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ORIGINAL PAPER

Yeasts from phylloplane and their capability to produce indole-3-acetic acid

Savitree Limtong · Nampueng Koowadjanakul

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Abstract Yeasts were isolated from the phylloplane of various plant species collected from seven provinces in Thailand. A total of 114 yeast strains and 10 strains of a yeast-like fungus were obtained by enrichment isolation from 91 out of 97 leaf samples (93.8 %). On the basis of the D1/D2 domain of the large subunit rRNA gene sequence similarity, 98 strains were identified to be of 36 yeast species in 18 genera belonging to Ascomycota viz. *Candida*, *Clavispora*, *Cyberlindnera*, *Debaryomyces*, *Hanseniaspora*, *Hyphopichia*, *Kazachstania*, *Kluyveromyces*, *Kodamaea*, *Lachancea*, *Metschnikowia*, *Meyrozyma*, *Pichia*, *Starmerella*, *Torulaspora* and *Wickerhamomyces*, and to Basidiomycota viz. *Sporidiobolus* and *Trichosporon.* Three strains were found to represent two novels *Candida* species which were previously described as *C. sirachaensis* and *C. sakaeoensis*. Ten strains of yeast-like fungus were identified as *Aureobasidium pullulans* of the phylum Ascomycota. Ascomycetous yeast species accounted altogether for 98.0 % of the 98 strains. The prevalent species was *Candida tropicalis* with a low frequency of isolation (14.3 %). Diversity of yeasts other than ballistoconidium-forming yeast in phylloplane in a tropical country in Asia has been reported for the first time. All strains obtained were accessed for the capability to produce IAA and result revealed that 39 strains in 20 species, one strain each of an undescribed and a novel species, and two unidentified strains showed the capability of producing IAA when cultivated in yeast extract peptone dextrose broth supplemented with 0.1 % L-tryptophan. All five strains of *Candida maltosa* produced relatively high concentrations of IAA.

Keywords Phylloplane · Yeast · Indole-3-acetic acid · Thailand

S. Limtong (✉) · N. Koowadjanakul
Department of Microbiology, Faculty of Science, Kasetsart University, Bangkok 10900, Thailand
e-mail: fscistl@ku.ac.th

S. Limtong
Center for Advanced Studies in Tropical Natural Resources, National Research University-Kasetsart University, Kasetsart University, Bangkok 10900, Thailand

Introduction

The external surface of plant leaves, which is usually referred to as the phylloplane or phyllosphere, has been recognized as an important habitat for epiphytic microorganisms (Fonseca and Inacio 2006; Phaff and Starmer 1987). In the phylloplane, the growth of microorganisms is dependent on nutrients from plant metabolites that are secreted to the phylloplane or on compounds in materials from external sources that drop on the plant surface. The plant metabolites are organic substances, mostly simple sugars e.g. glucose, fructose and sucrose, while the materials from external sources are inorganic nutrients (Xin et al. 2009). While bacteria are the most abundant phylloplane microorganisms, yeasts and yeast-like fungi such as *Aureobasidium pullulans* are also active phylloplane colonizers (Andrews and Harris 2000). The phylloplane of diverse temperate, tropical and Mediterranean plants have been found to be colonized by both basidiomycetous and ascomycetous yeasts (Fonseca and Inacio 2006; Glushakova and Chernov 2010; Glushakova et al. 2007; Inácio et al. 2005; Landell et al. 2010; Nakase et al. 2001; Slavikova et al. 2009). Although the common phylloplane yeasts were basidiomycetous species belonging to the genera *Bullerra*, *Cryptococcus*, *Dioszegia*, *Rhodotorula*, *Sporobolomyces*, *Tilletiopsis* and

Trichosporon such as *Cryptococcus laurentii*, *Rhodotorula mucilaginosa*, *Rhodotorula glutinis* and *Sporobolomyces roseus* (de Azeredo et al. 1998; Fonseca and Inacio 2006; Glushakova et al. 2007; Nakase et al. 2001; Sharma et al. 2009; Slavikova et al. 2009), some ascomycetous species have also been found such as *Debaryomyces hansenii*, *Hanseniaspora uvarum*, *Kazachstania barnetii*, *Metschnikowia pulcherima*, *Metschnikowia reukaufii*, *Pichia membranifaciens*, *Saccharomyces cerevisiae* and various species of *Candida* (Glushakova and Chernov 2010; Glushakova et al. 2007; Koowadjanakul et al. 2011; Landell et al. 2010; Sharma et al. 2009; Slavikova et al. 2009). Yeasts colonizing the phylloplane were studied intensively; however, limited investigation on diversity of yeasts in phylloplane in tropical area was conducted so far. For example Nakase et al. (2001) reported ballistoconidium-froming yeasts found in the phylloplane of Thailand.

Indole-3-acetic acid (IAA) is the major member of plant growth promoter in the auxin class that is known to stimulate both rapid and long-term responses in plants by regulation of various developmental and physiological processes (Cleland 1990). It is produced by plants and microorganisms including bacteria (Xinxian et al. 2011), actinomycetes (Khamna et al. 2010), yeasts (El-Tarabily 2004; Nakamura et al. 1991; Nassar et al. 2005), and filamentous fungi (Ruanpanun et al. 2010). IAA-producing microorganisms are receiving attention as good sources of biofertilizer (Sasikala and Ramana 1998). Applications of IAA producing yeasts, such as *S. roseus*, *Candida valida*, *R. glutinis* and *Trichosporon asahii*, *Lindera* (*Williopsis*) *saturnus* and *R. mucilaginosa*, to promoting growth of plants have been reported (El-Tarabily 2004; Nassar et al. 2005; Perondi et al. 1996; Xin et al. 2009).

There is little information on IAA-producing yeasts, especially those of the phylloplane. Therefore, the objectives of this study were isolation and identification of yeasts isolated from phylloplane in Thailand, followed by assessment of their capacity to produce indole-3-acetic acid in vitro.

Materials and methods

Sample collection

Green and undamaged plant leaves were collected and placed in plastic bags, sealed and transferred in ice-box to laboratory. The samples were kept at 8 °C until subjected for yeast isolation.

Yeast isolation

Yeast was isolated by an enrichment technique using yeast extract malt extract (YM) broth (3 g/L yeast extract, 3 g/L malt extract, 5 g/L peptone and 10 g/L glucose) supplemented with 0.025 % sodium propionate and 0.02 % chloramphenicol (Limtong et al. 2007). Three grams of cut leaves, derived from cutting few leaves to the size that can be put into a 250 mL Erlenmeyer, was inoculated into 50 mL enrichment broth in the flask and incubated on a rotary shaker at 30 ± 3 °C for 2 days. A loopful of the enriched culture was streaked on YM agar supplemented with 25 mg/L sodium propionate and 20 mg/L chloramphenicol. Yeast colonies of different morphologies were picked and purified by cross streaking on YM agar. Purified yeast strains were suspended in YM broth supplemented with 10 % v/v glycerol and maintained at −80 °C.

Yeasts identification and phylogenetic analysis

Yeasts were identified by molecular taxonomy based on the analysis of the D1/D2 domain of the large subunit (LSU) rRNA gene sequences similarities according to a guideline of Kurtzman and Robnett (1998) that yeast strains with 0–3 nucleotide differences are conspecific or sister species and yeast strains showing nucleotide substitutions greater than 6 are usually different species. Therefore, a strain showing nucleotide substitutions greater than six from the type strain of the closest species could be designed as the novel species. Undescribed species are the species that the D1/D2 domain of the LSU rRNA gene sequences was deposited in the GenBank without description.

Methods for DNA isolation and amplification of the D1/D2 domain of the LSU rRNA gene were as described previously by Limtong et al. (2007). The PCR product was checked by agarose gel electrophoresis and purified by using the QIA quick purification kit (Qiagen, Hilden, Germany). The purified product was sequenced commercially by Macrogen Inc. (Seoul, Korea) with primers, NL1 and NL4. The sequences were compared pairwise using a BLAST search (Altschul et al. 1997).

A phylogenetic tree was constructed from the evolutionary distance data with Kimura's two-parameter correction (Kimura 1980), using the neighbor-joining method (Saitou and Nei 1987). Confidence levels of the clades were estimated from bootstrap analysis (1,000 replicates; Felsenstein 1985).

Determination of indole-3-acetic acid production

Production of indole-3-acetic acid (IAA) by the phylloplane yeasts was investigated by the method of Xin et al. (2009). A yeast culture cultivated for 1–2 days on YM agar at 25 °C was inoculated in 5 mL of yeast extract peptone dextrose (YPD) broth (10 g/L yeast extract, 2 g/L peptone and 2 g/L dextrose) supplemented with 1 g/L L-tryptophan in a test tube and incubated on a shaker at 30 ± 2 °C and

150 rpm for 7 days. An aliquot of 1.5 mL of the culture broth was centrifuged at 8,000 rpm for 5 min and the supernatant was collected for determination of IAA concentration. One mL of supernatant was mixed with 1 mL of Salkowski reagent (12 g/l $FeCl_3$ and 7.9 M H_2SO_4; Glickmann and Dessaux 1994), and the intensity of pink color developing in the mixture after 30 min was quantified with a spectrophotometer (UV-1700, Shimadzu, Japan) at a wavelength of 530 nm. Calibration curve using pure IAA was established for calculation of IAA concentration. Growth was determined as dry weight by drying cells after centrifugation at 100 °C until constant weight was obtained.

Results

Sample collection and yeast isolation

Yeasts were isolated from the phylloplane of 76 leaf samples of 45 plant species and 21 samples of unknown plants which had been collected from 19 locations in seven provinces in the eastern, central, north–eastern and peninsular regions of Thailand during April and May 2009 (Table 1).

A total of 114 yeast strains and 10 strains of yeast-like fungus were obtained from 91 samples representing 93.8 % of the samples investigated (Table 1). Among these 91 samples three samples contained only the yeast-like fungus.

Yeast identification

On the basic of the D1/D2 domain of the LSU rRNA gene sequence similarity and the generally accepted criteria of Kurtzman and Robnett (1998), 96 yeast strains were identified to be 36 species in 18 genera (Tables 1 and 2). Thirty-four species were in 16 genera of Phylum Ascomycota (15 genera) viz. *Candida* (15 species), *Clavispora* (1 species), *Cyberlindnera* (1 species), *Debaryomyces* (1 species), *Hanseniaspora* (3 species), *Hyphopichia* (1 species), *Kazachstania* (1 species), *Kluyveromyces* (1 species), *Kodamaea* (1 species), *Lachancea* (1 species), *Metschnikowia* (1 species), *Meyerozyma* (1 species), *Pichia* (2 species), *Starmerella* (1 species), *Torulaspora* (2 species) and *Wickerhamomyces* (1 species), and two species were in Phylum Basidiomycota (2 genera) viz. *Sporidiobolus* (1 species), and *Trichosporon* (1 species). Four strains were similar to three undescribed species in Ascomycota and nine strains require further analysis for identification. Three strains were found to represent two novels *Candida* species which were previously proposed to be *C. sirachaensis* and *C. sakaeoensis*. The 10 strains of yeast-like fungus were identified to be *A. pullulans* (Table 1, 2). Phylogenetic positions of all yeast species obtained in this study were shown in Fig. 1. Most *Candida* species were distributed in five phylogenetically distinct clades including *Kodamaea*, *Lodderomyces-Spathospora*, *Nakaseozyma*, *Starmerella* and *Yamadazyma* clades while *Candida rugosa* was not placed in any clade.

The results indicated that 98.0 % of the strains isolated by the enrichment technique were ascomycetous yeasts, and only 2.0 % represented basidiomycetous species. The dominant species was *Candida tropicalis*, although only 14 strains of this species were isolated from 14 samples, represented a 14.3 % frequency of isolation (Table 2). Ten strains of *A. pullulans*, the yeast-like fungus, were isolated from 10 samples, giving a frequency of isolation of 7.8 %.

Iodole-3-acetic acid production

Among the 114 strains of yeast, 39 strains in 20 species, one strain of an undescribed species, one strain of a novel species, and two unidentified strains showed the capability of producing IAA when cultivated in YPD broth supplemented with 0.1 % L-tryptophan (Table 3). The other 71 strains grew in this medium, but no IAA was produced. All five strains of *C. maltosa* produced relatively high concentrations (121.4–234.1 mg/L) of IAA. This result indicated IAA production was strain-dependent; some strains of some species were able to produce IAA while others were not. All 10 strains of *A. pullulans* produced IAA; however, the concentrations were relatively low.

Discussion

The two findings of the present study were, first, that phylloplane yeasts are present on diverse plant species in Thailand and *C. tropicalis* was frequently found and second, that approximately 37.7 % of the phylloplane yeasts found were capable of in vitro IAA biosynthesis. The study found that by enrichment isolation at 30 ± 3 °C most yeasts obtained from phylloplane in Thailand were in the phylum Ascomycota (98.0 %); this is in contrast with the other investigations, which report the dominance of basidiomycetous yeasts on the phylloplane in the other regions (de Azeredo et al. 1998; Fonseca and Inacio 2006; Glushakova et al. 2007; Nakase et al. 2001; Sharma et al. 2009). This difference may have resulted from the different technique and incubation temperature employed for isolation. While in most investigations leaf washing followed by dilution plating technique was used, Nakase et al. (2001) used the ballistoconidium fall method with YM agar without any antibacterial and antifungal agents, and they found more yeast species when the incubation temperature

Table 1 Leaf from diverse plant species and yeasts isolated from phylloplane with their accession numbers of the D1/D2 domain of the large subunit rRNA gene

Sample collection		Identification of yeast and yeast like fungus			Identification result	
Location (date)	Plant	Strain	Closest species (GenBank accession no.)	Nucleotide substitutions/total nt	Species	Accession no. (D1/D2)
Wachirawut Boy Scout Camp, Si Racha destrict, Chonburi province (26 April 2009)	Bermese Ebony (*Pterocarpus macrocarpus* Kurz.)	LM001	*Candida glabrata* (U44808)	1/581	*C. glabrata*	AB617902
	Teak (*Tectona grandis* Linn.)	LM002	*Kazachstania siamensis* (AB258462)	0/574	*K. siamensis*	AB617903
	Eucalyptus (*Eucalyptus camaldulensis* Dehnh.)	LM003	*Candida stigmatis* (GQ184144)	0/423	*C. stigmatis*	AB617904
	Mango (*Mangifera indica* Linn.)	–			–	–
	Black Wattle (Acacia auriculaeformis Cunn.)	LM004	*Candida etchellsii* (U45723)	0/482	*C. etchellsii*	AB617905
	Canna (Canna indica Linn.)	LM005	*Candida apicola* (U45703)	2/480	*C. apicola*	AB617906
	Cashew Nut (*Anacardirm occidentale* Linn.)	–			–	–
	Jack Fruit (*Artocarpus eterophyllus* Lam.)	LM006	*Pichia kudriavzevii* (U76347)	0/564	*P. kudriavzevii*	AB617907
		LM007	*Hanseniaspora opuntiae* (AJ512453)	0/572	*H. opuntiae*	AB617908
	Bengal Almond (*Terminalia catappa* Linn.)	–	–	–	–	–
	Copper pod (*Peltophorum pterocarpum* (DC.) Backer ex K. Heyne.)	LM008	*Candida bombi* (AF406929)	50/485	*Candida sirachaensis* sp. nov.[a]	AB617909
	Flame Tree (*Delonix regia* (Bojer) Raf.)	LM009	*K. siamensis* (AB258462)	0/574	*K. siamensis*	AB617910
	Rain Tree (*Samanea saman* Merr.)	–			–	
	Siamese Rough Bush (*Streblus asper* Lour.)	LM010	*C. glabrata* (U44808)	1/581	*C. glabrata*	AB617911
	Kurchi (*Wrightia religiosa* Benth.)	–			–	
	Chinese Rose (*Hibiscus rosa-sinensis* Linn.)	LM011	*C. glabrata* (U44808)	1/581	*C. glabrata*	AB617912
	Tamarind (*Tamarindus indica* Linn.)	LM012	*C. glabrata* (U44808)	1/581	*C. glabrata*	AB617913
	Devil Tree (*Alstonia scholaris* (L.) R. Br.)	LM013	*Candida potacharoeniae* (AB537430)	0/450	*C. potacharoeniae*	AB617914
	She Oak (*Casuarina junghuhniana* Miq.)	–			–	–
	Golden Shower Tree (*Cassia fistula* Linn.)	LM014	*C. etchellsii* (U45723)	0/482	*C. etchellsii*	AB617915
Mueang Nakhon Nayok district, Nakhon Nayok province (10 May 2009)	Coconut (*Cocos nucifera* Linn.)	LM015	*Sporidiobolus ruineniae* (AF387128)	1/574	*S. ruineniae*	AB617916
		LM016	–	–	Unidentified	–
		LM017	*A. pullulans* (FJ515219)	0/571	*A. pullulans*	AB617918
	Bougainvillea (*Bougainvillea* sp.)	LM018	*A. pullulans* (FJ515219)	1/571	*A. pullulans*	AB617919
	Unknown	LM019	*C. tropicalis* (U45749)	0/570	*C. tropicalis*	AB617920
	West Indian Jasmine (*Ixora chinensis* Lamk.)	LM020	*A. pullulans* (FJ515219)	0/571	*A. pullulans*	AB617921
	Papaya (*Carica papaya* Linn.)	LM021	*A. pullulans* (FJ515219)	0/577	*A. pullulans*	AB617922
	Bamboo (*Bambusa* sp.)	LM022	*Hyphopichia burtonii* (U45712)	0/524	*H. burtonii*	AB617923
		LM023	*Pichia* sp. ST-335 (DQ404505)	0/530	Similar to *Pichia* sp. ST-335	AB617924
	Jujube (*Zizyphus mauritiana* Lamk.)	LM024	*C. tropicalis* (U45749)	0/570	*C. tropicalis*	AB617925

Table 1 continued

Sample collection		Identification of yeast and yeast like fungus			Identification result	
Location (date)	Plant	Strain	Closest species (GenBank accession no.)	Nucleotide substitutions/total nt	Species	Accession no. (D1/D2)
Khlong Bod reservoir, Mueang Nakhon Nayok district, Nakhon Nayok province (10 May 2009)	Governor's plum (*Flacourtia cataphracta* Roxb.)	LM025	*A. pullulans* (FJ515219)	0/571	*A. pullulans*	AB617926
		LM026	*Candida trypodendroni* (AF017240)	2/532	*C. trypodendroni*	AB617927
	Bengal Almond (*T. catappa* Linn.)	LM028	*Wickerhamomyces edaphicus* (AB436763)	0/567	*W. edaphicus*	AB617929
	Bitter Bush (*Eupatorium odoratum* Linn.)	LM029	*Metschnikowia koreensis* (AF296438)	0/512	*M. koreensis*	AB617930
		LM030	*P. kudriavzevii* (U76347)	0/564	*P. kudriavzevii*	AB617931
Khundanprakanchon dam, Mueang Nakhon Nayok district, Nakhon Nayok province (10 May 2009)	Black Wattle (A. auriculaeformis Cunn.)	LM031	*A. pullulans* (FJ515219)	0/578	*A. pullulans*	AB617932
		LM032	*Starmerella meliponinorum* (AF313354)	1/478	*S. meliponinorum*	AB617933
		LM034	*C. amphixiae* (FJ614671)	2/542	*C. amphixiae*	AB617935
	Frangipan (temple tree) (*Plumeria* sp.)	LM035	*S. meliponinorum* (AF313354)	1/478	*S. meliponinorum*	AB617936
		LM036	*A. pullulans* (FJ515219)	0/577	*A. pullulans*	AB617937
	Tamarind (*T. indica* Linn.)	LM037	*Kodamaea ohmeri* (U45702)	0/486	*K. ohmeri*	AB617938
Chak Pong reservoir, Mueang district, Prachin Buri province (10 May 2009)	Golden Shower Tree (*C. fistula* Linn.)	LM038	*A. pullulans* (FJ515219)	0/557	*A. pullulans*	AB617939
		LM039	*C. jaroonii* (DQ404493)	0/541	*C. jaroonii*	AB617940
	Flame Tree (*D. regia* (Bojer) Raf.)	LM040	*P. kudriavzevii* (U76347)	0/562	*P. kudriavzevii*	AB617941
	Bougainvillea (*Bougainvillea* sp.)	LM041	*Torulaspora delbrueckii* (U72156)	0/573	*T. delbrueckii*	AB617943
		LM042	*A. pullulans* (FJ515219)	0/571	*A. pullulans*	AB617944
	Mango (*M. indica* Linn.)	LM043	*H. opuntiae* (AJ512453)	0/572	*H. opuntiae*	AB617945
	Black Wattle (A. auriculaeformis Cunn.)	LM044	*Pichia manshurica* (EF550223)	0/566	*P. manshurica*	AB617946
		LM045	*Torulaspora pretoriensis* (U72157)	0/574	*T. pretoriensis*	AB617947
Ito mountain, Mueang district, Prachin Buri province (10 May 2009)	Wild Tamarind (*Leucaena leucocephala* (Lam) de Wit.)	LM046	*H. burtonii* (U45712)	0/524	*H. burtonii*	AB617948
	Bitter Bush (*E. odoratum* Linn.)	LM047	*Lachancea thermotolerans* (U69581)	0/571	*L. thermotolerans*	AB617949
		LM048	*A. pullulans* (FJ515219)	0/571	*A. pullulans*	AB617950
Kabin Chaloem Rat park, Kabin Buri district, Prachin Buri province (10 May 2009)	Sacred Fig Tree (*Ficus religiosa* Linn.)	LM049	*C. tropicalis* (U45749)	0/570	*C. tropicalis*	AB617951
		LM050	*C. rugosa* (U45727)	1/485	*C. rugosa*	AB617952
	Devil Tree (*A. scholaris* (L.) R. Br.)	LM051	*C. tropicalis* (U45749)	0/570	*C. tropicalis*	AB617953
	Tamarind (*T. indica* Linn.)	LM052	*K. ohmeri* (U45702)	2/493	*K. ohmeri*	AB617954
		LM053	*C. rugosa* (U45727)	2/484	*C. rugosa*	AB617955
		LM054	*P. kudriavzevii* (U76347)	0/564	*P. kudriavzevii*	AB617956
	Burma Padauk (*Pterocarpus indicus* Willd.)	LM055	*C. tropicalis* (U45749)	0/570	*C. tropicalis*	AB617957
	Frangipan (temple tree) (*Plumeria* sp.)	LM057	*C. tropicalis* (U45749)	0/570	*C. tropicalis*	AB617958

Table 1 continued

Sample collection		Identification of yeast and yeast like fungus			Identification result	
Location (date)	Plant	Strain	Closest species (GenBank accession no.)	Nucleotide substitutions/ total nt	Species	Accession no. (D1/D2)
Mueang Sa Kaeo district, Sakoeo province (11 May 2009)	Manaila Tamarind (*Pithecellobium dulce* (Roxb.) Benth.)	LM059	*C. tropicalis* (U45749)	0/570	*C. tropicalis*	AB617959
		LM060	*C. rugosa* (U45727)	1/485	*C. rugosa*	AB617960
Watthana Nakhon district, Sakoeo province (11 May 2009)	Crown Flower (*Calotropis gigantea* (Linn.) R.Br.ex Ait.)	LM061	*K. ohmeri* (U45702)	0/493	*K. ohmeri*	AB617961
	Jujube (*Z. mauritiana* Lamk.)	LM062	*C. tropicalis* (U45749)	0/570	*C. tropicalis*	AB617962
		LM063	*P. kudriavzevii* (U76347)	0/564	*P. kudriavzevii*	AB617963
	Sugarcane (*Saccharum officinarum* Linn.)	LM064	*H. opuntiae* (AJ512453)	0/572	*H. opuntiae*	AB617964
		LM065	–	–	Unidentified	–
Phra Prong reservoir, Watthana Nakhon district, Sakoeo province (11 May 2009)	Devil Tree (*A. scholaris* (L.) R. Br.)	LM066	*C. rugosa* (U45727)	1/485	*C. rugosa*	AB617966
	Golden Shower Tree (*C. fistula* Linn.)	LM067	*H. opuntiae* (AJ512453)	1/572	*H. opuntiae*	AB617967
	Frangipan (temple tree) (*Plumeria* sp.)	LM068	*Candida morakotiae* (DQ400364)	14/574	*Candida sakaeoensis* sp. nov.[a]	AB617968
		LM069	*C. maltosa* (U45745)	0/572	*C. maltosa*	AB617969
	Lotus (*Nelumbo nuclfera* Gaertn.)	LM070	*C. glabrata* (U44808)	1/581	*C. glabrata*	AB617970
	Teak (*T. grandis* Linn.)	LM071	*C. tropicalis* (U45749)	0/570	*C. tropicalis*	AB617971
	Dasheen (*Colocasia esculenta* (L.) Schott.)	LM072	*C. rugosa* (U45727)	1/485	*C. rugosa*	AB617972
Huai Chan reservoir, Ta Phraya district, Sakoeo province (11 May 2009)	Crown Flower (*C. gigantea* (Linn.) R.Br.ex Ait.)	LM073	*P. manshurica* (U75738)	0/560	*P. manshurica*	AB617973
		LM074	*C. rugosa* (U45727)	0/484	*C. rugosa*	AB617974
	Unknown	LM075	*Cyberlindnera rhodanensis* (U73571)	3/578	*C. a rhodanensis*	AB617975
	Coconut (*C. nucifera* Linn.)	LM076	*H. burtonii* (U45712)	0/524	*H. burtonii*	AB617976
		LM077	*Candida metapsilosis* (FJ746055)	0/556	*C. metapsilosis*	AB617977
	Burma Padauk (*P. indicus* Willd.)	LM078	*C. morakotiae* (DQ400364)	14/574	*C. sakaeoensis* sp. nov.[a]	AB617978
Water reservoir, Mueang district, Buri Ran province (11 May 2009)	Sacred Fig Tree (*F. religiosa* Linn.)	LM079	*C. tropicalis* (U45749)	0/570	*C. tropicalis*	AB617979
		LM080	*H. opuntiae* (AJ512453)	0/582	*H. opuntiae*	AB617980
	Weeping fig (*Ficus benjamina* Linn.)	LM081	*Kluyveromyces marxianus* (U94924)	1/545	*K. marxianus*	AB617981
	West Indian Jasmine (*I. chinensis* Lamk.)	LM082	*C. glabrata* (U44808)	1/581	*C. glabrata*	AB617982
	Star Gooseberry (*Phyllanthus acidus* (Linn.) Skeels.)	LM083	*C. lusitaniae* (GQ396270)	0/517	*C. lusitaniae*	AB617983
Tabtai sub-district, Hua Hin district, Prachuap Khiri Khan province (18 May 2009)	Pineapple (*Ananas comosus* (L.) Merr.)	LM084	*Candida sorboxylosa* (U62314)	4/339	*C. sorboxylosa*	AB617984
	Sugarcane (dry leaves) (*S. officinarum* Linn.)	LM085	*Trichosporon asahii* (AF105393)	0/606	*T. asahii*	AB617985
		LM086	–	–	Unidentified	–

Table 1 continued

Sample collection		Identification of yeast and yeast like fungus			Identification result	
Location (date)	Plant	Strain	Closest species (GenBank accession no.)	Nucleotide substitutions/total nt	Species	Accession no. (D1/D2)
Hua Hin district, Prachuap Khiri Khan province (18 May 2009)	Sugarcane (*S. officinarum* Linn.)	LM087	–	–	Unidentified	–
	Sugarcane (dry leaves) (*S. officinarum* Linn.)	LM088	–	–	Unidentified	–
Mueang Chumphon district, Chumphon province (18 May 2009)	Jujube (*Z. mauritiana* Lamk.)	LM089	*P. kudriavzevii* (U76347)	0/564	*P. kudriavzevii*	AB617989
Paknam Chumphon, Chumphon province (18 May 2009)	Palm (*Palmae* sp.)	LM090	*K. ohmeri* (U45702)	0/493	*K. ohmeri*	AB617990
		LM091	*Debaryomyces nepalensis* (U45839)	1/570	*D. nepalensis*	AB617991
	Palm (dry leaves) (*Palmae* sp.)	LM092	*Geotrichum* sp. SKK15 (AB500211)	0/545	Similar to *Geotrichum* sp. SKK15	AB617992
		LM093	–	–	Unidentified	–
		LM094	–	–	Unidentified	–
Tha Sae district, Chumphon province (18, 20 May 2009)	Para rubber (*Hevea brasiliensis* Müll. Arg.)	LM095	*D. nepalensis* (U45839)	1/570	*D. nepalensis*	AB617995
	Pummelo (*Citrus maxima* (Burm.) Merr.)	LM125	*Candida* sp. 05-7-186T (FJ537069)	0/495	Similar to *Candida* sp. 05-7-186T	AB618025
	Unknown	LM126	*Candida* sp. 05-7-186T (FJ537069)	0/495	Similar to *Candida* sp. 05-7-186T	AB618026
	Mangosteen (*Garcinia mangostana* Linn.)	LM127	*C. tropicalis* (U45749)	0/570	*C. tropicalis*	AB618027
	Banana (*Musa sapientum* Linn.)	LM128	*P. kudriavzevii* (U76347)	0/564	*P. kudriavzevii*	AB618028
		LM129	*H. guilliermondii* (U84230)	0/572	*H. guilliermondii*	AB618029
Forest on Mattra island, Chumphon Islands National Park, Chumphon province (19 May 2009)	Banana (*M. sapientum* Linn.)	LM096	*C. tropicalis* (U45749)	0/570	*C. tropicalis*	AB617996
	Unknown	LM097	*Hanseniaspora thailandica* (DQ404527)	0/572	*H. thailandica*	AB617997
	Unknown	LM098	*H. thailandica* (DQ404527)	0/579	*H. thailandica*	AB617998
	Unknown	LM099	*Candida parapsilosis* (U45754)	0/570	*C. parapsilosis*	AB617999
	Unknown	LM100	*C. maltosa* (U45745)	2/572	*C. maltosa*	AB618000
	Unknown	LM101	*D. nepalensis* (U45839)	1/570	*D. nepalensis*	AB618001
		LM102	*Candida nivariensis* (AY627305)	1/549	*C. nivariensis*	AB618002
	Unknown	LM103	*Candida maltosa* (U45745)	2/572	*C. maltosa*	AB618003
	Unknown	LM104	*D. nepalensis* (U45839)	1/570	*D. nepalensis*	AB618004
	Unknown	LM105	*C. tropicalis* (U45749)	0/570	*C. tropicalis*	AB618005
		LM106	–	–	Unidentified	–
	Unknown	LM107	*D. nepalensis* (U45839)	1/570	*D. nepalensis*	AB618007
	Unknown	LM109	*C. nivariensis* (AY627305)	1/549	*C. nivariensis*	AB618009
	Unknown	LM110	*C. maltosa* (U45745)	2/572	*C. maltosa*	AB618010
	Unknown	LM111	*K. ohmeri* (U45702)	0/493	*K. ohmeri*	AB618011

Table 1 continued

Sample collection		Identification of yeast and yeast like fungus			Identification result	
Location (date)	Plant	Strain	Closest species (GenBank accession no.)	Nucleotide substitutions/ total nt	Species	Accession no. (D1/D2)
	Unknown	LM112	*H. thailandica* (DQ404527)	0/572	*H. thailandica*	AB618012
	Unknown	LM113	–	–	Unidentified	–
		LM114	*C. maltosa* (U45745)	2/572	*C. maltosa*	AB618014
	Unknown	LM115	*C. nivariensis* (AY627305)	1/549	*C. nivariensis*	AB618015
	Unknown	LM116	*C. nivariensis* (AY627305)	1/549	*C. nivariensis*	AB618016
	Unknown	LM118	*C. tropicalis* (U45749)	0/570	*C. tropicalis*	AB618018
		LM119	*H. burtonii* (U45712)	0/524	*H. burtonii*	AB618019
		LM120	*M. guilliermondii* (U45709)	2/570	*M. guilliermondii*	AB618020
	Sugarcane (*S. officinarum* Linn.)	LM121	*C. glabrata* (U44808)	1/581	*C. glabrata*	AB618021
	Fig (*Ficus racemosa* Linn.)	LM122	*C. amphixiae* (AY520327)	2/533	*C. amphixiae*	AB618022
	Coconut (*C. nucifera* Linn.)	LM123	*C. nivariensis* (AY627305)	1/543	*C. nivariensis*	AB618023
	Unknown	LM124	*D. nepalensis* (U45839)	3/570	*D. nepalensis*	AB618024
Bang Saphan district, Prachuap Khiri Khan province (20 May 2009)	Frangipan (temple tree) (*Plumeria* sp.)	LM130	*K. ohmeri* (U45702)	1/493	*K. ohmeri*	AB618030

[a] Limtong et al. (2012)

was at 23 °C than at 30 °C. This may due to the fact that most of basidiomycete yeasts grow rather slow and they have fairly low maximum growth temperature in comparison with ascomycete yeasts and the enrichment isolation at high temperature (30 ± 3 °C) selects rapid growing yeasts. Therefore, more ascomycete yeasts were obtained.

Among yeast species found on phylloplane in this study only *S. ruineniae* has been stated that its primary habitat is possible to be the phylloplane (Sampaio 2011). Strains of many yeast species found in this study were reported to isolate from insects viz. *Candida amphixiae*, *C. apicola*, *C. etchellsii*, *C. glabrata*, *C. trypodendroni*, *Debaryomyces nepalensis*, *Hanseniaspora guilliermondii*, *Hyphopichia burtonii*, *Kluyveromyces marxianus*, *Kodamae ohmeri*, *Lachances thermotolerans* and *Starmerella meliponinorum* (Cadez and Smith 2011; Kurtzman 2011a, d; Lachance 2011b; Lachance and Kurtzman 2011a, b; Rosa et al. 2003) and from plants including flowers, fruits and tree parks viz. *Candida jaroonii*, *C. nivariensis*, *C. potacharoeniae*, *C. stigmatis*, *Clavispora lusitaniae*, *Hanseniaspora opuntiae*, *H. thailandica*, *Metschnikowia koreensis*, *Meyerozyma guilliermondii* and *Pichia kudriavzevii* (Cadez and Smith 2011; Imanishi et al. 2008; Kurtzman 2011b, c; Lachance 2011a, c; Lachance et al. 2011; Nakase et al. 2010; Jindamorakot et al. 2009; Sipiczki 2010). The present of these yeast species on the phylloplanes in this study may resulted from visiting of insects that carried these yeasts to the phylloplane. Strains of some species obtained in this study were previously reported to be the novel species discovered in Thailand isolated from the other sources viz. *C. jaroonii* (Imanishi et al. 2008), *C. potacharoeniae* (Nakase et al. 2010), *H. thailandica* (Jindamorakot et al. 2009), *Kazachstania siamensis* (Limtong et al. 2007) and *Wickerhamomyces edaphicus* (Limtong et al. 2009). Moreover, *A. pullulans*, the yeast-like fungus, which was found to occur regularly on the leaves of fruit trees in the Czech Republic (Slavikova et al. 2009), was also frequently found in the present study.

Investigation of the IAA production capability of the phylloplane yeasts in this study revealed that about 37.7 % of investigated yeast strains possessed this ability. It was found that among the species of one genus, both IAA producing species and non-producing species were detected. Moreover, not all strains within the same species had the ability to produce IAA. It therefore seems that IAA production capability is strain-dependent in these phylloplane yeasts. Variation in IAA biosynthesis among strains within the same species in the other microorganisms has also been reported by the other investigators (Ruanpanun et al. 2010; Tsavkelova et al. 2006).

IAA production by *C. maltosa* LM114 (314.3 mg/L) seemed to be higher than that reported for the other yeasts such as *Lindera* (*Williopsis*) *saturnus* (22.5 mg/L; Nassar

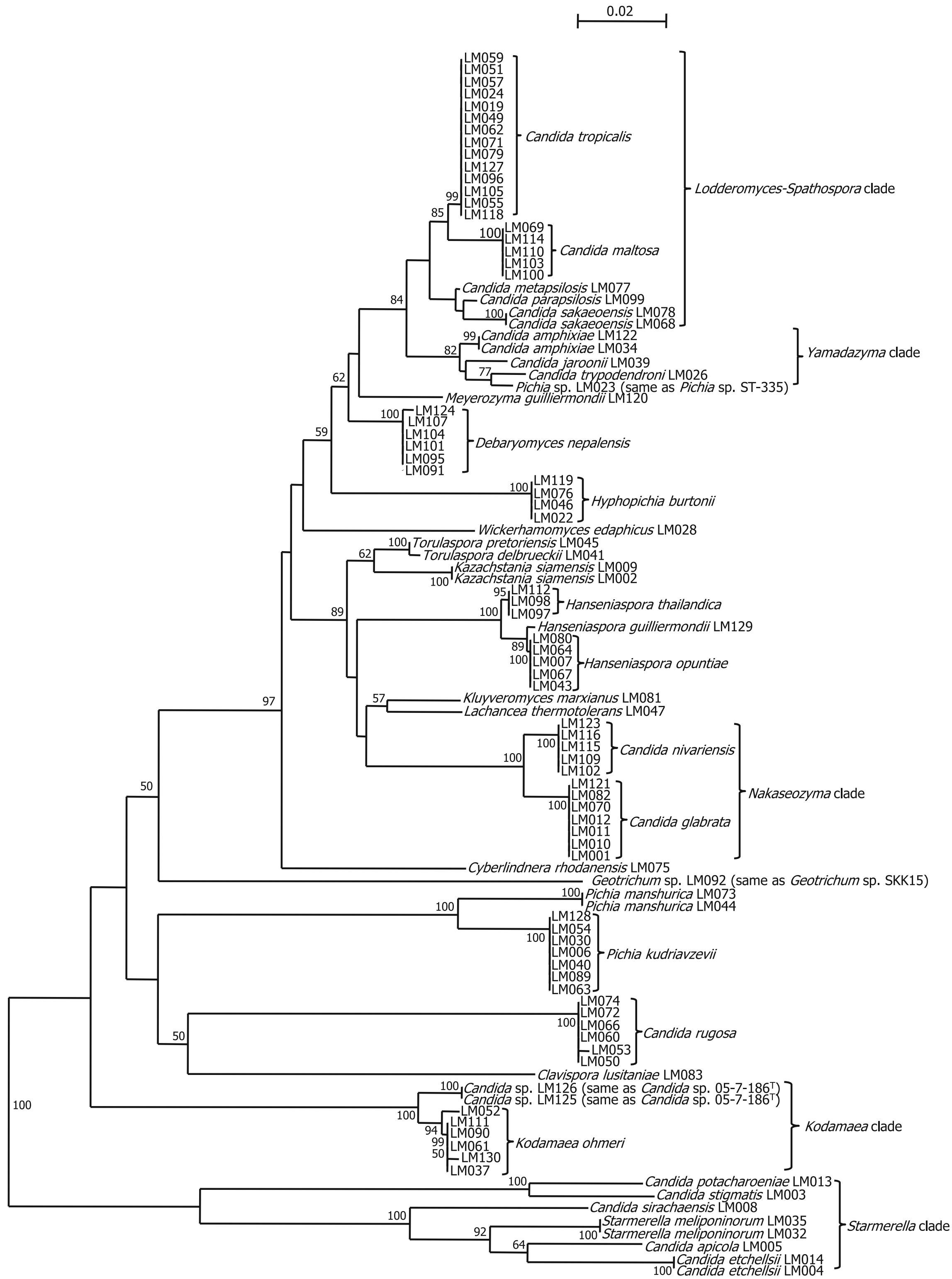

Fig. 1 Phylogeny of yeasts isolated from phylloplanes based on the D1/D2 domains of the LSU rRNA gene

et al. 2005); fungi such as *Aspergillus niger* (132.7 µg/mL; Bilkay et al. 2010); some actinomycetes such as *Streptomyces* sp. CMU-H009 (143.95 µg/mL; Khamna et al. 2010); and bacteria such as *Rubrivivax benzoatilyticus* JA2 (58.1 mg/L; Mujahid et al. 2001) and *Klebsiellas* sp. SN1 (291 mg/L; Xinxian et al. 2011). However, the

Table 2 Frequency of isolation of phylloplane yeasts obtained from diverse plant species in Thailand

Species and strain	No. of plant with this species	Frequency of isolation (%)[a]
Phylum Ascomycota		
C. amphixiae	2	2.04
C. apicola	1	1.02
C. etchellsii	2	2.04
C. glabrata	7	7.14
C. jaroonii	1	1.02
C. maltosa	5	5.10
C. metapsilosis	1	1.02
C. nivariensis	5	5.10
C. parapsilosis	1	1.02
C. potacharoeniae	1	1.02
C. rugosa	6	6.12
C. sorboxylosa	1	1.02
C. stigmatis	1	1.02
C. tropicalis	14	14.29
C. trypodendroni	1	1.02
C. lusitaniae	1	1.02
C. rhodanensis	1	1.02
D. nepalensis	6	6.12
H. guilliermondii	1	1.02
H. opuntiae	5	5.10
H. thailandica	3	3.06
H. burtonii	4	4.08
K. siamensis	2	2.04
K. marxianus	1	1.02
K. ohmeri	6	6.12
L. thermotolerans	1	1.02
M. koreensis	1	1.02
M. guilliermondii	1	1.02
P. manshurica	2	2.04
P. kudriavzevii	7	7.14
S. meliponinorum	2	2.04
T. delbrueckii	2	2.04
W. edaphicus	1	1.02
Subtotal of Ascomycota	96	97.96
Phylum Basidiomycota		
S. ruineniae	1	1.02
T. asahii	1	1.02
Subtotal of Basidiomycota	2	2.04
Total	98	100

[a] Number of plant leaf sample from which that species was isolated/number of plant leaf sample examined × 100

concentration of IAA produced by *C. maltosa* LM114 needs to be confirmed with more specific method for IAA determination such as high-performance liquid chromatography or gas chromatography-mass spectrometry.

Table 3 Indole-3-acetic acid productions in YPD broth supplemented with 1 mg/L L-tryptophan in a test tube after 7 days by shake cultivation at 150 rpm and 30 ± 3 °C

Species and strain	IAA (mg/L)
Phylum Ascomycota	
C. amphixiae LM034	–
C. amphixiae LM122	85.7
C. apicola LM005	–
C. etchellsii LM004, LM014	–
C. glabrata LM001	50.5
C. glabrata LM121	25.7
C. glabrata LM010, LM011, LM012, LM070, LM082	–
C. jaroonii LM039	–
C. maltosa LM069	121.4
C. maltosa LM100	130.5
C. maltosa LM103	237.1
C. maltosa LM110	159.5
C. maltosa LM114	314.3
C. metapsilosis LM077	81.0
C. nivariensis LM102	–
C. nivariensis LM109	39.0
C. nivariensis LM115	27.1
C. nivariensis LM116	37.6
C. nivariensis LM123	51.4
C. parapsilosis LM099	71.4
C. potacharoeniae LM013	–
C. rugosa LM050	–
C. rugosa LM060	98.6
C. rugosa LM066	101.9
C. rugosa LM074	66.9
C. rugosa LM053, LM072	–
C. sorboxylosa LM084	–
C. stigmatis LM003	–
C. tropicalis LM049	32.9
C. tropicalis LM051	54.3
C. tropicalis LM057	33.8
C. tropicalis LM062	31.9
C. tropicalis LM071	31.4
C. tropicalis LM105	43.8
C. tropicalis LM118	53.3
C. tropicalis LM127	37.6
C. tropicalis LM019, LM024, LM055, LM059, LM079, LM096	–
C. trypodendroni LM026	–
C. lusitaniae LM083	–
C. rhodanensis LM075	–
D. nepalensis LM107	32.4
D. nepalensis LM108	36.2
D. nepalensis LM091, LM124, LM095, LM101, LM104	–

Table 3 continued

Species and strain	IAA (mg/L)
H. guilliermondii LM129	–
H. opuntiae LM043	44.8
H. opuntiae LM007, LM064, LM067, LM080	–
H. thailandica LM097, LM112	–
K. siamensis LM002	43.3
K. siamensis LM009	–
K. marxianus LM081	–
K. ohmeri LM052	25.7
K. ohmeri LM111	24.3
K. ohmeri LM037, LM061, LM090, LM130	–
L. thermotolerans LM047	35.7
M. koreensis LM029	–
M. guilliermondii LM120	68.1
H. burtonii LM046	38.6
H. burtonii LM022, LM076, LM119	–
P. manshurica LM044, LM073	–
P. kudriavzevii LM128	27.1
P. kudriavzevii LM006, LM030, LM040, LM054, LM063, LM089	–
S. meliponinorum LM032, LM035	–
T. delbrueckii LM041	27.1
T. pretoriensis LM045	36.2
W. edaphicus LM028	–
Phylum Basidiomycota	–
Sporidiobolus euieneniae LM015	84.3
T. asahii LM085	–
Novel species*	
C. sirachaensis LM068	31.9
C. sakaeoensis LM078	–
C. sakaeoensis LM008	–
Undescribed species	
Strain LM092 (similar to *Geotrichum* sp. SKK15)	–
Strain LM023 (similar to *Pichia* sp. ST-335)	–
Strain LM117 (similar to *Wickerhamia* sp. ST-122)	41.9
Strains LM125, LM126 (similar to *Candida* sp. 05-7-186T)	–
Unidentified strains	
Strain LM113 Unidentified	–
Strain LM093	62.9
Strain LM065	31.9
Strains LM016, LM086, LM087, LM088, LM094, LM106	–
Yeast-like fungus	
A. pullulans LM017	52.9
A. pullulans LM018	57.1
A. pullulans LM020	33.3
A. pullulans LM025	34.8
A. pullulans LM027	29.5
A. pullulans LM038	58.6
A. pullulans LM042	43.8
A. pullulans LM048	35.7
A. pullulans LM021, LM031, LM033, LM036	–

Remark: The results are means of two replications per strain

– = no IAA production

[a] Limtong et al. (2012)

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References

Altschul SF, Madden TL, Schäffer JZ, Zhang J, Zhang Z, Miller W, Lipman DJ (1997) Gapped BLAST and PSI-BLAST: a new generation of protein database search programs. Nucleic Acids Res 25:3389–3402

Andrews JH, Harris RE (2000) The ecology and biogeography of microorganisms on plant surfaces. Ann Rev Phytopathol 38:145–180

Bilkay IS, Karakoc S, Aksoz N (2010) Indole-3-acetic acid and gibberellic acid production in *Aspergillus niger*. Turk J Biol 34:313–318

Cadez N, Smith MTh (2011) *Hanseniaspora* Ziker (1912). In: Kurtzman CP, Fell JW, Boekhout T (eds) The yeasts, a taxonomic study, 5th edn. Elsevier, Amsterdam, pp 421–434

Cleland RE (1990) Auxin and cell elongation. In: Davies PJ (ed) Plant hormones and their role in plant growth and development. Kluwer, Dordrecht, pp 132–148

de Azeredo LAI, Gomes EAT, Mendonca-Hagler LC, Hagler AN (1998) Yeast communities associated with sugarcane in Campos, Rio de Janeiro, Brazil. Int Microbiol 1:205–208

El-Tarabily KA (2004) Suppression of *Rhizoctonia solani* diseases of sugar beet by antagonistic and plant growth-promoting yeasts. J Appl Microbiol 96:69–75

Felsenstein J (1985) Confidence limits on phylogenies: an approach using the bootstrap. Evolution 39:783–791

Fonseca A, Inacio J (2006) Phylloplane yeasts. In: Rosa C, Peter G (eds) Biodiversity and ecophysiology of yeasts. Springer, Berlin, pp 263–301

Glickmann E, Dessaux Y (1994) A critical examination of the specificity of the Salkoski reagent for indolic compounds produced by phytopathogenic bacteria. Appl Environ Microbiol 61:793–796

Glushakova AM, Chernov IY (2010) Seasonal dynamics of the structure of epiphytic yeast communities. Microbiology 79:830–839

Glushakova AM, Yurkov AM, Chernov IY (2007) Massive isolation of anamorphous ascomycete yeasts *Candida oleophila* from plant phyllosphere. Microbiology 76:799–803

Imanishi Y, Jindamorakot S, Mikata K, Nakagiri A, Limtong S, Potacharoen W, Tanticharoen M, Nakase T (2008) Two new ascomycetous anamorphic yeast species related to *Candida friedrichii*-*Candida jaroonii* sp. nov., and *Candida songkhlaensis* sp. nov. isolated in Thailand. Antonie Van Leeuwenhoek 94: 267–276

Inácio J, Portugal L, Spencer-Martins I, Fonseca A (2005) Phylloplane yeasts from Portugal: seven novel anamorphic species in the Tremellales lineage of the Hymenomycetes (Basidiomycota) producing orange-coloured colonies. FEMS Yeast Res 5:1167–1183

Jindamorakot S, Ninomiya S, Limtong S, Yongmanitchai W, Tuntirungkij M, Potacharoen W, Tanaka K, Kawasaki H, Nakase T (2009) Three new species of bipolar budding yeasts of the genus *Hanseniaspora* and its anamorph *Kloeckera* isolated in Thailand. FEMS Yeast Res 9:1327–1337

Khamna S, Yokota A, Peberdy JF, Lumyong S (2010) Indole-3-acetic acid production by *Streptomyces* sp. isolated from some Thai medicinal plant rhizosphere soils. EurAsia J Biosci 4:23–32

Kimura M (1980) A simple method for estimating evolutionary rate of base substitutions through comparative studies of nucleotide sequences. J Mol Evol 16:111–120

Koowadjanakul N, Jindamorakot S, Yongmanitchai W, Limtong S (2011) *Ogataea phyllophila* sp. nov., *Candida chumphonensis* sp. nov. and *Candida mattranensis* sp. nov., three methylotrophic yeast species from phylloplane in Thailand. Antonie Van Leeuwenhoek 100:207–217

Kurtzman CP (2011a) *Hyphopichia* van Arx & van der Walt 1976. In: Kurtzman CP, Fell JW, Boekhout T (eds) The yeasts, a taxonomic study, 5th edn. Elsevier, Amsterdam, pp 987–1279

Kurtzman CP (2011b) *Pichia* EC Hansen (1904). In: Kurtzman CP, Fell JW, Boekhout T (eds) The yeasts, a taxonomic study, 5th edn. Elsevier, Amsterdam, pp 685–708

Kurtzman CP (2011c) *Meyerozyma* Kurtzman & M. Suzuki (2010). In: Kurtzman CP, Fell JW, Boekhout T (eds) The yeasts, a taxonomic study, 5th edn. Elsevier, Amsterdam, pp 621–624

Kurtzman CP (2011d) *Starmerella* Rosa & Lachance (1998). In: Kurtzman CP, Fell JW, Boekhout T (eds) The yeasts, a taxonomic study, 5th edn. Elsevier, Amsterdam, pp 811–816

Kurtzman CP, Robnett CJ (1998) Identification and phylogeny of ascomycetous yeasts from analysis of nuclear large subunit (26S) ribosomal DNA partial sequences. Antonie Van Leeuwenhoek 73:331–371

Lachance M-A (2011a) *Clavispora* Rodrigues de Mirande (1979). In: Kurtzman CP, Fell JW, Boekhout T (eds) The yeasts, a taxonomic study, 5th edn. Elsevier, Amsterdam, pp 349–354

Lachance M-A (2011b) *Kluyveromyces* van der Walt (1971). In: Kurtzman CP, Fell JW, Boekhout T (eds) The yeasts, a taxonomic study, 5th edn. Elsevier, Amsterdam, pp 471–482

Lachance M-A (2011c) *Metschnikowia* Kamienski (1899). In: Kurtzman CP, Fell JW, Boekhout T (eds) The yeasts, a taxonomic study, 5th edn. Elsevier, Amsterdam, pp 575–620

Lachance M-A, Kurtzman CP (2011a) *Kodamae* Y Yamada, T Suzuki, Matsuda & Mikata emend. Rosa, Lachance, Starmer, Barker, Bowles & Schlag-Edler (1999). In: Kurtzman CP, Fell JW, Boekhout T (eds) The yeasts, a taxonomic study, 5th edn. Elsevier, Amsterdam, pp 483–490

Lachance M-A, Kurtzman CP (2011b) *Lachancea* Kurtzman (2003). In: Kurtzman CP, Fell JW, Boekhout T (eds) The yeasts, a taxonomic study, 5th edn. Elsevier, Amsterdam, pp 511–520

Lachance M-A, Boekhout T, Scorzetti G, Fell JW, Kurtzman CP (2011) *Candida* Berkhout. In: Kurtzman CP, Fell JW, Boekhout T (eds) The yeasts, a taxonomic study, 5th edn. Elsevier, Amsterdam, pp 987–1279

Landell MF, Billodre R, Ramos JP, Leoncini O, Vainstein MH, Valente P (2010) *Candida aechmeae* sp. nov. and *Candida vrieseae* sp. nov., novel yeast species isolated from the phylloplane of bromeliads in Southern Brazil. Int J Syst Evol Microbiol 60: 244–248

Limtong S, Yongmanitchai W, Tun MM, Kawasaki H, Seki T (2007) *Kazachstania siamensis* sp. nov., an ascomycetous yeast species from forest soil in Thailand. Int J Syst Evol Microbiol 57: 419–422

Limtong S, Yongmanitchai W, Kawasaki H, Fujiyama K (2009) *Wickerhamomyces edaphicus* sp. nov. and *Pichia jaroonii* sp. nov., two ascomycetous yeast species isolated from forest soil in Thailand. FEMS Yeast Res 9:504–510

Limtong S, Koowadjanakul N, Jindamorakot S, Yongmanitchai W, Nakase T (2012) *Candida sirachaensis* sp. nov. and *Candida sakaeoensis* sp. nov. two anamorphic yeast species from phylloplane in Thailand. Antonie van Leeuwenhoek. doi:10.1007/s10482-012-9728-9

Mujahid M, Sasikala Ch, Ramana CV (2001) Production of indole-3-acetic acid and related indole derivatives from L-tryptophan by *Rubrivivax benzoatilyticus* JA2. Appl Microbiol Biotechnol 89:1001–1008

Nakamura T, Murakami T, Saotome M, Tomita K, Kitsuwa T, Meyers SP (1991) Identification of indole-3-acetic acid in *Pichia spartina* an ascosporogenous yeast from *Spartina alterniflora* marshland environments. Mycologia 83:662–664

Nakase T, Takashima M, Itoh M, Fungsin B, Potacharoen W, Atthasampunna P, Komagata K (2001) Ballistoconidium-forming yeasts found in the phyllosphere of Thailand. Microbiol Cult Coll 17:23–33

Nakase T, Jindamorakot S, Imanishi Y, Am-In S, Ninomiya S, Kawasaki H, Limtong S (2010) *Candida potacharoeniae* sp. nov. and *Candida spenceri* sp. nov., two novel galactose-containing ascomycetous anamorphic yeast species isolated in Thailand. J Gen Appl Microbiol 56:287–295

Nassar AH, El-Tarabily KA, Sivasithamparam K (2005) Promotion of plant growth by an auxin-producing isolate of the yeast *Williopsis saturnus* endophytic in maize (*Zea mays* L.) roots. Biol Fertil Soils 42:97–108

Perondi NL, Luz WC, Thomas R (1996) Microbiological control of *Gibberella* in wheat in wheat. Fitopatol Bras 21:243–2496

Phaff HJ, Starmer WT (1987) Yeasts associated with plants, insects and soil. In: Rose AH, Harrison JS (eds) The yeasts, 2nd edn. Academic, London, pp 123–180

Rosa CA, Lachance M-A, Silva JOC, Teixeira ACP, Marini MM, Antonini Y, Martins RP (2003) Yeast communities associated with stingless bees. FEMS Yeast Res 4:271–275

Ruanpanun P, Tangchitosomkid N, Hyde KD, Lumyong S (2010) Actinomycetes and fungi isolated from plant-parasitic nematode infested soils: screening of the effective biocontrol potential, indole-3-acetic acid and siderophores production. World J Microbiol Biotechnol 26:1569–1578

Saitou N, Nei M (1987) The neighbor-joining method: a new method for reconstructing phylogenetic trees. Mol Biol Evol 4:406–425

Sampaio JP (2011) *Sporidiobolus* Naland 1949. In: Kurtzman CP, Fell JW, Boekhout T (eds) The yeasts, a taxonomic study, 5th edn. Elsevier, Amsterdam, pp 1549–1561

Sasikala C, Ramana CV (1998) Biodegradation and metabolism of unusual carbon compounds by anoxygenic phototrophic bacteria. Adv Microbial Physiol 39:339–377

Sharma RR, Singh D, Singh R (2009) Biological control of postharvest diseases of fruits and vegetables by microbial antagonists: a review. Biol Control 50:205–221

Sipiczki M (2010) *Candida stigmatis* sp. nov., a new anamorphic yeast species isolated from flowers. FEMS Yeast Res 10:362–365

Slavikova E, Vadkertiova R, Vranova D (2009) Yeasts colonizing the leaves of fruit trees. Ann Microbiol 59:419–424

Tsavkelova EA, Klimova SY, Cherdyntseva TA, Netrusov AI (2006) Microbial producers of plant growth stimulators and their practical use: a review. Appl Biochem Microbiol 42:117–126

Xin G, Glawe D, Doty SL (2009) Characterization of three endophytic, indole-3-acetic acid-producing yeasts occurring in *Populus* trees. Mycol Res 113:973–980

Xinxian L, Xuemei C, Yagang C, Woon-Chung W, Zebin W, Qitang W (2011) Isolation and characterization endophytic bacteria from hyperaccumulator *Sedum alfredii* Hance and their potential to promote phytoextraction of zinc polluted soil. World J Microbiol Biotechnol 27:1197–1207