape, Durbanville, from internal wood necrosis of apple (*Malus domestica*), 17 June 2014, *P. Moyo* (holotype CBS-H 23166, culture ex-type CBS 142706 = STE-U 8368 = PMM2231).

MEA slide culture micromorphology — *Mycelium* hyaline, smooth to tuberculate, 1.5–2.5(–3) (av. 2)  $\mu\text{m}$  wide with warts up to 3  $\mu\text{m}$ , in bundles of up to 7 strands. *Conidiophores* smooth to roughly verruculose, usually branched, hyaline to pale brown, with up to 4 septa, 22–42.5(–57.5)  $\times$  2–3 (av. 31.5  $\times$  2.5)  $\mu\text{m}$ . *Phialides* terminal or lateral, commonly becoming polyphialides, smooth to roughly verruculose, hyaline to pale brown, with types II and III dominant; with collarettes 0.5–2  $\times$  1–2(–2.5) (av. 1  $\times$  1.5)  $\mu\text{m}$ ; percurrent rejuvenation and lateral proliferation observed occasionally. Type I phialides tapering or subcylindrical, occasionally elongate-ampulliform, 3.5–13.5(–17.5)  $\times$  1–2.5(–3) (av. 7  $\times$  1.5)  $\mu\text{m}$ ; type II mainly elongate-ampulliform to navicular, occasionally subcylindrical with tapering apex, (7.5–)9–14  $\times$  (1.5–)2–2.5(–3) (av. 12  $\times$  2.5)  $\mu\text{m}$ ; type III subcylindrical to elongate-ampulliform to navicular, 14.5–22.5(–26.5)  $\times$  2–2.5(–3) (av. 17.5  $\times$  2)  $\mu\text{m}$ . *Conidia* borne in slimy heads, oblong-ellipsoidal to reniform, 3–5(–5.5)  $\times$  (1–)1.5(–2) (av. 4  $\times$  1.5)  $\mu\text{m}$ , microcyclic conidiation observed.

Colony morphology — Colonies reaching a radius of 9–10 mm in 8 d at 25 °C. Minimum temperature for growth 10 °C, optimum 25 °C, maximum 37 °C. Colonies on MEA smooth, flat, with entire edge; after 16 d white with umber centre. Colonies on PDA smooth to felty, with entire edge; after 16 d white to pale buff with central hazel patches above and in reverse. Colonies on OA flat, felty, with entire edge; after 16 d white to buff.

Markers used for identification — *TUB2* = KY906903, *ACT* = KY906902.

*Additional strains examined.* SOUTH AFRICA, Western Cape, Vredendal, from internal wood necrosis of rose (*Rosa* sp.) associated with an old pruning wound, 13 Aug. 2013, *P. Moyo* (CBS 142707 = STE-U 8369 = PMM990); ditto, from internal wood necrosis of rose (*Rosa* sp.) associated with an old pruning wound, 13 Aug. 2013, *P. Moyo* (STE-U 8370 = PMM991).

Notes — *Phaeoacremonium proliferatum* is phylogenetically related to *P. australiense* and *P. subulatum*. *ACT* and *TUB2* sequences of the three isolates included in the phylogeny were identical. Micromorphological characteristics of the three strains were also very similar with only minor variations in the size of hyphae, conidiophores, phialides, collarettes and conidia. On PDA and OA strain CBS 142707 tended toward more woolly growth than CBS 142706 (ex-type), and the umber pigmentation on MEA had a more stellate pattern. Colony morphology of STE-U 8370 was not determined.

***Phaeoacremonium rosicola*** C.F.J. Spies, Moyo, Halleen & L. Mostert, *sp. nov.* — MycoBank MB821014; Fig. 13

*Etymology.* In reference to the host (*Rosa* sp.) from which the type strain was recovered.

*Type specimen.* SOUTH AFRICA, Western Cape, Vredendal, from internal wood necrosis of rose (*Rosa* sp.) associated with an old pruning wound, 13 Aug. 2013, *P. Moyo* (holotype CBS-H 23167, culture ex-type CBS 142708 = STE-U 8390 = PMM1002).

MEA slide culture micromorphology — *Mycelium* hyaline to pale brown, smooth to tuberculate, 1.5–3 (av. 2)  $\mu\text{m}$  wide, warts not observed, in bundles of up to 5 strands. *Conidiophores* uncommon (only 9 characterised), smooth to verruculose, branched, hyaline, with up to 5 septa, 13.5–34.5  $\times$  2–3.5 (av. 23  $\times$  2.5)  $\mu\text{m}$ . *Phialides* lateral or terminal, monopodialic, sometimes percurrently rejuvenating, with type I dominant, smooth to verruculose, hyaline; collarettes (only 24 characterised) usually short 0.5–1.5  $\times$  0.5–2(–2.5) (av. 1  $\times$  1.5)  $\mu\text{m}$ . Type I phialides subcylindrical, sometimes tapering toward the apex or elongate-ampulliform, (1–)1.5–8(–12.5)  $\times$  1–2.5 (av. 3.5  $\times$  1.5)  $\mu\text{m}$ ; type II

elongate-ampulliform to subcylindrical tapering toward the apex, or navicular, (6–)7.5–13.5  $\times$  (1.6–)2–2.5(–3) (av. 11  $\times$  2.5)  $\mu\text{m}$ ; type III navicular to elongate-ampulliform, sometimes subcylindrical tapering toward the apex, (13.5–)14–24.5  $\times$  1.5–3 (av. 17  $\times$  2)  $\mu\text{m}$ . *Conidia* reniform to oblong-ellipsoidal, (3–)3.5–5(–5.5)  $\times$  1–1.5 (av. 4  $\times$  1.5)  $\mu\text{m}$ .

Colony morphology — Colonies reaching a radius of 10–11 mm in 8 d at 25 °C. Minimum temperature for growth 10 °C, optimum 25 °C, maximum 30 °C. Colonies on MEA flat, smooth, with entire edge; after 16 d dark brick fading to buff margin above and in reverse. Colonies on PDA flat, smooth, with entire edge; after 16 d dark brick fading to buff margin above and in reverse. Colonies on OA felty with central woolly patches, with entire edge; after 16 d buff to white with rosy buff to vinaceous buff central patches.

Markers used for identification — *TUB2* = KY906831, *ACT* = KY906830.

Notes — *Phaeoacremonium rosicola* is related to *P. bendum* and *P. album* in the larger clade also containing *P. angustius*, *P. austroafricanum*, *P. longicollarum*, *P. pallidum*, *P. roseum*, *P. theobromatis* and *P. viticola*. Several *Phaeoacremonium* species produce colonies with various shades of brown pigmentation on MEA, including *P. aureum* (described above); however, the dark brick pigmentation observed in *P. rosicola* has not been recorded for other species. Additional strains of this species would need to be examined to determine if this trait has diagnostic value.

***Phaeoacremonium spadicum*** C.F.J. Spies, Moyo, Halleen & L. Mostert, *sp. nov.* — MycoBank MB821017; Fig. 14

*Etymology.* Latin, *spadicum* (from *spadix*), meaning brown, chestnut. In reference to the colony colour on PDA and, for some strains, also on MEA.

*Type specimen.* SOUTH AFRICA, Western Cape, Darling, from internal wood necrosis of loquat (*Eriobotrya japonica*) associated with a branch canker, 23 Oct. 2013, *P. Moyo* (holotype CBS-H 23169, culture ex-type CBS 142711 = STE-U 8386 = PMM1315).

MEA slide culture micromorphology — *Mycelium* hyaline to medium brown, smooth to verruculose or finely tuberculate, (1–)1.5–2.5 (av. 2)  $\mu\text{m}$  wide, in bundles of up to 13 or more strands. *Conidiophores* smooth to verruculose, branched or unbranched, hyaline to pale brown, with up to 5 septa, (13.5–)14.5–42(–71.5)  $\times$  2–3.5 (av. 29  $\times$  3)  $\mu\text{m}$ . *Phialides* terminal or lateral, monopodialic, sometimes percurrently rejuvenating, with type III dominant, smooth to verruculose, hyaline to medium brown; collarettes usually small or inconspicuous 0.5–1.5  $\times$  0.5–2 (av. 1  $\times$  1)  $\mu\text{m}$ . Type I phialides subcylindrical to elongate-ampulliform, 2.5–16(–16.5)  $\times$  1–3 (av. 8  $\times$  1.5)  $\mu\text{m}$ ; type II elongate-ampulliform to navicular, sometimes subcylindrical tapering toward apex, 7.5–13.5(–14)  $\times$  (1.5–)2–3(–4) (av. 11  $\times$  2.5)  $\mu\text{m}$ ; type III subcylindrical tapering toward the apex, or elongate-ampulliform, sometimes navicular or subulate, (14.5–)15.5–30  $\times$  1.5–3 (av. 22.5  $\times$  2.5)  $\mu\text{m}$ . *Conidia* borne in slimy heads, oblong-ellipsoidal to reniform, obovoid or subcylindrical, 3–4(–5)  $\times$  1.5–2 (av. 3.5  $\times$  1.5)  $\mu\text{m}$ ; microcyclic conidiation observed.

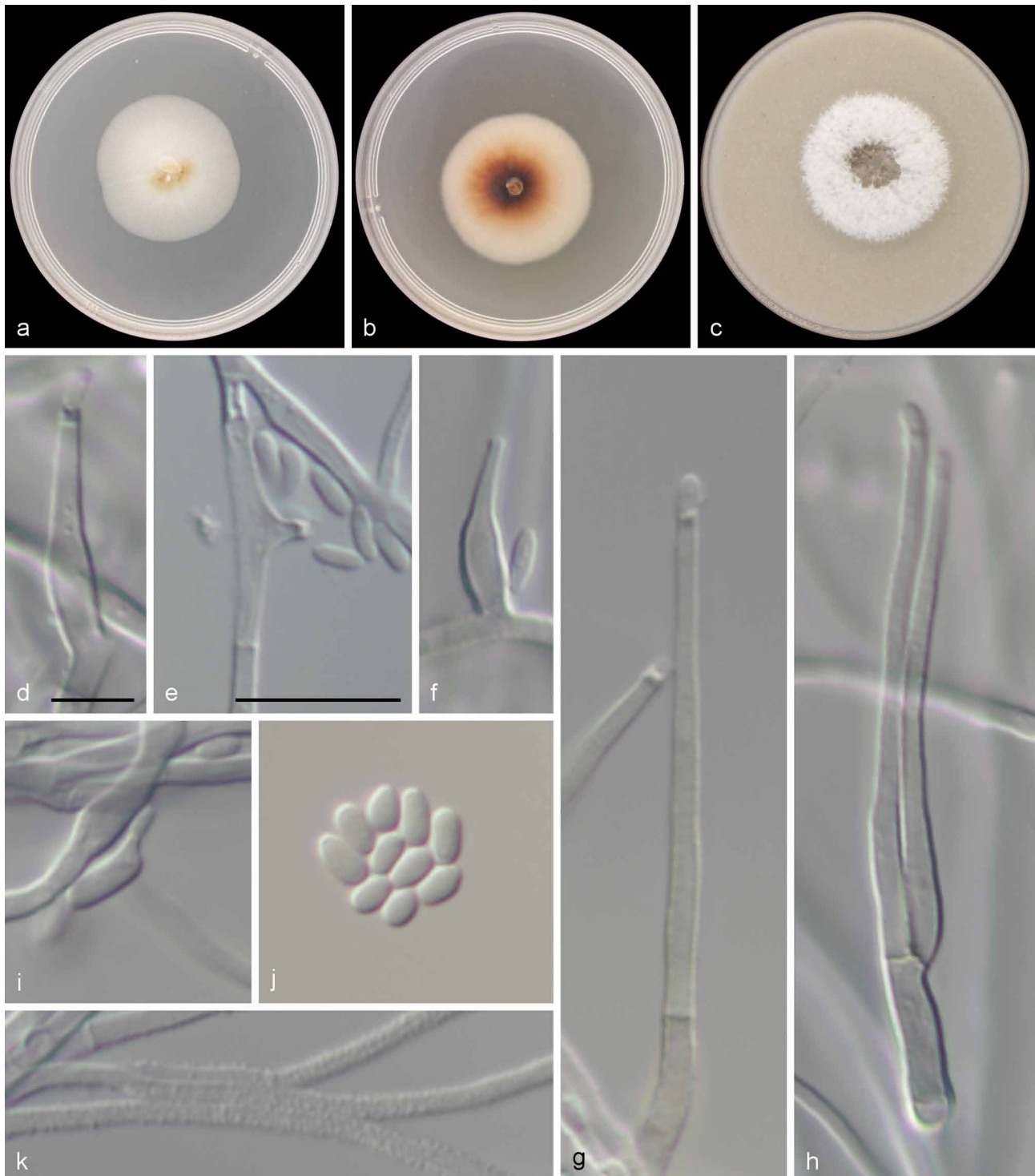
Colony morphology — Colonies reaching a radius of 10 mm in 8 d at 25 °C. Minimum temperature for growth 10 °C, optimum 20–25 °C, maximum 30 °C. Colonies on MEA flat, smooth, with entire edge; after 16 d white to pale buff with central honey patches above, buff with central isabelline patches in reverse. Colonies on PDA flat, smooth, with entire edge; after 16 d buff deepening through luteous to a chestnut centre above, pale luteous with chestnut centre in reverse. Colonies on OA woolly, with entire edge; after 16 d white with olivaceous grey centre.

Markers used for identification — *TUB2* = KY906839, *ACT* = KY906838.

Notes — *Phaeoacremonium spadicum* occupies a basal phylogenetic position within the larger clade containing *P. africanum*, *P. argentinense*, *P. armeniacum*, *P. canadense*, *P. croatiense*, *P. fraxinopennsylvanicum*, *P. globosum*, *P. griseo-olivaceum*, *P. hungaricum*, *P. novae-zealandiae*, *P. occidentale*, *P. oleae*, *P. prunicola* and *P. tectonae*. Two additional strains of *P. spadicum* included in the phylogeny (CBS 142714 and CBS 142715) were not characterised with regards to micromorphology; however, strain ID208 also produced colonies pigmented in shades of brown varying from dark amber to chestnut on PDA and MEA, and had similar growth rates and cardinal temperatures when compared to the ex-type.

## DISCUSSION

South Africa currently has the highest reported diversity of *Phaeoacremonium* species with 35 species, followed by Italy with 15, Spain with 15 and the USA with 13, seven of which have only been reported from human infections (Gramaje et al. 2015; Appendix 3). Most records of *Phaeoacremonium* in South Africa are from the Western Cape, which comprises a large part of the floristically diverse Cape Floristic Region (CFR; Myers et al. 2000). The CFR consists mainly of fynbos, a vegetation type that is dominated by plant species from the *Ericaceae*, *Proteaceae* and *Restionaceae*. It is possible



**Fig. 14** *Phaeoacremonium spadicum* (CBS 142711 – ex-type culture STE-U 8386 = PMM1315). a–c. Sixteen-day-old colonies incubated at 25 °C on MEA (a), PDA (b) and OA (c); d–e. type I phialides, elongate ampulliform (d) and short with widening base (e); f. elongate ampulliform type II phialide; g–h. unbranched (g) and branched (h) conidiophores with subcylindrical (g) and subulate (h) type III phialides; i. microcyclic conidiation; j. oblong-ellipsoidal conidia; k. verruculose hyphae. — Scale bars: d = 5 µm, applies to f; e = 10 µm, applies to g–k.



that the high diversity of possible hosts has generated the high diversity of *Phaeoacremonium* species in this region. Unfortunately, the *Ericaceae*, *Proteaceae* and *Restionaceae* were not represented among the hosts covered in the current survey. The only records of *Phaeoacremonium* associated with these plant families in South Africa are of perithecia of *P. austroafricanum*, *P. minimum* and *P. parasiticum* that were found on twig litter of two *Proteaceae* species collected in the Western Cape (Marincowitz et al. 2008). The same study also reported a putative new species as '*Togninia* sp.' from fynbos twig litter; however, BLAST searches of the ITS sequences of this taxon (EU552159 and EU552160) suggest that it is a species of *Jattaea* (95–98 % similarity to ITS sequences of *J. aphanospora*, *J. discreta* and *J. taediosa*). Dieback or canker disease symptoms observed in fynbos have not been linked to *Phaeoacremonium* infections (Taylor & Crous 2000, Crous et al. 2013) and the association and interaction of this genus with living fynbos still needs to be elucidated. Only four of the hosts in the current investigation are indigenous to South Africa including coral tree, wild grape, wild olive and yellowwood. It is interesting to note that two of the new species described in this study were recovered from two of the indigenous hosts: *P. oleae* was recovered only from wild olive (*Olea europaea* subsp. *cuspidata*) and *P. spadicum* was recovered from wild grape (*Rhoicissus tomentosa*) and wild olive in addition to loquat (*Eriobotrya japonica*, not indigenous to South Africa).

Damm et al. (2008b) analysed stone fruit samples from the Limpopo Province (a region with summer rainfall) as well as the Western Cape Province (a region with winter rainfall) and, upon finding three new species from Limpopo, but none from the Western Cape, she proposed a lack of previous sampling in Limpopo or the different climate as reasons for this. In the current survey we showed that two of the three species described by Damm et al. (2008b) are also present in the Western Cape, namely, *P. griseo-olivaceum* and *P. prunicola*. An additional new species described by us, *P. junior*, was also recovered both in Limpopo and in the Western Cape. Other species that have been reported from both regions include *P. parasiticum* and *P. scolyti* (Damm et al. 2008b, Spies unpubl. data). This suggests that climatological variation does not have a direct impact on the distribution of these *Phaeoacremonium* species in South Africa. In addition, climatological factors may not directly explain the high diversity of *Phaeoacremonium* species in this country.

The general perception that *Phaeoacremonium* species have broad host ranges and lack host specificity were confirmed by this study. Species known to have broad host ranges such as *P. minimum*, *P. parasiticum* and *P. scolyti* (Gramaje et al. 2015) are now respectively known from 19, 17 and 20 hosts in South Africa (Groenewald et al. 2001, Mostert et al. 2005, Damm et al. 2008b, Marincowitz et al. 2008, Cloete et al. 2011, Moyo et al. 2014, 2016; Appendix 3). Other species were thought to have more restricted host ranges; for example, *P. prunicola* had only been reported from plums (Damm et al. 2008b). The present survey, however, reports an additional nine hosts for this species. Similarly, the recovery of *P. africanum*, *P. globosum* and *P. griseo-olivaceum* from three, two and one additional hosts, respectively, excludes the possibility of host-specificity in these species, each of which had previously only been reported from single hosts (Damm et al. 2008b, Graham et al. 2009). Eight of the 10 *Phaeoacremonium* species in South Africa that are currently known globally only from single plant hosts are only known from less than three strains, suggesting that insufficient data is available to draw conclusions regarding the host range of these. The remaining two species in South Africa that are only known from single plant hosts are *P. krajdennii* and *P. oleae*. *Phaeoacremonium krajdennii* has only been recorded on grape-

vines in South Africa and Spain, but human infections by this species have been reported from Africa, Asia, Europe, the USA and Scandinavia (Gramaje et al. 2015). *Phaeoacremonium oleae*, on the other hand, has been recovered from eight wild olive samples in four different regions in the Western Cape Province (data not shown). The fact that this species has a wide distribution in the Western Cape, but was not recovered from any other host, not even from European olive, a closely related taxon that was sampled in the same regions, stands in contrast to the lack of host specificity generally observed in *Phaeoacremonium* species. Seventeen other *Phaeoacremonium* species not reported in South Africa are only known from single plant hosts or substrates (Appendix 3); however, of these, only *P. amygdalinum*, *P. cinereum*, *P. luteum*, *P. nordesticola*, *P. santali* and *P. tectonae* are known from more than three strains and only *P. cinereum*, *P. hispanicum* and *P. tuscanicum* have been recovered from more than one country (Crous & Gams 2000, Essakhi et al. 2008, Graham et al. 2009, Gramaje et al. 2009b, 2012, 2014, 2015, Berraf-Tebbal et al. 2011, Hu et al. 2012, Urbez-Torres et al. 2014, Ariyawansa et al. 2015; Appendix 3).

An emerging problem in *Phaeoacremonium* species-level taxonomy is the lack of distinction between some species using *ACT-TUB2* phylogenies. Specific issues have been observed with the resolution of and support for *P. griseorubrum*, the distinction between *P. alvesii* and *P. italicum*, and resolution within the *P. angustius/P. roseum/P. viticola* group (Gramaje et al. 2015; this study). Incongruence between the *ACT* and *TUB2* regions make these issues difficult to address using currently available molecular data. Although morphological differences between some closely related species have been reported, the use of such data to resolve species requires prior validation of putative distinctive characteristics in a collection of strains that are sufficiently representative of all species in question. In the case of *P. italicum* and *P. alvesii*, Raimondo et al. (2014) considered the production of yellow pigment on MEA, PDA and OA one of the features distinguishing the species; however, Mostert et al. (2006) reported yellow pigment production only in *P. alvesii* strains CBS 110034 (ex-type) and CBS 408.78, but not in CBS 729.97 (phylogenetically *P. alvesii* s.str.) and CBS 113590 (here classified as *P. italicum* s.lat.). Other morphological differences between these species were also highlighted, e.g., differences in the number of hyphae in bundles, the number of septa in conidiophores, the predominant phialide types, and minimum, optimum and maximum growth temperatures (Raimondo et al. 2014). In the current investigation, such traits were found to vary among isolates of some species and the variation observed did not correspond to intraspecific phylogenetic variation. This suggests that these morphological differences are not reliable in distinguishing phylogenetically closely related species and can therefore not be used to clarify the species identity of strains that have an unresolved phylogenetic identity, such as PMM744. In light of these shortcomings of morphological data and the available molecular data, a more inclusive approach was followed in the taxonomic treatment of species that exhibited considerable intraspecific phylogenetic variation possibly suggestive of species boundaries, i.e., *P. africanum*, *P. aureum*, *P. australiense*, *P. inflatipes*, *P. junior*, *P. oleae*, *P. scolyti* and *P. subulatum*. Species boundaries within such clades need to be investigated using multi-locus sequence data of sufficiently representative collections of strains and applying techniques such as genealogical concordance phylogenetic species recognition (GCPSR) and coalescent-based species delimitation (Taylor et al. 2000, Fujita et al. 2012, Rintoul et al. 2012). Other gene regions previously used for phylogenetic analyses of *Phaeoacremonium* that could be included in such analyses include translation elongation factor 1-alpha (*TEF1-α*) and calmodulin (Mostert



et al. 2005, Úrbez-Torres et al. 2014). Although the internal transcribed spacer (ITS) region has been used in *Phaeoacremonium* phylogenies (Groenewald et al. 2001, Úrbez-Torres et al. 2014), it has proven insufficiently variable to distinguish among several *Phaeoacremonium* species (Groenewald et al. 2001). Indeed the ITS region is identical in *P. angustius* and *P. viticola* (over 517 nucleotides) and 99 % similar in *P. fraxinopennsylvanicum* and *P. occidentale* (504/506 with 1 gap), *P. minimum* and *P. iranianum* (518/520 with 2 gaps), *P. griseorubrum* and *P. amstelodamense* (470/471 with 1 gap) and *P. alvesii* and *P. rubrigenum* (527/528 with one C to G transversion). Mostert et al. (2005) sequenced the calmodulin region for a subset of isolates to elucidate the relationships among taxa related to *P. rubrigenum*. These included species that were paraphyletic or exhibited considerable levels of intraspecific variation in our *ACT-TUB* phylogeny, such as *P. alvesii*, *P. australiense*, *P. griseorubrum*, *P. scolyti* and *P. subulatum*. Unfortunately, calmodulin sequences for only 19 strains representing 11 *Phaeoacremonium* spp. are currently available on GenBank. For the *TEF1- $\alpha$*  region, on the other hand, sequences are available for ex-type strains of 31 *Phaeoacremonium* species (Úrbez-Torres et al. 2014). Other alternatives that could be considered include new markers such as FG1093 and MS204 that were recently introduced by Walker et al. (2012a) for species-level systematics in the *Sordariomycetes*. These regions have been used in phylogenetic analyses of the genera *Ceratocystis*, *Juglanconis* and *Ophiognomonina* (Walker et al. 2012b, Fourie et al. 2015, Voglmayr et al. 2017). They have not as yet been sequenced for any *Phaeoacremonium* species.

Thorough taxonomic treatment including phylogenetic analyses of the genus *Phaeoacremonium* by Mostert et al. (2006), relatively soon after its introduction in 1996 (Crous et al. 1996), provided a good foundation for the identification and description of species within the genus. Sound taxonomic practice has mostly been upheld during the expansion of the genus over the next decade, bringing us to the current 61 species included in *Phaeoacremonium*. Actin and beta-tubulin data generated from type material are publicly available for 59 species, the only exceptions being *P. aquaticum* (only ITS data available) and *P. inconspicuum* (no sequence data or strains available). If the current study is to be taken as an indication, a considerable number of *Phaeoacremonium* species remain to be discovered when samples from additional hosts and regions are analysed. Care is needed to prevent misidentifications and the introduction of vague species boundaries as the number of species in this genus increases. In light of the shortcomings of the *ACT-TUB2* phylogeny highlighted above, the identification of additional phylogenetic markers or techniques to improve phylogenetic resolution of species should be a priority.

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**Appendix 1** Reference strain data (host and country of origin) and GenBank accession numbers of actin (*ACT*) and beta-tubulin (*TUB2*) sequences included in the phylogeny.

Organism	Strain	Host	Country	<i>ACT</i>	<i>TUB2</i>	References
<i>Calosphaeria africana</i>	CBS 120870	<i>Prunus armeniaca</i>	South Africa	n/a <sup>a</sup>	EU367464	Damm et al. 2008a
<i>Jattaea algeriensis</i>	CBS 120871	<i>Prunus salicina</i>	South Africa	n/a	EU367466	Damm et al. 2008a
<i>Phaeoacremonium africanum</i>	CBS 120863 <sup>†</sup>	<i>Prunus armeniaca</i>	South Africa	EU128142	EU128100	Damm et al. 2008b
	STE-U 6364	<i>Prunus armeniaca</i>	South Africa	EU128143	EU128101	Damm et al. 2008b
<i>Phaeoacremonium alvesii</i>	STE-U 6365	<i>Prunus armeniaca</i>	South Africa	n/a	EU128102	Damm et al. 2008b
	CBS 110034 <sup>†</sup>	<i>Homo sapiens</i>	Brazil	AY579234	AY579301	Mostert et al. 2005
	CBS 408.78	<i>Homo sapiens</i>	USA	AY579236	AY579303	Mostert et al. 2005
<i>Phaeoacremonium amstelodamense</i>	CBS 729.97	<i>Homo sapiens</i>	USA	AY579235	AY579302	Mostert et al. 2005
	CBS 110627 <sup>†</sup>	<i>Homo sapiens</i>	Netherlands	AY579228	AY579295	Mostert et al. 2005
<i>Phaeoacremonium amygdalinum</i>	CBS 128570 <sup>†</sup>	<i>Prunus dulcis</i>	Spain	JN191303	JN191307	Gramaje et al. 2012
	Psp-1	<i>Prunus dulcis</i>	Spain	JN191301	JN191305	Gramaje et al. 2012
	Psp-2	<i>Prunus dulcis</i>	Spain	JN191302	JN191306	Gramaje et al. 2012
<i>Phaeoacremonium angustius</i>	CBS 114991	<i>Vitis vinifera</i>	USA	DQ173126	DQ173103	Mostert et al. 2006
	CBS 114992 <sup>†</sup>	<i>Vitis vinifera</i>	USA	DQ173127	DQ173104	Mostert et al. 2006
<i>Phaeoacremonium argentinense</i>	CBS 777.83 <sup>†</sup>	Soil	Argentina	DQ173135	DQ173108	Mostert et al. 2006
<i>Phaeoacremonium armeniacum</i>	ICMP17421 <sup>†</sup>	<i>Vitis berlandieri</i> × <i>Vitis riparia</i>	New Zealand	EU595463	EU596526	Graham et al. 2009
<i>Phaeoacremonium australiense</i>	CBS 113589 <sup>†</sup>	<i>Vitis vinifera</i>	Australia	AY579229	AY579296	Mostert et al. 2005
	CBS 113592	<i>Vitis vinifera</i>	Australia	AY579230	AY579297	Mostert et al. 2005
	CBS 120861	<i>Prunus salicina</i>	South Africa	EU128115	EU128073	Damm et al. 2008b
	STE-U 5838	<i>Prunus salicina</i>	South Africa	EU128114	EU128072	Damm et al. 2008b
	STE-U 5839	<i>Prunus salicina</i>	South Africa	EU128113	EU128071	Damm et al. 2008b
	STE-U 5960	<i>Prunus salicina</i>	South Africa	EU128111	EU128069	Damm et al. 2008b
	STE-U 5961	<i>Prunus salicina</i>	South Africa	EU128112	EU128070	Damm et al. 2008b
	STE-U 7823	<i>Diospyros kaki</i>	South Africa	MF352194	MF352201	Moyo et al. 2016
	CBS 112949 <sup>†</sup>	<i>Vitis vinifera</i>	South Africa	DQ173122	DQ173099	Mostert et al. 2006
	CBS 114993	<i>Vitis vinifera</i>	South Africa	DQ173124	DQ173101	Mostert et al. 2006
	CBS 114994	<i>Vitis vinifera</i>	South Africa	DQ173125	DQ173102	Mostert et al. 2006
<i>Phaeoacremonium canadense</i>	CBS 118482	<i>Vitis vinifera</i>	South Africa	DQ173123	DQ173100	Mostert et al. 2006
	DAOM 242366 <sup>†</sup>	<i>Vitis riparia</i> × <i>Vitis rupestris</i>	Canada	KF764499	KF764651	Úrbez-Torres et al. 2014
<i>Phaeoacremonium cinereum</i>	PARC392	<i>Vitis berlandieri</i> × <i>Vitis riparia</i>	Canada	KF764500	KF764652	Úrbez-Torres et al. 2014
	CBS 123909 <sup>†</sup>	<i>Vitis vinifera</i>	Iran	FJ517153	FJ517161	Gramaje et al. 2009b
	Pm2	<i>Vitis vinifera</i>	Iran	FJ517150	FJ517158	Gramaje et al. 2009b
<i>Phaeoacremonium croatiense</i>	Pm4	<i>Vitis vinifera</i>	Iran	FJ517152	FJ517160	Gramaje et al. 2009b
	CBS 123037 <sup>†</sup>	<i>Vitis vinifera</i>	Croatia	EU863514	EU863482	Essakhi et al. 2008
<i>Phaeoacremonium fraxinopennsylvanicum</i>	CBS 101585 <sup>†</sup>	<i>Vitis vinifera</i>	USA	DQ173137	KF764684	Groenewald et al. 2001, Mostert et al. 2006
	CBS 110212	<i>Fraxinus pennsylvanica</i>	USA	DQ173136	DQ173109	Mostert et al. 2006
	CBS 120865	<i>Prunus salicina</i>	South Africa	EU128121	EU128079	Damm et al. 2008b
	CBS 211.97	<i>Fraxinus excelsior</i>	Sweden	DQ173138	AF246810	Groenewald et al. 2001, Mostert et al. 2006
	STE-U 6102	<i>Prunus salicina</i>	South Africa	EU128122	EU128080	Damm et al. 2008b
	STE-U 6987	<i>Vitis vinifera</i>	South Africa	JQ038924	JQ038913	White et al. 2011
	STE-U 7350	<i>Pyrus communis</i>	South Africa	n/a	JF934951	Cloete et al. 2011
	STE-U 7351	<i>Pyrus communis</i>	South Africa	n/a	JF934952	Cloete et al. 2011
	CBS 120856 <sup>†</sup>	<i>Prunus salicina</i>	South Africa	EU128141	EU128098	Damm et al. 2008b
	STE-U 6366	<i>Prunus salicina</i>	South Africa	EU128140	EU128099	Damm et al. 2008b
	<i>Phaeoacremonium globosum</i>	ICMP16987	<i>Vitis berlandieri</i> × <i>Vitis riparia</i>	New Zealand	EU595459	EU596527
ICMP16988 <sup>†</sup>		<i>Vitis berlandieri</i> × <i>Vitis riparia</i>	New Zealand	EU595466	EU596528	Graham et al. 2009
ICMP17038		<i>Vitis berlandieri</i> × <i>Vitis riparia</i>	New Zealand	EU595465	EU596521	Graham et al. 2009
<i>Phaeoacremonium griseo-olivaceum</i>	CBS 120857 <sup>†</sup>	<i>Prunus armeniaca</i>	South Africa	EU128139	EU128097	Damm et al. 2008b
<i>Phaeoacremonium griseorubrum</i>	CBS 111657 <sup>†</sup>	<i>Homo sapiens</i>	USA	AY579227	AY579294	Mostert et al. 2005
	CBS 120860	<i>Prunus salicina</i>	South Africa	EU128116	EU128074	Damm et al. 2008b
	CBS 566.97	<i>Homo sapiens</i>	Japan	AY579226	AF246801	Groenewald et al. 2001, Mostert et al. 2005
	STE-U 5958	<i>Prunus salicina</i>	South Africa	EU128117	EU128075	Damm et al. 2008b
	CBS 123910 <sup>†</sup>	<i>Vitis vinifera</i>	Spain	FJ517156	FJ517164	Gramaje et al. 2009b
<i>Phaeoacremonium hungaricum</i>	CBS 123036 <sup>†</sup>	<i>Vitis vinifera</i>	Hungary	EU863515	EU863483	Essakhi et al. 2008
<i>Phaeoacremonium inflatipes</i>	CBS 113273	<i>Hypoxylon truncatum</i>	USA	AY579260	AY579323	Mostert et al. 2005
	CBS 166.75	<i>Nectandra</i> sp.	Costa Rica	AY579258	AY579322	Mostert et al. 2005
<i>Phaeoacremonium iranianum</i>	CBS 391.71 <sup>†</sup>	<i>Quercus virginiana</i>	USA	AY579259	AF246805	Groenewald et al. 2001, Mostert et al. 2005
	CBS 101357 <sup>†</sup>	<i>Vitis vinifera</i>	Italy	DQ173120	DQ173097	Mostert et al. 2006
	CBS 117114	<i>Vitis vinifera</i>	Iran	DQ173121	DQ173098	Mostert et al. 2006
	CBS 120864	<i>Prunus armeniaca</i>	South Africa	EU128120	EU128078	Damm et al. 2008b
	Pir-1	<i>Prunus dulcis</i>	Spain	JN191300	JN191299	Gramaje et al. 2012
	STE-U 6092	<i>Prunus armeniaca</i>	South Africa	EU128118	EU128076	Damm et al. 2008b
	STE-U 6179	<i>Prunus armeniaca</i>	South Africa	EU128119	EU128077	Damm et al. 2008b
	STE-U 6998	<i>Vitis vinifera</i>	South Africa	JQ038922	JQ038911	White et al. 2011
	STE-U 6999	<i>Vitis vinifera</i>	South Africa	JQ038923	JQ038912	White et al. 2011
	STE-U 7349	<i>Pyrus communis</i>	South Africa	n/a	JF934948	Cloete et al. 2011
	<i>Phaeoacremonium italicum</i>	CBS 113590 <sup>b</sup>	<i>Dodonaea viscosa</i>	Australia	AY579237	AY579304
CBS 137763 <sup>†</sup>		<i>Vitis vinifera</i>	Italy	KJ534046	KJ534074	Raimondo et al. 2014
CBS 137764		<i>Vitis vinifera</i>	Italy	KJ534047	KJ534075	Raimondo et al. 2014
Pm21		<i>Vitis vinifera</i>	Italy	KJ534048	KJ534076	Raimondo et al. 2014
PMC206 <sup>b</sup>		Arthropods	South Africa	n/a	MF352204	Moyo et al. 2014
PMC217 <sup>b</sup>		Arthropods	South Africa	n/a	MF352205	Moyo et al. 2014
STE-U 6988 <sup>b</sup>		<i>Vitis vinifera</i>	South Africa	JQ038925	JQ038914	White et al. 2011
<i>Phaeoacremonium krajdienii</i>	STE-U 6989 <sup>b</sup>	<i>Vitis vinifera</i>	South Africa	JQ038926	JQ038915	White et al. 2011
	CBS 109479 <sup>†</sup>	<i>Homo sapiens</i>	Canada	AY579267	AY579330	Mostert et al. 2005
	CBS 110118	<i>Vitis vinifera</i>	South Africa	AY579261	AY579324	Mostert et al. 2005
	CBS 110368	<i>Homo sapiens</i>	USA	AY579269	AY579332	Mostert et al. 2005
	CBS 113588	<i>Vitis vinifera</i>	South Africa	AY579262	AY579325	Mostert et al. 2005

## Appendix 1 (cont.)

Organism	Strain	Host	Country	ACT	TUB2	References	
<i>Phaeoacremonium leptorhynchum</i>	CBS 110156 <sup>o</sup>	<i>Cupressus macrocarpa</i>	New Zealand	DQ173139	DQ173110	Mostert et al. 2006	
	CBS 110157	<i>Pinus radiata</i>	New Zealand	DQ173140	DQ173111	Mostert et al. 2006	
	CBS 114512	<i>Ficinia spiralis</i>	New Zealand	DQ173141	DQ173112	Mostert et al. 2006	
<i>Phaeoacremonium luteum</i>	A34	<i>Santalum album</i>	Australia	KJ533543	KJ533541	Gramaje et al. 2014	
	CBS 137497 <sup>T</sup>	<i>Santalum album</i>	Australia	KF835406	KF823800	Gramaje et al. 2014	
<i>Phaeoacremonium minimum</i>	CBS 100397	<i>Vitis vinifera</i>	Italy	AY735498	AF246806	Groenewald et al. 2001, Mostert et al. 2005	
	CBS 110703	<i>Vitis vinifera</i>	South Africa	DQ173115	DQ173094	Mostert et al. 2006	
	CBS 121434	<i>Prunus armeniaca</i>	South Africa	EU128105	EU128063	Damm et al. 2008b	
	CBS 121435	<i>Prunus salicina</i>	South Africa	EU128107	EU128065	Damm et al. 2008b	
	CBS 121436	<i>Prunus persica</i>	South Africa	EU128110	EU128068	Damm et al. 2008b	
	CBS 246.91 <sup>T</sup>	<i>Vitis vinifera</i>	Yugoslavia	AY735497	AF246811	Groenewald et al. 2001, Mostert et al. 2005	
	L.M.483	<i>Prunus armeniaca</i>	South Africa	DQ173116	DQ173095	Mostert et al. 2006	
	PMC178	Arthropods	South Africa	n/a	MF352202	Moyo et al. 2014	
	STE-U 3093	<i>Vitis vinifera</i>	South Africa	n/a	AF246813	Groenewald et al. 2001	
	STE-U 3094	<i>Vitis vinifera</i>	South Africa	n/a	AF246812	Groenewald et al. 2001	
	STE-U 5962	<i>Prunus salicina</i>	South Africa	EU128108	EU128066	Damm et al. 2008b	
	STE-U 5963	<i>Prunus salicina</i>	South Africa	EU128109	EU128067	Damm et al. 2008b	
	STE-U 6088	<i>Prunus armeniaca</i>	South Africa	EU128104	EU128062	Damm et al. 2008b	
	STE-U 6090	<i>Prunus armeniaca</i>	South Africa	EU128106	EU128064	Damm et al. 2008b	
	STE-U 6986	<i>Vitis vinifera</i>	South Africa	JQ038920	JQ038909	White et al. 2011	
	STE-U 6991	<i>Vitis vinifera</i>	South Africa	JQ038921	JQ038910	White et al. 2011	
	STE-U 7319	<i>Pyrus communis</i>	South Africa	n/a	JF934931	Cloete et al. 2011	
	STE-U 7320	<i>Pyrus communis</i>	South Africa	n/a	JF934932	Cloete et al. 2011	
	STE-U 7321	<i>Pyrus communis</i>	South Africa	n/a	JF934933	Cloete et al. 2011	
	STE-U 7322	<i>Pyrus communis</i>	South Africa	n/a	JF934943	Cloete et al. 2011	
	STE-U 7323	<i>Pyrus communis</i>	South Africa	n/a	JF934939	Cloete et al. 2011	
	STE-U 7324	<i>Pyrus communis</i>	South Africa	n/a	JF934940	Cloete et al. 2011	
	STE-U 7325	<i>Pyrus communis</i>	South Africa	n/a	JF934947	Cloete et al. 2011	
	STE-U 7326	<i>Pyrus communis</i>	South Africa	n/a	JF934941	Cloete et al. 2011	
	STE-U 7327	<i>Malus domestica</i>	South Africa	n/a	JF934934	Cloete et al. 2011	
	STE-U 7330	<i>Malus domestica</i>	South Africa	n/a	JF934935	Cloete et al. 2011	
	STE-U 7331	<i>Malus domestica</i>	South Africa	n/a	JF934936	Cloete et al. 2011	
	STE-U 7332	<i>Malus domestica</i>	South Africa	n/a	JF934937	Cloete et al. 2011	
	STE-U 7333	<i>Malus domestica</i>	South Africa	n/a	JF934938	Cloete et al. 2011	
	STE-U 7334	<i>Malus domestica</i>	South Africa	n/a	JF934946	Cloete et al. 2011	
	STE-U 7336	<i>Malus domestica</i>	South Africa	n/a	JF934942	Cloete et al. 2011	
	STE-U 7337	<i>Pyrus communis</i>	South Africa	n/a	JF934944	Cloete et al. 2011	
	STE-U 7338	<i>Pyrus communis</i>	South Africa	n/a	JF934945	Cloete et al. 2011	
	STE-U 7339	<i>Pyrus communis</i>	South Africa	n/a	JF934928	Cloete et al. 2011	
	STE-U 7340	<i>Pyrus communis</i>	South Africa	n/a	JF934930	Cloete et al. 2011	
	STE-U 7344	<i>Pyrus communis</i>	South Africa	n/a	JF934927	Cloete et al. 2011	
	STE-U 7348	<i>Malus domestica</i>	South Africa	n/a	JF934929	Cloete et al. 2011	
	STE-U 7826	<i>Diospyros kaki</i>	South Africa	MF352200	MF352203	Moyo et al. 2016	
	<i>Phaeoacremonium nordesticola</i>	CMM 4312 <sup>T</sup>	<i>Vitis vinifera</i>	Brazil	KY030803	KY030807	Da Silva et al. 2017
		CMM 4313	<i>Vitis vinifera</i>	Brazil	KY030806	KY030808	Da Silva et al. 2017
		CMM 4314	<i>Vitis vinifera</i>	Brazil	KY030804	KY030809	Da Silva et al. 2017
		CMM 4334	<i>Vitis vinifera</i>	Brazil	KY030805	KY030810	Da Silva et al. 2017
	<i>Phaeoacremonium occidentale</i>	ICMP17037 <sup>T</sup>	<i>Vitis berlandieri</i> × <i>Vitis riparia</i>	New Zealand	EU595460	EU596524	Graham et al. 2009
	<i>Phaeoacremonium pallidum</i>	CBS 120862 <sup>T</sup>	<i>Prunus armeniaca</i>	South Africa	EU128144	EU128103	Damm et al. 2008b
	<i>Phaeoacremonium parasiticum</i>	CBS 113585	<i>Vitis vinifera</i>	South Africa	AY579241	AY579307	Mostert et al. 2005
		CBS 113586	<i>Vitis vinifera</i>	South Africa	AY579242	AY579308	Mostert et al. 2005
		CBS 113594	<i>Vitis vinifera</i>	South Africa	AY579244	AY579310	Mostert et al. 2005
		CBS 121437	<i>Prunus armeniaca</i>	South Africa	EU128123	EU128081	Damm et al. 2008b
		CBS 514.82	<i>Homo sapiens</i>	Finland	AY579240	AY579306	Mostert et al. 2005
		CBS 860.73 <sup>T</sup>	<i>Homo sapiens</i>	USA	AY579253	AF246803	Groenewald et al. 2001
		PMC240	Arthropods	South Africa	n/a	MF352212	Moyo et al. 2014
		STE-U 6990	<i>Vitis vinifera</i>	South Africa	JQ038928	JQ038917	White et al. 2011
		STE-U 6993	<i>Vitis vinifera</i>	South Africa	JQ038927	JQ038916	White et al. 2011
		STE-U 7821	<i>Diospyros kaki</i>	South Africa	MF352197	MF352210	Moyo et al. 2016
		STE-U 7824	<i>Diospyros kaki</i>	South Africa	MF352199	MF352211	Moyo et al. 2016
	<i>Phaeoacremonium prunicola</i>	CBS 120858 <sup>T</sup>	<i>Prunus salicina</i>	South Africa	EU128137	EU128095	Damm et al. 2008b
		STE-U 5968	<i>Prunus salicina</i>	South Africa	EU128138	EU128096	Damm et al. 2008b
<i>Phaeoacremonium pseudopanicis</i>	CBS 142101	<i>Pseudopanax crassifolius</i>	New Zealand	KY173569	KY173609	Crous et al. 2016	
<i>Phaeoacremonium roseum</i>	DAOM 242365 <sup>T</sup>	<i>Vitis vinifera</i>	Canada	KF764507	KF764659	Úrbez-Torres et al. 2014	
	PARC273	<i>Vitis vinifera</i>	Canada	KF764506	KF764658	Úrbez-Torres et al. 2014	
<i>Phaeoacremonium rubrigenum</i>	CBS 112046	<i>Homo sapiens</i>	USA	AY579239	AY579305	Mostert et al. 2005	
	CBS 498.94 <sup>T</sup>	<i>Homo sapiens</i>	USA	AY579238	AF246802	Groenewald et al. 2001, Mostert et al. 2005	
<i>Phaeoacremonium santali</i>	A4	<i>Santalum album</i>	Australia	KF835397	KF823791	Gramaje et al. 2014	
	A37	<i>Santalum album</i>	Australia	KJ533538	KJ533534	Gramaje et al. 2014	
	CBS 137498 <sup>T</sup>	<i>Santalum album</i>	Australia	KF835403	KF823797	Gramaje et al. 2014	
<i>Phaeoacremonium scolyti</i>	CBS 112585	Larvae of <i>Scolytus intricatus</i>	Czech Republic	AY579223	AY579292	Mostert et al. 2005	
	CBS 113593	<i>Vitis vinifera</i>	France	AY579225	AY579293	Mostert et al. 2005	
	CBS 113597 <sup>T</sup>	<i>Vitis vinifera</i>	South Africa	AY579224	AF246800	Groenewald et al. 2001, Mostert et al. 2005	
	CBS 121438	<i>Prunus armeniaca</i>	South Africa	EU128125	EU128083	Damm et al. 2008b	
	CBS 121439	<i>Prunus salicina</i>	South Africa	EU128132	EU128090	Damm et al. 2008b	
	CBS 121755	<i>Prunus persica</i> var. <i>nucipersica</i>	South Africa	EU128124	EU128082	Damm et al. 2008b	
	CBS 121756	<i>Prunus persica</i>	South Africa	EU128128	EU128086	Damm et al. 2008b	
	STE-U 5834	<i>Prunus salicina</i>	South Africa	EU128131	EU128089	Damm et al. 2008b	

## Appendix 1 (cont.)

Organism	Strain	Host	Country	ACT	TUB2	References
<i>Phaeoacremonium scolyti</i> (cont.)	STE-U 5956	<i>Prunus salicina</i>	South Africa	EU128133	EU128091	Damm et al. 2008b
	STE-U 6096	<i>Prunus armeniaca</i>	South Africa	EU128126	EU128084	Damm et al. 2008b
	STE-U 6097	<i>Prunus persica</i>	South Africa	EU128127	EU128085	Damm et al. 2008b
	STE-U 6099	<i>Prunus persica</i>	South Africa	EU128129	EU128087	Damm et al. 2008b
	STE-U 6100	<i>Prunus persica</i>	South Africa	EU128130	EU128088	Damm et al. 2008b
	STE-U 7819	<i>Diospyros kaki</i>	South Africa	MF352195	MF352206	Moyo et al. 2016
	STE-U 7820	<i>Diospyros kaki</i>	South Africa	MF352196	MF352207	Moyo et al. 2016
	STE-U 7822	<i>Diospyros kaki</i>	South Africa	MF352198	MF352208	Moyo et al. 2016
<i>Phaeoacremonium sicilianum</i>	CBS 123034 <sup>†</sup>	<i>Vitis vinifera</i>	Italy	EU863520	EU863488	Essakhi et al. 2008
	CBS 123035	<i>Vitis vinifera</i>	Italy	EU863521	EU863489	Essakhi et al. 2008
	PMC220	Arthropods	South Africa	n/a	MF352209	Moyo et al. 2014
	STE-U 6992	<i>Vitis vinifera</i>	South Africa	JQ038929	JQ038918	White et al. 2011
<i>Phaeoacremonium</i> sp.	STE-U 6994	<i>Vitis vinifera</i>	South Africa	JQ038930	JQ038919	White et al. 2011
	CBS 142686	<i>Vitis berlandieri</i> × <i>Vitis rupestris</i>	South Africa	KY084248	KY084246	Spies unpublished
<i>Phaeoacremonium sphinctrophorum</i>	CBS 142687	<i>Vitis vinifera</i>	South Africa	KY084247	KY084245	Spies unpublished
	CBS 337.90 <sup>†</sup>	<i>Homo sapiens</i>	Laos	DQ173142	DQ173113	Mostert et al. 2006
<i>Phaeoacremonium subulatum</i>	CBS 694.88	<i>Homo sapiens</i>	USA	DQ173143	DQ173114	Mostert et al. 2006
	CBS 113584 <sup>†</sup>	<i>Vitis vinifera</i>	South Africa	AY579231	AY579298	Mostert et al. 2005
<i>Phaeoacremonium tardicrescens</i>	CBS 113587	<i>Vitis vinifera</i>	South Africa	AY579232	AY579299	Mostert et al. 2005
	CBS 120866	<i>Prunus armeniaca</i>	South Africa	EU128134	EU128092	Damm et al. 2008b
	CBS 110573 <sup>†</sup>	<i>Homo sapiens</i>	USA	AY579233	AY579300	Mostert et al. 2005
<i>Phaeoacremonium tectonae</i>	MFLUCC 13-0707 <sup>†</sup>	<i>Tectona grandis</i>	Thailand	KT285555	KT285563	Ariyawansa et al. 2015
	MFLUCC 14-1125	<i>Tectona grandis</i>	Thailand	KT285557	KT285565	Ariyawansa et al. 2015
	MFLUCC 14-1130	<i>Tectona grandis</i>	Thailand	KT285561	KT285569	Ariyawansa et al. 2015
<i>Phaeoacremonium theobromatis</i>	CBS 111586 <sup>†</sup>	<i>Theobroma gileri</i>	Ecuador	DQ173132	DQ173106	Mostert et al. 2006
<i>Phaeoacremonium tuscanicum</i>	CBS 123033 <sup>†</sup>	<i>Vitis vinifera</i>	Italy	EU863490	EU863458	Essakhi et al. 2008
<i>Phaeoacremonium venezuelense</i>	CBS 110119	<i>Vitis vinifera</i>	South Africa	AY579254	AY579318	Mostert et al. 2005
	CBS 113595	<i>Homo sapiens</i>	Canada	AY579255	AY579319	Mostert et al. 2005
	CBS 651.85 <sup>†</sup>	<i>Homo sapiens</i>	Venezuela	AY579256	AY579320	Mostert et al. 2005
<i>Phaeoacremonium vibratile</i>	CBS 117115 <sup>†</sup>	<i>Fagus sylvatica</i>	France	DQ649064	DQ649063	Réblova & Mostert 2007
<i>Phaeoacremonium viticola</i>	CBS 101737	<i>Vitis vinifera</i>	France	DQ173129	AF246817	Groenewald et al. 2001, Mostert et al. 2006
	CBS 101738 <sup>†</sup>	<i>Vitis vinifera</i>	France	DQ173131	AF192391	Groenewald et al. 2001, Mostert et al. 2006
	CBS 113065	<i>Vitis vinifera</i>	South Africa	DQ173128	DQ173105	Mostert et al. 2006
	CBS 121440	<i>Prunus salicina</i>	South Africa	EU128135	EU128093	Damm et al. 2008b
	STE-U 6180	<i>Prunus salicina</i>	South Africa	EU128136	EU128094	Damm et al. 2008b
	STE-U 7352	<i>Pyrus communis</i>	South Africa	n/a	JF934949	Cloete et al. 2011
	STE-U 7353	<i>Pyrus communis</i>	South Africa	n/a	JF934950	Cloete et al. 2011
<i>Pleurostoma richardsiae</i>	CBS 270.33 <sup>†</sup>	Unknown	Sweden	AY579271	AY579334	Mostert et al. 2005

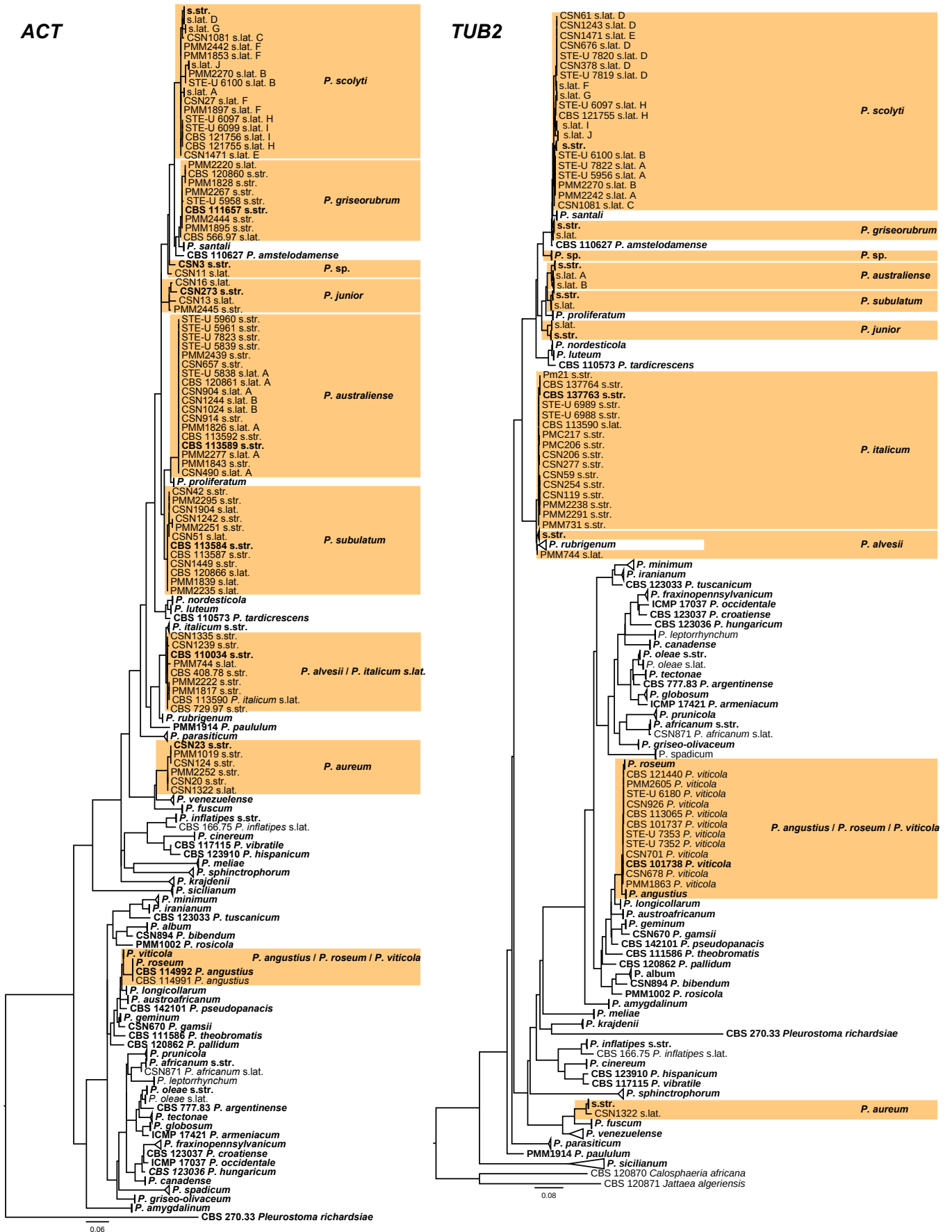
<sup>a</sup> n/a – Data not available.

<sup>b</sup> Previously reported as *P. alvesii*.

<sup>c</sup> Ex-type strain of *P. novae-zealandiae*, which was synonymised with *P. leptorrhynchum* by Réblova (2011).

<sup>†</sup> Ex-type strain.





**Appendix 2** Maximum likelihood phylogenies of the individual actin (ACT) and beta-tubulin (TUB2) regions. Species-level clades and sub-clades corresponding to those designated in Fig. 1 have been collapsed. *Sensu stricto* (s.str.) and *sensu lato* (s.lat.) designations corresponding to those provided in Fig. 1 are indicated next to collapsed clades or individual strain numbers. Paraphyletic species and clades that are incongruent between these individual phylogenies and/or the combined phylogeny (Fig. 1) are highlighted in orange. Ex-type strains or collapsed clades containing ex-type strains are indicated in bold typeface.

**Appendix 3** List of known plant-associated *Phaeoacremonium* species, their plant host/substrate range and worldwide distribution.

<i>Phaeoacremonium</i> species	Host/Substrate	Country (Reference)
<i>P. africanum</i>	<i>Cydonia oblonga</i>	South Africa (this study)
	<i>Eriobotrya japonica</i>	South Africa (this study)
	<i>Olea europaea</i> subsp. <i>europaea</i>	South Africa (this study)
	<i>Prunus armeniaca</i>	South Africa (Damm et al. 2008b)
<i>P. album</i>	<i>Cydonia oblonga</i>	South Africa (this study)
	<i>Pyrus communis</i>	South Africa (this study)
	<i>Vitis vinifera</i>	South Africa (this study)
<i>P. alvesii</i>	<i>Dodonaea viscosa</i>	Australia (Mostert et al. 2005)
	<i>Ficus carica</i>	South Africa (this study)
	<i>Fraxinus excelsior</i>	Iran (Kazemzadeh Chakusary et al. 2017)
	<i>Melia azedarach</i>	South Africa (this study)
	<i>Olea europaea</i> subsp. <i>europaea</i>	Italy (Nigro et al. 2013)
	<i>Pinus eldarica</i>	Iran (Kazemzadeh Chakusary et al. 2017)
	<i>Prunus persica</i>	South Africa (this study)
	<i>Psidium guajava</i>	South Africa (this study)
	<i>Pterocarya fraxinifolia</i>	Iran (Kazemzadeh Chakusary et al. 2017)
	<i>Rosa</i> sp.	South Africa (this study)
	<i>Vitis vinifera</i>	Turkey (Essakhi et al. 2008)
<i>P. amygdalinum</i>	<i>Prunus dulcis</i>	Spain (Gramaje et al. 2012)
<i>P. angustius</i>	<i>Malus</i> sp.	USA (Rooney-Latham et al. 2006)
	<i>Vitis vinifera</i>	France and Italy (Dupont et al. 1998); Portugal (Chicau et al. 2000); Spain (García-Benavides et al. 2013); USA (Groenewald et al. 2001)
<i>P. aquaticum</i>	Submerged wood	China (Hu et al. 2012)
<i>P. argentinense</i>	Soil	Argentina (Crous & Gams 2000)
<i>P. armeniacum</i>	<i>Vitis vinifera</i>	New Zealand (Graham et al. 2009)
<i>P. aureum</i>	<i>Melia azedarach</i>	South Africa (this study)
	<i>Psidium guajava</i>	South Africa (this study)
	<i>Rosa</i> sp.	South Africa (this study)
<i>P. australiense</i>	<i>Cydonia oblonga</i>	South Africa (this study)
	<i>Diospyros kaki</i>	South Africa (Moyo et al. 2016)
	<i>Eriobotrya japonica</i>	South Africa (this study)
	<i>Ficus carica</i>	South Africa (this study)
	<i>Malus domestica</i>	South Africa (this study)
	<i>Prunus salicina</i>	South Africa (Damm et al. 2008b)
	<i>Psidium guajava</i>	South Africa (this study)
	<i>Punica granatum</i>	South Africa (this study)
	<i>Rosa</i> sp.	South Africa (this study)
	<i>Vitis vinifera</i>	Australia (Mostert et al. 2005); South Africa (this study); Uruguay (Abreo et al. 2011)
	<i>P. austroafricanum</i>	<i>Leucadendron</i> sp. (twig litter)
<i>Vitis vinifera</i>		South Africa (Mostert et al. 2006)
<i>P. bibendum</i>	<i>Schinus molle</i>	South Africa (this study)
<i>P. canadense</i>	<i>Vitis vinifera</i>	Canada (Úrbez-Torres et al. 2014)
<i>P. cinereum</i>	<i>Vitis vinifera</i>	Iran and Spain (Gramaje et al. 2009b)
<i>P. croatiense</i>	<i>Alnus glutinosa</i>	Iran (Kazemzadeh Chakusary et al. 2017)
	<i>Quercus castaneifolia</i>	Iran (Kazemzadeh Chakusary et al. 2017)
	<i>Vitis vinifera</i>	Croatia (Essakhi et al. 2008)
<i>P. fraxinopennsylvanicum</i>	<i>Actinidia deliciosa</i>	Italy (Prodi et al. 2008)
	<i>Alnus glutinosa</i>	Iran (Kazemzadeh Chakusary et al. 2017)
	<i>Fraxinus excelsior</i>	Sweden (Groenewald et al. 2001)
	<i>Fraxinus latifolia</i>	USA (Eskalen et al. 2005)
	<i>Fraxinus pennsylvanica</i>	USA (Hausner et al. 1992)
	<i>Malus domestica</i>	Iran (Sami et al. 2014); South Africa (this study)
	<i>Malus</i> sp.	USA (Rooney-Latham et al. 2006)
	<i>Mespilus germanica</i>	Iran (Kazemzadeh Chakusary et al. 2017)
	<i>Parrotia persica</i>	Iran (Kazemzadeh Chakusary et al. 2017)
	<i>Prunus salicina</i>	South Africa (Damm et al. 2008b)
	<i>Pyrus communis</i>	South Africa (Cloete et al. 2011)
	<i>Quercus agrifolia</i>	USA (Lynch et al. 2013)
	<i>Vitis vinifera</i>	Canada (Úrbez-Torres et al. 2014); Croatia and Hungary (Essakhi et al. 2008); Iran (Mohammadi 2011); South Africa (White et al. 2011); Spain (Gramaje et al. 2007); USA (Groenewald et al. 2001)
	<i>P. fuscum</i>	<i>Prunus salicina</i>
<i>P. gamsii</i>	<i>Callistemon</i> sp.	South Africa (this study)
<i>P. geminum</i>	<i>Malus domestica</i>	South Africa (this study)
<i>P. globosum</i>	<i>Cydonia oblonga</i>	South Africa (this study)
	<i>Vitis vinifera</i>	New Zealand (Graham et al. 2009); South Africa (this study)
<i>P. griseo-olivaceum</i>	<i>Prunus armeniaca</i>	South Africa (Damm et al. 2008b)
	<i>Vitis vinifera</i>	South Africa (this study)
<i>P. griseorubrum</i>	<i>Melia azedarach</i>	South Africa (this study)
	<i>Prunus persica</i>	South Africa (this study)
	<i>Prunus salicina</i>	South Africa (Damm et al. 2008b)
	<i>Psidium guajava</i>	South Africa (this study)
	<i>Rosa</i> sp.	South Africa (this study)
	<i>Vitis vinifera</i>	Italy (Essakhi et al. 2008); South Africa (this study)
<i>P. hispanicum</i>	<i>Vitis vinifera</i>	Algeria (Berraf-Tebbal et al. 2011); Spain (Gramaje et al. 2009b)
<i>P. hungaricum</i>	<i>Vitis vinifera</i>	Hungary (Essakhi et al. 2008)
<i>P. inconspicuum</i>	<i>Bambusa vulgaris</i>	Philippines (Eriksson & Yue 1990)
	<i>Gigantochloa schribneriana</i>	Philippines (Eriksson & Yue 1990)
<i>P. inflatipes</i>	<i>Cinnamomum camphora</i>	South Africa (this study)

## Appendix 3 (cont.)

<i>Phaeoacremonium</i> species	Host/Substrate	Country (Reference)	
<i>P. inflatipes</i> (cont.)	<i>Cydonia oblonga</i>	South Africa (this study)	
	<i>Eriobotrya japonica</i>	South Africa (this study)	
	<i>Ficus carica</i>	South Africa (this study)	
	<i>Hypoxylon truncatum</i>	USA (Mostert et al. 2005)	
	<i>Malus domestica</i>	South Africa (this study)	
	<i>Morus</i> sp.	South Africa (this study)	
	<i>Nectandra</i> sp.	Costa Rica (Groenewald et al. 2001)	
	<i>Prunus armeniaca</i>	South Africa (this study)	
	<i>Prunus persica</i>	South Africa (this study)	
	<i>Psidium guajava</i>	South Africa (this study)	
	<i>Quercus robur</i>	South Africa (this study)	
	<i>Quercus virginiana</i>	USA (Groenewald et al. 2001)	
	<i>Salix</i> sp.	South Africa (this study)	
	Soil	USA (Rooney et al. 2001)	
	<i>Vitis vinifera</i>	Chile (Mostert et al. 2006); Iran (Mohammadi et al. 2013); Spain (Gramaje et al. 2009a)	
	<i>P. iranianum</i>	<i>Actinidia chinensis</i>	Italy (Mostert et al. 2006)
		<i>Alnus glutinosa</i>	Iran (Kazemzadeh Chakusary et al. 2017)
		<i>Cinnamomum camphora</i>	South Africa (this study)
		<i>Crataegus rhipidophylla</i>	Iran (Sami et al. 2014)
		<i>Cydonia oblonga</i>	Iran (Sami et al. 2014); South Africa (this study)
<i>Malus domestica</i>		Iran (Arzanlou et al. 2014, Sami et al. 2014)	
<i>Prunus armeniaca</i>		South Africa (Damm et al. 2008b)	
<i>Prunus dulcis</i>		Spain (Gramaje et al. 2012)	
<i>Prunus persica</i> var. <i>nucipersica</i>		South Africa (this study)	
<i>Prunus salicina</i>		South Africa (this study)	
<i>Punica granatum</i>		Iran (Kazemzadeh Chakusary et al. 2017)	
<i>Pyrus communis</i>		South Africa (Cloete et al. 2011)	
<i>Vitis vinifera</i>		Canada (Úrbez-Torres et al. 2014); Iran (Mostert et al. 2006); Italy (Essakhi et al. 2008); South Africa (White et al. 2011); Spain (Gramaje et al. 2009a)	
<i>Zelkova carpinifolia</i>		Iran (Kazemzadeh Chakusary et al. 2017)	
<i>P. italicum</i>		Arthropods	South Africa (Moyo et al. 2014; reported as <i>P. alvesii</i> )
	<i>Cydonia oblonga</i>	South Africa (this study)	
	<i>Ficus carica</i>	South Africa (this study)	
	<i>Malus domestica</i>	South Africa (this study)	
	<i>Melia azedarach</i>	South Africa (this study)	
	<i>Morus</i> sp.	South Africa (this study)	
	<i>Olea europaea</i> subsp. <i>europaea</i>	Italy (Carlucci et al. 2015)	
	<i>Prunus persica</i>	South Africa (this study)	
	<i>Psidium guajava</i>	South Africa (this study)	
	<i>Punica granatum</i>	South Africa (this study)	
	<i>Vitis vinifera</i>	Italy (Raimondo et al. 2014); South Africa (White et al. 2011; reported as <i>P. alvesii</i> )	
	<i>P. junior</i>	<i>Prunus armeniaca</i>	South Africa (this study)
		<i>Schinus molle</i>	South Africa (this study)
		<i>Vitis vinifera</i>	South Africa (this study)
	<i>P. krajdienii</i>	<i>Vitis vinifera</i>	South Africa (Mostert et al. 2005); Spain (Gramaje et al. 2011)
<i>P. leptorrhynchum</i>	<i>Acer saccharum</i>	USA (Réblová 2011)	
	<i>Acer spicatum</i>	USA (Réblová 2011)	
	<i>Castanea sativa</i>	Italy (Réblová 2011)	
	<i>Chamaerops humilis</i>	Algeria (Réblová 2011)	
	<i>Cupressus macrocarpa</i>	New Zealand (Hausner et al. 1992; reported as <i>P. novae-zealandiae</i> )	
	<i>Fagus sylvatica</i>	Ukraine (Réblová 2011)	
	<i>Ficinia spiralis</i>	New Zealand (Hausner et al. 1992; reported as <i>P. novae-zealandiae</i> )	
	<i>Lactuca canadensis</i>	USA (Réblová 2011)	
	<i>Pinus radiata</i>	New Zealand (Hausner et al. 1992; reported as <i>P. novae-zealandiae</i> )	
	<i>Prunus armeniaca</i>	South Africa (this study)	
	<i>Psidium guajava</i>	South Africa (this study)	
	<i>P. luteum</i>	<i>Santalum album</i>	Australia (Gramaje et al. 2014)
		<i>Melia azedarach</i>	South Africa (this study)
	<i>P. meliae</i>	<i>Actinidia chinensis</i>	Italy (Crous & Gams 2000)
	<i>P. minimum</i>	<i>Actinidia deliciosa</i>	Italy (Prodi et al. 2008)
<i>Alnus glutinosa</i>		Iran (Kazemzadeh Chakusary et al. 2017)	
Arthropods		South Africa (Moyo et al. 2014)	
<i>Brabejum stellatifolium</i> (twig litter)		South Africa (Marincowitz et al. 2008)	
<i>Cupressus sempervirens</i>		Iran (Mohammadi et al. 2014)	
<i>Cydonia oblonga</i>		Iran (Sami et al. 2014); South Africa (this study)	
<i>Diospyros kaki</i>		South Africa (Moyo et al. 2016)	
<i>Eriobotrya japonica</i>		South Africa (this study)	
<i>Gleditsia caspica</i>		Iran (Kazemzadeh Chakusary et al. 2017)	
<i>Malus domestica</i>		Iran (Arzanlou et al. 2014, Sami et al. 2014); South Africa (Cloete et al. 2011)	
<i>Morus</i> sp.		South Africa (this study)	
<i>Olea europaea</i> subsp. <i>europaea</i>		Italy (Crous & Gams 2000); South Africa (this study); USA (Úrbez-Torres et al. 2013)	
<i>Parrotia persica</i>		Iran (Kazemzadeh Chakusary et al. 2017)	
<i>Phoenix dactylifera</i>		Iran (Mohammadi 2014)	
<i>Prunus armeniaca</i>		Iran (Arzanlou et al. 2014); South Africa (Damm et al. 2008b)	
<i>Prunus dulcis</i>		South Africa (this study)	
<i>Prunus pennsylvanica</i>		USA (Hausner et al. 1992)	
<i>Prunus persica</i>		South Africa (Damm et al. 2008b)	
<i>Prunus salicina</i>		South Africa (Damm et al. 2008b)	
<i>Psidium guajava</i>		South Africa (this study)	



## Appendix 3 (cont.)

<i>Phaeoacremonium</i> species	Host/Substrate	Country (Reference)
<i>P. minimum</i> (cont.)	<i>Punica granatum</i>	South Africa (this study)
	<i>Pyrus communis</i>	Iran (Sami et al. 2014); South Africa (Cloete et al. 2011)
	<i>Rosa</i> sp.	South Africa (this study)
	<i>Salix alba</i>	Iran (Hashemi & Mohammadi 2016)
	<i>Salix</i> sp.	South Africa (this study); USA (Hausner et al. 1992)
	<i>Schinus molle</i>	South Africa (this study)
	Soil	Spain (Agustí-Brisach et al. 2013); USA (Rooney et al. 2001)
	<i>Vitis vinifera</i>	Algeria (Berraf-Tebbal et al. 2011); Argentina (Gatica et al. 2001); Australia (Pascoe & Cottral 2000); Austria (Reisenzein et al. 2000); Brasil (Correia et al. 2013); Canada (Úrbez-Torres et al. 2014); Chile (Auger et al. 2005); France (Larignon & Dubos 1997); Germany (Fischer & Kassemeyer 2003); Greece and Hungary (Essakhi et al. 2008); Iran (Mostert et al. 2006); Israel (Essakhi et al. 2008); Italy (Crous et al. 1996); Portugal (Rego et al. 2000); South Africa (Crous et al. 1996); Spain (Armengol et al. 2001); Turkey (Ari 2000); Uruguay (Abreo et al. 2011); USA (Crous et al. 1996); Yugoslavia (Crous et al. 1996)
	<i>P. nordesticola</i>	<i>Vitis vinifera</i> Brazil (Da Silva et al. 2017)
	<i>P. occidentale</i>	<i>Vitis vinifera</i> New Zealand (Graham et al. 2009)
<i>P. oleae</i>	<i>Olea europaea</i> subsp. <i>cuspidata</i> South Africa (this study)	
<i>P. pallidum</i>	<i>Prunus armeniaca</i> South Africa (Damm et al. 2008b)	
<i>P. parasiticum</i>	<i>Actinidia chinensis</i>	Italy (Di Marco et al. 2004)
	<i>Afrocarpus falcatus</i>	South Africa (this study)
	<i>Aquilaria agallocha</i>	No data (Mostert et al. 2006)
	Arthropods	South Africa (Moyo et al. 2014)
	<i>Carpinus betulus</i>	Iran (Kazemzadeh Chakusary et al. 2017)
	<i>Cupressus sempervirens</i>	Iran (Mohammadi et al. 2014)
	<i>Cupressus</i> sp.	No data (Mostert et al. 2006)
	<i>Cydonia oblonga</i>	Iran (Sami et al. 2014); South Africa (this study)
	<i>Diospyros kaki</i>	South Africa (Moyo et al. 2016)
	<i>Eriobotrya japonica</i>	South Africa (this study)
	<i>Erythrina</i> sp.	South Africa (this study)
	<i>Ficus carica</i>	South Africa (this study)
	<i>Leucadendron</i> sp. (twig litter)	South Africa (Marincowitz et al. 2008)
	<i>Malus domestica</i>	Iran (Sami et al. 2014); South Africa (this study)
	<i>Melia azedarach</i>	South Africa (this study)
	<i>Nectandra</i> sp.	Costa Rica (Hawksworth et al. 1976)
	<i>Olea europaea</i> subsp. <i>europaea</i>	Italy (Nigro et al. 2013); South Africa (this study)
	<i>Parrotia persica</i>	Iran (Kazemzadeh Chakusary et al. 2017)
	<i>Phoenix dactylifera</i>	Iran (Mohammadi 2014); Iraq (Hawksworth et al. 1976)
	<i>Populus caspica</i>	Iran (Kazemzadeh Chakusary et al. 2017)
	<i>Populus nigra</i>	Iran (Hashemi & Mohammadi 2016)
	<i>Prunus armeniaca</i>	South Africa (Damm et al. 2008b); Tunisia (Hawksworth et al. 1976)
	<i>Prunus avium</i>	Greece (Rumbos 1986)
	<i>Psidium guajava</i>	South Africa (this study)
	<i>Punica granatum</i>	South Africa (this study)
	<i>Pyrus communis</i>	Iran (Sami et al. 2014)
	<i>Quercus virginiana</i>	USA (Halliwell 1966)
	<i>Rosa</i> sp.	South Africa (this study)
	<i>Salix alba</i>	Iran (Hashemi & Mohammadi 2016)
	<i>Salix</i> sp.	South Africa (this study)
	Soil	Tahiti (Dupont et al. 2002); Spain (Agustí-Brisach et al. 2013)
	<i>Ulmus carpiniifolia</i>	Iran (Kazemzadeh Chakusary et al. 2017)
	<i>Vitis vinifera</i>	Algeria (Berraf-Tebbal et al. 2011); Argentina (Gatica et al. 2001); Australia (Pascoe & Cottral 2000); Brasil (Correia et al. 2013); Chile (Auger et al. 2005); Iran (Mostert et al. 2006); Italy (Essakhi et al. 2008); Peru (Romero-Rivas et al. 2009); South Africa (Mostert et al. 2005); Spain (Aroca et al. 2006); USA (Mostert et al. 2006)
	<i>P. paululum</i>	<i>Zelkova carpiniifolia</i> Iran (Kazemzadeh Chakusary et al. 2017)
	<i>P. proliferatum</i>	<i>Psidium guajava</i> South Africa (this study)
	<i>P. prunicola</i>	<i>Malus domestica</i> South Africa (this study)
		<i>Rosa</i> sp. South Africa (this study)
		<i>Afrocarpus falcatus</i> South Africa (this study)
		<i>Cinnamomum camphora</i> South Africa (this study)
		<i>Cydonia oblonga</i> South Africa (this study)
	<i>Eriobotrya japonica</i> South Africa (this study)	
	<i>Olea europaea</i> subsp. <i>cuspidata</i> South Africa (this study)	
	<i>Prunus salicina</i> South Africa (Damm et al. 2008b)	
	<i>Psidium guajava</i> South Africa (this study)	
	<i>Pyrus communis</i> South Africa (this study)	
	<i>Schinus molle</i> South Africa (this study)	
	<i>Vitis vinifera</i> South Africa (this study)	
<i>P. pseudopanacis</i>	<i>Pseudopanax crassifolius</i> New Zealand (Crous et al. 2016)	
<i>P. roseum</i>	<i>Vitis vinifera</i> Canada (Úrbez-Torres et al. 2014)	
<i>P. rosicola</i>	<i>Rosa</i> sp. South Africa (this study)	
<i>P. rubrigenum</i>	<i>Cydonia oblonga</i>	Iran (Sami et al. 2014)
	<i>Dactylis glomerata</i>	Spain (Sánchez-Márquez et al. 2007)
	<i>Diospyros kaki</i>	Iran (Jamali & Banihashemi 2012)
	<i>Olea europaea</i> subsp. <i>europaea</i>	Italy (Nigro et al. 2013)
	<i>Pyrus communis</i>	Iran (Sami et al. 2014)
	<i>Salix alba</i>	Iran (Hashemi & Mohammadi 2016)
	<i>Vitis vinifera</i>	Chile (Auger et al. 2005); Croatia (Essakhi et al. 2008); New Zealand (Manning & Munday 2009)

## Appendix 3 (cont.)

<i>Phaeoacremonium</i> species	Host/Substrate	Country (Reference)	
<i>P. santali</i>	<i>Santalum album</i>	Australia (Gramaje et al. 2014)	
<i>P. scolyti</i>	<i>Cydonia oblonga</i>	Iran (Sami et al. 2014); South Africa (this study)	
	<i>Diospyros kaki</i>	South Africa (Moyo et al. 2016)	
	<i>Eriobotrya japonica</i>	South Africa (this study)	
	Larvae of <i>Scolytus intricatus</i>	Czech Republic (Kubátova et al. 2004)	
	<i>Malus domestica</i>	South Africa (this study)	
	<i>Melia azedarach</i>	South Africa (this study)	
	<i>Olea europaea</i> subsp. <i>cuspidata</i>	South Africa (this study)	
	<i>Olea europaea</i> subsp. <i>europaea</i>	Italy (Carlucci et al. 2015); South Africa (this study)	
	<i>Parrotia persica</i>	Iran (Kazemzadeh Chakusary et al. 2017)	
	<i>Prunus armeniaca</i>	South Africa (Damm et al. 2008b)	
	<i>Prunus domestica</i>	South Africa (this study)	
	<i>Prunus dulcis</i>	South Africa (this study)	
	<i>Prunus persica</i>	South Africa (Damm et al. 2008b)	
	<i>Prunus persica</i> var. <i>nucipersica</i>	South Africa (Damm et al. 2008b)	
	<i>Prunus salicina</i>	South Africa (Damm et al. 2008b)	
	<i>Psidium guajava</i>	South Africa (this study)	
	<i>Punica granatum</i>	Iran (Kazemzadeh Chakusary et al. 2017); South Africa (this study)	
	<i>P. scolyti</i> (cont.)	<i>Pyrus communis</i>	Iran (Sami et al. 2014); South Africa (this study)
		<i>Quercus suber</i>	South Africa (this study)
		<i>Rosa</i> sp.	South Africa (this study)
<i>Salix</i> sp.		South Africa (this study)	
<i>Vitis vinifera</i>		France (Mostert et al. 2005); Italy (Essakhi et al. 2008); South Africa (Mostert et al. 2005); Spain (Gramaje et al. 2008); Turkey (Özben et al. 2012)	
<i>P. sicilianum</i>	Arthropods	South Africa (Moyo et al. 2014)	
	<i>Ficus carica</i>	South Africa (this study)	
	<i>Juglans</i> sp.	South Africa (this study)	
	<i>Olea europaea</i> subsp. <i>europaea</i>	Italy (Carlucci et al. 2015)	
	<i>Vitis vinifera</i>	Italy (Essakhi et al. 2008); South Africa (White et al. 2011); Spain (Gramaje et al. 2009a)	
<i>P. spadicum</i>	<i>Eriobotrya japonica</i>	South Africa (this study)	
	<i>Olea europaea</i> subsp. <i>cuspidata</i>	South Africa (this study)	
	<i>Rhoicissus tomentosa</i>	South Africa (this study)	
<i>P. subulatum</i>	<i>Cydonia oblonga</i>	South Africa (this study)	
	<i>Malus domestica</i>	South Africa (this study)	
	<i>Prunus armeniaca</i>	South Africa (Damm et al. 2008b)	
	<i>Prunus salicina</i>	South Africa (this study)	
	<i>Psidium guajava</i>	South Africa (this study)	
	<i>Punica granatum</i>	South Africa (this study)	
	<i>Pyrus communis</i>	South Africa (this study)	
	<i>Rosa</i> sp.	South Africa (this study)	
	<i>Schinus molle</i>	South Africa (this study)	
	<i>Vitis vinifera</i>	South Africa (Mostert et al. 2006)	
	<i>P. tectonae</i>	<i>Tectona grandis</i>	Thailand (Ariyawansa et al. 2015)
<i>P. theobromatis</i>	<i>Theobroma gileri</i>	Ecuador (Mostert et al. 2006)	
<i>P. tuscanicum</i>	<i>Vitis vinifera</i>	Iran (Mohammadi 2012); Italy (Essakhi et al. 2008)	
<i>P. venezuelense</i>	<i>Prunus armeniaca</i>	Spain (Olmo et al. 2014)	
	<i>Rosa</i> sp.	South Africa (this study)	
<i>P. venezuelense</i> (cont.)	<i>Vitis vinifera</i>	Algeria (Berraf-Tebbal et al. 2011); South Africa (Mostert et al. 2005)	
<i>P. vibratile</i>	<i>Fagus sylvatica</i>	France and Hungary (Réblová & Mostert 2007)	
	<i>Prunus padus</i>	Sweden (Réblová & Mostert 2007)	
	<i>Sorbus</i> sp.	Italy (Réblová & Mostert 2007)	
<i>P. viticola</i>	<i>Actinidia chinensis</i>	France (Hennion et al. 2001)	
	<i>Cydonia oblonga</i>	South Africa (this study)	
	<i>Eriobotrya japonica</i>	South Africa (this study)	
	<i>Prunus salicina</i>	South Africa (Damm et al. 2008b)	
	<i>Psidium guajava</i>	South Africa (this study)	
	<i>Pyrus communis</i>	South Africa (Cloete et al. 2011)	
	<i>Quercus robur</i>	South Africa (this study)	
	<i>Salix</i> sp.	South Africa (this study)	
	<i>Sorbus intermedia</i>	Germany (Mostert et al. 2006)	
	<i>Vitis vinifera</i>	France (Dupont et al. 2000); Iran (Mostert et al. 2006); Italy (Dupont et al. 2000); South Africa (Mostert et al. 2006); Spain (Aroca et al. 2008); USA (Dupont et al. 2000)	