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(71) Applicant: RUTGERS, THE STATE UNIVERSITY OF NEW JERSEY [US/US]; Office of Corporate Liaison &, Technology Transfer, ASB 111, 3 Rutgers Plaza, 3rd Floor, New Brunswick, NJ 08901-8559 (US).

(72) Inventor: ZHANG, Ning; 254 Rooney Court, East Brunswick, NJ 08816 (US).

(74) Agents: RIGAUT, Kathleen, D. et al.; Dann, Dorfman, Herrell and Skillman, 1601 Market Street, Suite 2400, Philadelphia, PA 19103-2307 (US).

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(54) Title: COMPOSITIONS AND METHODS THEREOF INCREASING PLANT GROWTH AND RESISTANCE TO ENVIRONMENTAL STRESS

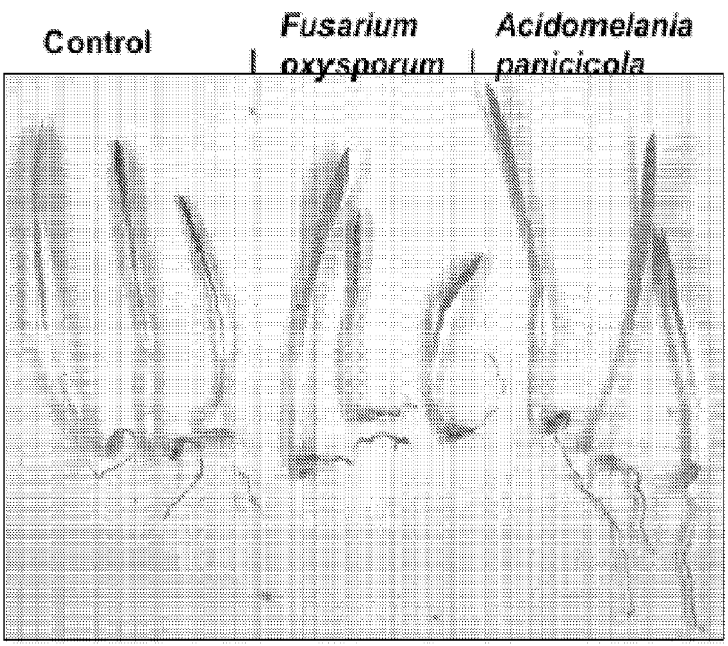

Figure 10

(57) Abstract: Compositions and methods for enhancing plant growth and resistance to adverse abiotic conditions are disclosed.

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COMPOSITIONS AND METHODS THEREOF FOR INCREASING PLANT GROWTH AND RESISTANCE TO ENVIRONMENTAL STRESS

NING ZHANG

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims priority to US Provisional Application No. 62/047,226 filed September 8, 2014, the entire contents being incorporated herein by reference.

FIELD OF THE INVENTION

This invention relates to the fields of agriculture and propagation of plants under abiotic stress conditions. More specifically, the invention provides methods and microbial based compositions which facilitate improved plant growth and stress tolerance.

BACKGROUND OF THE INVENTION

Several publications and patent documents are referenced throughout this application in order to more fully describe the state of the art to which this invention pertains. The disclosure of each of these publications and patent documents is incorporated by reference herein.

Pine barrens (pinelands) comprise a unique type of eco-system that is oligotrophic, and both drought- and fire-prone. Pine barrens occur throughout northeastern USA from New Jersey to Maine (Forman et al. 1998). Pines and oaks are the most common trees in pine barrens, while the understory is composed of grasses (Poaceae), sedges (Cyperaceae), blueberries and other members of heath family (Ericaceae). The largest and most uniform area of pine barrens in the United States is the 1.4 million acre pine barrens of New Jersey, where the soil is highly acidic, sandy and nutrient poor.

Dark septate endophytes (DSE) refer to a group of heterogeneous plant root-colonizing ascomycetes that produce melanized, septate hyphae. They have been isolated from over 110 plant families that grow in various environments (Knapp et al. 2012). The best studied DSE are the Phialocephala fortinii-Acephala applanata complex (PAC), a group of asexual fungi in Helotiales of Leotiomycetes (Wang et al. 2006). Fungi in PAC are characterized by darkly pigmented hyphae, and typically produce branched conidiophores, hyaline phialides with collarettes, and intracellular microsclerotia (Grünig et al. 2008a, 2008b; Yu et al. 2001). PAC are the common root associates of many tree species, specifically conifers in forests of the northern hemisphere (Grünig et al. 2008a, 2008b; Menkis 2004). Despite the global pervasiveness of DSE, their ecological roles, phylogenetic relationships and taxonomy remain poorly understood (Knapp et al. 2012; Mandyam and Jumpponen 2005). DSE fungal-plant interaction studies have yielded variable results, likely due to the use of differing experimental design strategies (Grünig et al. 2008b).

It is estimated that 30% of the world's total land area consists of acid soils, and 50% of the world's potential arable lands are acidic (Tuininga et al. 2004). In view of these adverse environmental conditions, improved methods to enhance growth of both edible and non-edible plants are needed.

SUMMARY OF INVENTION

In accordance with the present invention, a method for enhancing overall plant growth and resistance to adverse abiotic conditions comprising contacting a plant or seed therefrom with a composition comprising a biofertilizer comprising at least one endophytic fungi and optionally bacteria. In one aspect, the fungi is *Acidomelania panicicola* and the optional bacteria is from the *Burkholderia* genus. The method can include inoculating the seeds with the fungi and, or bacteria in agar or growth medium and placing seeds/agar composition in the soil. In another approach, after mixing the cultures, the seeds and cultures are subjected to drying to form a coating thereon. Vermiculite and rock phosphate may also be included in the composition to enhance plant growth and resistance to abiotic stress. The method can be applied to both monocots and dicots and can be used on plants which include without limitation, lettuce, corn, rice, soybeans, potatoes, barley, wheat, and carrots. In a particularly preferred embodiment, the plant is a turfgrass plant selected from a Ryegrass, Kentucky Bluegrass, Tall Fescue, Bermuda, St. Augustine or Zoysia plant or any other turfgrass plant.

In another aspect of the invention, a biofertilizer composition is provided. An exemplary biofertilizer includes an effective amount of *A. panicicola* and at least one agent or microorganism for promoting plant growth and resistance to abiotic stresses for use in the method described above. In a preferred embodiment, the composition contains *A. panicicola* and at least one *Burkholderia* species in equal concentrations. The composition may also contain a sun protecting product and a polysaccharide solution. The fungal strains may also be encapsulated in allignate beads.

In yet another aspect of the invention the fungus for use in the method is selected from the *Barrenia* genus. In a preferred embodiment, the fungi is *Barrenia panicia*. This composition may also comprise a bacteria selected from the *Burkholderia* genus.

The biofertilizer composition comprising at least *A. panicicola* and, or *Barrenia* and, optionally, other agents or microbial or fungal species are effective to enhance plant resistance to environmental stresses. Such agents may include gel formulations, agar, vermiculite, sun protectorants, rock phosphate, alginate, which when combined form an efficacious biofertilizer.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1. Maximum likelihood phylogenetic tree inferred from the large subunit of rRNA gene sequence. Bootstraps higher than 70 have thickened branches.

Figure 2. Maximum likelihood phylogenetic tree inferred from the internal transcribed spacer sequences of rRNA gene. Bootstraps higher than 70 have thickened branches.

Figure 3. Maximum likelihood phylogenetic tree inferred from combined ITS, LSU, and RPB1 gene sequence datasets. Bootstraps higher than 70 have thickened branches.

Figure 4. DNA sequence for *A. applanata AY078151*; SEQ ID NO: 1 (Fig. 4A), *A. panicicola KF874620*; SEQ ID NO: 2 (Fig. 4B), *A. panicicola KF874619*; SEQ ID NO: 3 (Fig. 4C), *A. panicicola AL5m2-2;* SEQ ID NO: 4 (Fig. 4D), *A. panicicola CM11M2*; SEQ ID NO: 5 (Fig. 4E), *A. panicicola WSF1-R37*; SEQ ID NO: 6 (Fig. 4F), *A. taeda CM14-P64;* SEQ ID NO: 7 (Fig. 4G), *A. taeda WSF14-P22*; SEQ ID NO: 8 (Fig. 4H), *A. taeda WSF14-P13*; SEQ ID NO: 9 (Fig. 4I), *C. clavus DQ491502*; SEQ ID NO: 10 (Fig. 4J)*, D. acerina AF141164*; SEQ ID NO: 11 (Fig. 4K), *H. aureliella JN943611*; SEQ ID NO: 12 (Fig. 4L), *L. virgineum DQ491485*; SEQ ID NO: 13 (Fig. 4M), *L. macrospores DQ471005*; SEQ ID NO: 14 (Fig. 4N), *M. cinerea DQ491498*; SEQ ID NO: 15 (Fig. 4O), *M. laxa EF153017*; SEQ ID NO: 16 (Fig. 4P), *P. fortinii AB671499*; SEQ ID NO: 17 (Fig. 4Q), *and V. truncorum EU434855*; SEQ ID NO: 18 (Fig. 4R).

Figures 5A-5E. Switchgrass seedling two days after inoculation with *Acidomelania panicicola* holotype isolate 61R8 (Fig. 5A); Control (Fig. 5B); three days after inoculation with *Barrenia panicia* holotype isolate WSF1R37 (Fig. 5C); Control (Fig. 5D), *Barrenia taeda* holotype isolate WSF14P22 (Fig. 5E). Bar = 1 mm

Figures 6A-6C. Representative image of morphological characters of *Barrenia panicia* holotype isolate WSF1R37 (Fig. 6A); Representative image of morphological characters of *Barrenia panicia* holotype isolate WSF1R37 (Fig. 6B); Representative image of morphological characters of *Barrenia panicia* holotype isolate WSF1R37 (Fig. 6C). A-Bar = 10 μm

Figure 7. Micrographs of control and *Acidomelania panicicola* inoculated switchgrass seedling roots 2 days post inoculation.

Figure 8. Micrographs of control and *Acidomelania panicicola* inoculated rice seedling roots 4 days post inoculation.

Figure 9. Micrographs showing control, *Fusarium oxysporum* inoculated and *Acidomelania panicicola* inoculated switchgrass seedling survival percentage.

Figure 10. Micrographs showing control, *Fusarium oxysporum* inoculated and *Acidomelania panicicola* inoculated switchgrass roots.

Figure 11. Micrographs showing control and *Acidomelania panicicola* inoculated lettuce roots 4 days post inoculation.

DETAILED DESCRIPTION OF THE INVENTION

Drought and low nutrient stress typified early terrestrial environments when plant colonization of land occurred and was facilitated by root-symbiotic fungi (Stoyke et al. 1991). Beneficial endophytes encompass bacteria and fungi that have the ability to alleviate abiotic stresses in combination with plant growth promotion. Endophytes have been reported to enhance early root differentiation, improve drought and salinity tolerance and increased survival rate. These endophytes play critical roles in litter decomposition, nutrient absorption and cycling (Forman et al. 1998; Blackwell et al. 2011).

A group of new fungal species were discovered from switchgrass and other grass roots in the New Jersey Pine Barrens, which is a dry, highly acidic environment, low in nutrients (P, K, organic matter etc.), with high aluminum toxicity (von Uexkull et al. 1995). Herein we describe two new genuses, *Acidomelania* and *Barrenia,* discovered in pine barren switchgrass roots.

Barrenia was classified using multi-gene phylogenetic analyses, along with phenotypic and ecological characteristics. While the new species was isolated from roots of switchgrass and pitch pine in the acidic and oligotrophic New Jersey Pine Barrens, *Barrenia* likely has a wide distribution as its internal transcribed spacer (ITS) sequence has high similarity with a number of GenBank sequences obtained in various ecological studies. The majority of these similar ITS sequences were obtained from roots in plants growing in acidic, nutrient-poor environments, as well as from managed sugarcane plantations. Phylogenetic analyses of ITS, LSU and RPB1 sequence data strongly support that *Barrenia* is a monophyletic clade in *Helotiales*, distinct from any known taxa. *Barrenia* is phylogenetically close to *Acidomelania, Loramyces, Mollisia*, and *Phialocephala fortinii - Acephala applanata* species complex (PAC), the dark septate endophytes. *Barrenia* can be distinguished from *Loramyces* and *Mollisia* by its association with living plant roots. While taxa in PAC also are root endophytes, they have complex phialid arrangements that appear to be lacking in *Barrenia*.

The present inventors have performed functional studies which demonstrate that application of biofertilizers comprising *Acidomelania panicicola* and *Barrenia panicia* significantly enhanced dense root hair growth in switchgrass. *Acidomelania pancicola* plant-fungal interactions with rice and lettuce seedlings under acidic and poor nutrient conditions also resulted in a significant promotion of root and shoot length.

In one aspect of the invention, a biofertilizer composition is prepared by inoculating seeds with fungi (e.g. *Acidomelania panicicola* or any fungus selected from the genus *Barrenia*) on agar or growth medium and placing seeds and agar in the soil. In another aspect of the invention, a biofertilizer composition is prepared by mixing fungi and bacterial cultures with seeds prior to placing seeds in the soil, the cultures optionally forming a coating around the seeds. In a third aspect of the invention, seeds are mixed with fungi and bacterial cultures and dried. In a fourth aspect of the invention, seeds are grown in fungal inoculated soil formulated with vermiculite and rock phosphate.

Definitions

An endophyte is an endosymbiont, often a bacterium or fungus, that lives within a plant without causing apparent disease. Endophytes may enhance a plant’s growth and improve the plant's ability to tolerate abiotic stresses such as drought or harsh soil conditions. In one embodiment an endophyte useful herein comprises the fungus, *Acidomelania panicicola*. In another embodiment, an endophyte comprises *Barrenia panicia*. Endophytes useful herein include the fungus *Acidomelania panicicola* in combination with certain bacteria selected from the bacterial species, *Burkholderia*. In yet another approach, the fungi *Acidomelania panicicola* and the fungi *Barrenia panicia* are used in combination to enhance plant growth under abiotic stress conditions.

The term “abiotic” includes non-living chemical and physical parts of the environment that affect ecosystems. An ecosystem's abiotic factors may be classified via "SWATS" (Soil, Water, Air, Temperature, Sunlight).

The term “biofertilizer” comprises at least one substance containing living microorganisms which, when applied to seed, plant surfaces, and/or soil, colonizes the rhizosphere or the interior of the plant and promotes growth by increasing the supply or availability of primary nutrients to the host plant. Biofertilizers can also comprise other agents which enhance the growth of the microorganisms present. Such agents include, without limitation, agar, gel, and minerals.

The term "crop" herein refers to any plant grown to be harvested or used for any economic purpose, including for example human foods, livestock fodder, fuel or pharmaceutical production.

The following materials and methods provided to facilitate the practice of the present invention.

Fungal isolation

Poaceae grass roots were collected from three locations (N 40 12.00, W 74 30.00; N40 04.084, W74 26.696; and N 39 46.136, W 74 40.885) in New Jersey Pine Barrens in 2012 and 2013. Native pitch pine (Pinus rigida) roots were collected from two locations (N40 04.084, W74 26.696; and N 39 46.136, W 74 40.885) in New Jersey Pine Barrens in 2014 (Tables 1 and 2). Soil pH of the sampling locations ranged from 4.7 to 5.2. Root samples were rinsed thoroughly to remove soil from the surface, cut into 10-20 mm pieces then surface disinfected with sequential washes of 95% ethanol for 30s, 0.5% NaOCl for 2 min and 70% ethanol for 2 min. After several rinses with sterile water and drying, the root samples were cut into 5 mm pieces and plated on acidified malt extract agar (AMEA, 1.5 ml 85% lactic acid per liter of 2% malt extract agar). Plates were incubated at room temperature with 12 h light and 12 h dark cycles. Fungal cultures were transferred to fresh AMEA and purified by sub-culturing from emergent hyphal tips.

Table 1

Species	MycoBank#	Etymology	Morphological description	Type species	Habitat	Known distribution
Barrenia E. Walsh & N. Zhang, **gen. nov.**	MB811715	*"Barren"* refers to the pine barrens ecosystem where the fungi were discovered	Colonies on MEA darkly pigmented, surface fluffy, aerial hyphae thick and light brown. Colonies on WA light brown; sparse aerial hyphae. Sporulation not observed	*Barrenia panicia*	Endophytic in roots of Poaceae grasses	New Jersey Pine Barrens, United States

Table 2

Species	MycoBank #	Etymology	Morphological Description	Holotype	Other materials examined
Barrenia panicia E. Walsh & N. Zhang, **sp. nov.**	MB811716	*"panici"* refers to the host	Colonies on MEA 55 mm diam after 20 d in the dark at 25C, Cinnamon Brown, surface fluffy, aerial hyphae thick and light brown, reverse pigmented, Warm Sepia. Colonies on WA reaching 51 mm diam after 20 d in the dark at 25C, Ochraceous Tawny, aerial hyphae sparse, reverse pigmented, Cinnamon Brown. Warm Sepia, paddle-shaped hyphopodium-like structures formed in inoculated switchgrass root tissue	**United States:** *New Jersey:* Wharton State Forest, N 39 45.346, W 074 41.684, 3 m alt., from roots of *Panicum virgatum*, 5 Jun. 2013, *E. Walsh & N. Zhang,* WSF1R37 (RUTPP-WSF1R37)	**United States**: *New Jersey:* Assunpink Lake, N 40 12.00, W 74 30.00, 3 m alt., from roots of *Digitaria* sp., 30 Aug. 2012, *E. Walsh & N. Zhang* AL5m2; Colliers Mills, N40 04.084 W74 26.696, 5 m alt., from roots of *Coix lacryma – jobi,* 30 Aug. 2012, *E. Walsh & N. Zhang* CM11m2
Barrenia taeda E. Walsh & N. Zhang, **sp. nov.**	MB811717	*"taeda"* means pine wood and refers to the host	Colonies on MEA 28 mm diam after 20 d in the dark at 25 C, Cinnamon Brown, surface fluffy, aerial hyphae thick and light brown, reverse pigmented, Mummy Brown. Colonies on WA reaching 31 mm diam after 20 d in the dark at 25C, Buckthorn Brown, sparse	**United States**: *New Jersey*: Wharton State Forest N 39 45.346, W 074 41.684, 3m alt., from roots of *Pinus rigida*, 26 Jun. 2014, *E. Walsh & N.*	**United States**: *New Jersey*: Wharton State Forest, N 39 45.346, W 074 41.684, 3 m alt., from roots of *Pinus rigida,* 26 Jun. 2014, *E. Walsh & N.*

			aerial hyphae, reverse pigmented, Buckthorn Brown. Sporulation not observed	*Zhang WSF14P22* (RUTPP-WSF14P22)	*Zhang* WFS14P13; Colliers Mills, N40 04.084 W74 26.696, 5 m alt., from roots of *Pinus rigida*, 4 Jun. 2014, *E. Walsh & N. Zhang* CM14P64

Morphological study and growth rate

Purified fungal isolates were grown on cellophane overlaid with 2% MEA (BD Difco, Maryland) and 2% water agar (WA). Cultures were incubated at 20°C in the dark with three replicates. Colony diameter was measured after 20 days. The color names of colonies followed Ridgway (1912).

DNA extraction, amplification and sequencing

Genomic DNA was extracted from fungal mycelium using the UltraClean Soil DNA isolation kit (MoBio, California) following the manufacturer's instructions. PCR was performed with Taq 2X Master Mix (New England BioLabs, Maine), following the manufacturer's instructions. PCR cycling conditions for the internal transcribed spacer (ITS) and the large subunit of ribosomal RNA genes (LSU) consisted of an initial denaturation step at 95° C for 2 min, 35 cycles of 95°C for 45s, 54°C for 45s, 72°C for 1.5 min, and a final extension at 72°C for 5 min. For the largest subunit of RNA polymerase II (RPB1), the cycling conditions included an initial denaturation step at 95°C for 2 min, 35°cycles of 95°C for 60 s, 55°C for 1.5 min, 72°C for 2 min, and a final extension at 72°C for 10 min. Primers used in this study are as follows: ITS1 and ITS4 for the ITS region (White et al. 1990), ITS1 and LR5 for the LSU locus (Rehner and Samuels 1995), and RPB1 Af (Hall and Stiller 1997) and RPB1 CrRev (Matheny et al. 2002) for the RPB1 gene. PCR products were purified with ExoSAP-IT (Affymetrix, California) and sequenced with the PCR primers by Genscript Inc. (Piscataway, New Jersey).

Sequence alignment and phylogenetic analyses

Six representative isolates of the new taxon (CM11m2, CM14P64, AL5m2, WSF1R37, WSF14P13, and WSF14P22) as well as other reference *Leotiomycetes* species (Table 3) were included in the phylogenetic analyses. The ITS dataset included sequences of the six new isolates from this study and 15 reference sequences of *Helotiales*. The LSU dataset included the six new sequences and 28 reference sequences of *Helotiales* and *Rhytismatale*s. The three-gene (ITS, LSU and RPB1) alignment included the six new sequences and 12 reference sequences of . Sequences were aligned with MUSCLE (Edgar 2004). Maximum likelihood (ML) tree was generated with MEGA 6 (Tamura et al. 2013). Models with the lowest BIC scores (Bayesian Information Criterion) were considered to describe the substitution pattern the best. The best models for LSU, ITS and three-gene datasets were Tamura-3 parameter, Kimura 2-parameter, Kimura 2-parameter, respectively. Initial tree(s) for the heuristic search were obtained automatically by applying Neighbor-Join and BioNJ algorithms to a matrix of pairwise distances estimated using the Maximum Composite Likelihood approach, and then selecting the topology with superior log likelihood value. A discrete Gamma distribution was used to model evolutionary rate differences among sites. Bootstrap was computed for 500 replications. All positions containing gaps and missing data were excluded from the analyses.

Table 3. Species name, isolate number, host, location and GenBank accession numbers of the fungi used in this study.

Species	Isolate number [a]	Host	Location	ITS	LSU	*RPB1*
Acephala applanata	CBS109321	*Picea abies*, root	Büdmerenwald, Switzerland	AY078145	KF951051	AFTOL 3613
Acephala macrosclerotium	CBS123555	*Pinus sylvestris*, root	Hubertusstock, Germany	HM189719		
Acidomelania panicola	CBS137156	*Panicum virgatum,* root	New Jersey Pine Barrens, USA	KF874619	KF874622	---
Acidomelania panicola	CM16s1	*Schizachyrium scoparium,* root	New Jersey Pine Barrens, USA	KF874620	KF874621	---
Barrenia panicia	AL5m2	*Digitaria* sp., root	New Jersey Pine Barrens,	---	---	---

			USA			
Barrenia panicia	CM11M2	*Coix lacryma – jobi*, root	New Jersey Pine Barrens, USA	---	---	---
Barrenia panicia	WSF1R37	*Panicum virgatum*, root	New Jersey Pine Barrens, USA	---	---	---
Barrenia taeda	CM14P64	*Pinus rigida*, root	New Jersey Pine Barrens, USA	---	---	---
Barrenia taeda	WSF14P13	*Pinus rigida*, root	New Jersey Pine Barrens, USA	---	---	---
Barrenia taeda	WSF14P22	*Pinus rigida*, root	New Jersey Pine Barrens, USA	---	---	---
Botryotinia fuckeliana			Oregon, USA		AY544651	
Bulgaria inquinas	CBS118.31		Germany		DQ470960	AFTOL916
Chloroscypha chloromela			Oregon, USA	U92311		
Chlorovibressea sp.			New Zealand		DQ257352	
Collembolispora aristata		foam in stream	Nova Ves, Czech Republic		KC005811	
Cudoniella clavus	AFTOL166	Hemlock cones and small sticks	Benton County, Oregon, USA		DQ470944	DQ471128
Dermea acerina	CBS161.38	*Acer rubrum*	Bear Island, Ontario, Canada	AF141164	DQ247801	DQ471164

Fabrella tsugae					AF356694	
Hyaloscypha aureliella			Scotland	JN943611	EU940152	JN985241
Hyaloscypha vitreola			Kaarina, Finland	FJ477059	FJ477058	
Lachnum virgineum	AFTOL49	*Alnus* sp., cones	Oregon, USA	DQ491485	AY544646	DQ842030
Lambertella subsubrenispora	CBS811.85	*Aster ageratoides* var. *ovata*	Honshu, Japan		DQ470978	
Leotia lubrica	AFTOL1	*Chrysolepis chrysophyla*	Oregon, USA		AY544644	
Loramyces macrosporus	CBS235.53	*Equisetum limosum*	UK	DQ471005	DQ470957	DQ471149
Microglossum rufum	AFTOL1292		Tennessee, USA		DQ470981	DQ471179
Mollisia cinerea	CBS122029	fallen log	Alsea Falls, Oregon, USA	DQ491498	DQ470942	DQ471122
Mollisia dextrinospora	ICMP18083	*Actinidia deliciosa* cv. *Hayward*	New Zealand		HM116757	
Monilinia laxa	CBS122031				AY544670	FJ238425
Neobulgaria lilacina			Finland		EU940141	
Neobulgaria pura	CBS477.97	log with moss	New York, USA		FJ176865	
Neofabrea malicorticis	CBS122030	*Malus* sp.	Oregon, USA		AY544662	
Phialocephala dimorphospora	CBS300.62	slime in pulp mill		AF486121	AB671465	

Phialocephala fortinii	CBS443.86	*Pinus sylvestris,* root	Suonenjoki, Finland	AB671499	AB671466	
Phialocephala scopiformis	CBS468.94	*Picea abies*, bark	Regensburg, Germany	AF486126		
Spathularia velutipes		*Tsuga Canadensis*	Tennessee, USA		FJ99786	
Varicosporium elodeae			Svalbard, Norway		JN941371	
Vibressea truncorum	CBS258.91	*Populus*, submerged root	Ontario, Canada	EU434854	FJ176874	FJ238438
Acephala sp.[c]		*Cymbidium insigne*	China	HQ889709		
Acephala sp.[c]		Sugarcane, root	Brazil	GU973749		
Phialocephala sp.[c]		*Rhododendron,* root	Smoky Mountain National Park, USA	JQ272328		

[a] AFTOL= Assembling the Fungal Tree of Life project; ATCC = American Type Culture Collection, Manassas, Virginia, USA; CBS = Centraalbureau voor Schimmelcultures, Utrecht, The Netherlands; ICMP = International Collection of Micro-organisms from Plants, Lincoln, New Zealand.

[b] Numbers in boldface indicating new sequences from this study.

[c] Taxon name was copied from GenBank. Phylogenetic analysis in this study indicated that they belong to *Barrenia*.

Plant-fungal interaction experiment

Fungal isolates WSF1R37, WSF14P22, and *A. panicicola* isolate 61R8 were used in the seedling inoculation experiment. Switchgrass ('Kanlow') seeds were surface disinfected as follows: 95% ethanol for 30s, 0.5% NaOCl for 1 min, 70% ethanol for 1 min, rinsed with sterile distilled H_2O and allowed to germinate in the dark at 25° C for 3 days. Agargel (Sigma-Aldrich, USA) plates were made following manufacturer's instructions, and were cut in half, with one side removed. On the cut surface of an Agargel plate, three 10 mm × 10 mm

× 5 mm plugs from a one-week old fungal culture grown on MEA were placed equidistance from one another. Germinated switchgrass seeds with visible radicle were then placed on the plugs. Sterile MEA plugs were used as negative control. Cultures were incubated at 25° C under 12 hr light and dark cycle with nine replicates. Root length was measured 7 days after inoculation.

The following examples are provided to illustrate certain embodiments of the invention. They are not intended to limit the invention in any way.

EXAMPLE I

Barrenia, a New Genus Associated with Roots of Switchgrass and Pine in the Oligotrophic Pine Barrens, Promotes Root Hair Growth

A. Culture morphology and growth rate

Isolate WSF1R37 produced dense Cinnamon Brown mycelium on MEA, and Ochraceous Tawny mycelium on WA. Colony diameter measurements for isolate WSF1R37 after 20 days were 75 mm on average on MEA with standard deviation (SD) of 2.6, and 47 mm on average on WA with SD of 2.6. Isolate WSF14P22 produced dense Cinnamon Brown mycelium on MEA, and Buckthorn Brown mycelium on WA. Colony diameter measurements for isolate WSF14P22 after 20 days were 28 mm on average on MEA with SD of 0.6, and 26 mm on average on WA with SD of 1.0.

B. Sequence data and phylogeny

There were 173 characters in the LSU alignment, 377 in ITS and 1291 in the three-gene alignment. Maximum likelihood trees based on LSU, ITS and three gene sequences are shown in Figs 1-3. All three phylogenies supported that the new isolates formed a monophyletic clade in *Helotiales* separated from any known taxa. The LSU tree indicated that they were close to *Acidomelania panicicola, Loramyces macrosporus, Mollisia cinerea* and PAC. The ITS tree showed that these new isolates were closely related to *A. panicicola, M. cinerea, Phialocephala scopiformis* and *L. macrosporus*. In the ITS tree, isolates

WSF1R37, AL5m2, and CM11m2 formed a well-supported group, while isolates WSF14P22, WSF14P13, and CM14P64 formed another. The two groups were also recognized and supported by the LSU and RPB1 trees, and variation in the phylogenetic relationships of these isolates only occurred within the groups. DNA sequence information for the different fungal species is displayed in Figs. 4A-4R.

Based on the molecular phylogenetic analyses, morphological characters and their ecological features, a new genus and two new species have been identified. *Barrenia* differs from *Loramyces* by its association with living plant roots while *Loramyces* species are associated with submerged dead plants (Digby and Goos 1987; Ingold and Chapman 1952; Weston 1929). Taxa in the PAC are also root endophytes, but they exhibit complex phialid arrangements that appear to be lacking in *Barrenia*. *Barrenia* also differs from *Mollisia* because of its lack of phialide producing conidia. Moreover, *Barrenia* has 93% or less ITS sequence similarity to the above-mentioned close relatives or any other described species with accessible ITS sequences. The two *Barrenia* species differ from each other on host and growth rate. The pine associated *B. taeda* exhibited slower growth than the grass associated *B. panicia* on both WA and MEA. There is a 96% similarity in ITS sequences between *B. panicia* and *B. taeda*.

C. Plant-fungal interaction experiment

Switchgrass seedlings inoculated with *A. panicicola* isolate 61R8 and *B. panicia* WSF1R37 produced dense root hairs all the way to the root apical meristem area, while the control seedlings only produced dense root hairs at the region of maturation of the root (Fig 5A and 5C). In addition, the roots inoculated with *A. panicicola* isolate 61R8 and *panicia* WSF1R37 had a serpentine growth pattern, while the control roots were straight. Hyphopodia-like strutures were observed on the switchgrass seedling roots inoculated with *B. panicia* WSF1R37 (Fig 6A-6C). Root length for seedlings inoculated with *B. panicia* WSF1R37 after 7 days were 17.4 mm on average with SD of 1.8, not significantly different from the control, which was 19 mm on average with SD of 5.1. Seedlings inoculated with *B. taeda* WSF14P22 showed no difference in root hair production with the control. Root length for *B. taeda* WSF14P22 after 7 days was 8.1 mm on average with SD of 1.6, which was significantly shorter than the control (Fig 5E).

DISCUSSION

Our recent survey on fungi associated with grass roots uncovered a number of novel DSE in Leotiomycetes from the pine barrens ecosystem (Luo et al. 2014a, 2014b; Walsh et al. 2014). Leotiomycetes are morphologically and ecologically diverse and the phylogenetic relationships within this class are not well resolved due to lack of molecular data (Wang et al. 2006). Based on the multi-locus phylogenetic analyses, the new genus *Barrenia* described here belongs to Helotiales, which encompasses plant pathogens, saprobes and endophytes. The dark, septate hyphal morphology of *Barrenia* spp., their root-colonizing habit and phylogenetic closeness to PAC indicate that they likely are also DSE.

The best studied DSE is the PAC, specifically *P. fortinii*. However, the ecological functions of PAC and other DSE remain elusive. Host-fungal interaction experiments often yielded inconsistent results under various experimental conditions in different laboratories (Mandyam and Jumpponen 2005). This prompted us to examine the interaction between *B. panicia, B. taeda, A. panicicola* and switchgrass, which is the host of *B. panicia* and *A. panicicola*. Our inoculation results indicated that *A. panicicola* and *B. panicia* remarkably promoted the root hair growth in switchgrass. In switchgrass roots, *B. panicia* produced hyphopodium-like structures, which may perform penetration and nutrient exchange function between the fungus and the host plant (Delaux et al. 2013; Walker 1980). *Barrenia taeda*, originally isolated from pine roots, had negative effect on root elongation in switchgrass seedlings. These results corroborate Mandyam et al. (2010; 2012) that while DSE fungi have a broad host range, their effects and characteristics can be considered host specific.

The phylogenetic analysis in this study indicated that *Barrenia* is close to *Acidomelania, Loramyces, Mollisia*, and PAC. The phylogenetic proximity of *Mollisia, Loramyces* and PAC was also supported by Zijlstra et al. (2005) and Wang et al. (2006). *Barrenia* can be distinguished from *Loramyces* and *Mollisia* by its association with living plant roots. While taxa in PAC also are root endophytes, morphologically they can be distinguished from *Barrenia*. In addition, *Barrenia* has 93% or less ITS sequence similarities to the above-mentioned close relatives or any other described species with accessible ITS sequences. The family placement of *Barrenia* is not determined here because the Leotiomycetes phylogeny is poorly resolved and several families in this class likely are polyphyletic (Wang et al. 2006).

The six *Barrenia* isolates from New Jersey Pine Barrens were grouped into two well-supported clades. We delimited the two species based on the genealogical concordance phylogenetic species recognition (Taylor et al. 2000). The BLAST results in GenBank indicated that *Barrenia* might have a wide distribution. Sixteen ITS sequences in GenBank had 97–99% identity with that of *B. panicia* isolate WSF1R37, for example, GU973749 from sugarcane root in Brazil, HQ889709 from Cymbidium insigne root in China, and AY599235 from grass root in The Netherlands. Twelve ITS sequences in GenBank had 97–99% identities with that of *B. taeda* isolate WSF14P22, for example, JQ272328 from Rhododendron root in USA and KJ817299 from Vaccinium vitis-idaea in Inner Mongolia. The host plants of the matched sequences in GenBank are largely Ericaceae, terrestrial orchids, grasses and conifers, usually found in acidic and infertile soils (Keddy 2007). This distribution pattern was also found in *Acidomelania panicicola*, the other root associated fungus frequently isolated from the pine barrens (Walsh et al. 2014).

Additional experiments to uncover fungal-plant interactions included the inoculation of switchgrass seedlings with *A. panicicola* isolate 61R8 and *B. panicia* WSF1R37 produced dense root hairs all the way to the root apical meristem area, while the control seedlings only produced dense root hairs at the region of maturation of the root. In addition, the roots inoculated with *A. panicicola* isolate 61R8 and B. *panicia* WSF1R37 had a serpentine growth pattern, while the control roots were straight. The plant growth promotion effect of A. *panicicola* and *B. panicia* discovered in this study coupled with their distribution pattern indicate that these species may play a role in plant adaptation to acid, low nutrient soils.

In conclusion, we discovered a new genus and two species of root-colonizing fungi associated with plants living in an acidic, nutrient poor environment. The phylogenetic and taxonomic work and the plant-fungal interaction results reported here will aid future ecological and evolutionary studies on root-associated fungi.

EXAMPLE II

Endophytic Fungi from Pine Barrens Grasses Promote Plant Growth In Acidic, High Aluminum Toxicity And Low Nutrient Conditions

A. Fungal Inoculation of Seeds on Agar

In this study, we performed functional studies that demonstrated that *Acidomelania panicocola* inoculation of seeds significantly increased root hair growth in switchgrass, rice and lettuce seedlings compared to the control.

To assess the effects of *Acidomelania panicicola* inoculation of switchgrass and rice seedlings on root hair abundance, fungus was grown on water agar under room temperature for 7 days. Seeds were germinated in sterile distilled water in a petri dish under room temperature in the dark for 7 days. Seedlings (roots down) were inserted in the 7 day-old fungal agar culture. Control seedlings were uninoculated but grown under the same conditions. Significant differences in root hair abundance were observed in inoculated seedlings when compared to negative, untreated controls (Figure 7 and 8). These findings indicate that *Acidomelania panicicola* inoculation enhances root hair abundance.

To evaluate switchgrass seedling survival percent and root and shoot length, switchgrass seeds were next inoculated with *Acidomelania panicicola* or *Fusarium oxysporum* or uninoculated using the method described above and agar and seedlings were covered with top soil. 6 days post-inoculation, *Acidomelania panicicola* inoculated seedlings exhibited a significant increase in survival (Figure 9). Root and shoot length of switchgrass seedlings were visualized 8 days after inoculation when enhanced root and shoot length were observed (Figure 10). These results demonstrate that colonization of switchgrass seedlings with *Acidomelania panicicola* enhances switchgrass growth and survival.

To assess the effects of *Acidomelania panicicola* inoculation on lettuce seed growth, seeds were inoculated and germinated as described above. Root length was assessed 4 days after inoculation. Increased root growth was observed for the inoculated lettuce seedlings (Figure 11). These findings indicate that *Acidomelania panicicola* can enhance growth of edible plants.

B. Bacterial and Fungal Mixing and Inoculation of Seeds

Fungus (e.g. *Acidomelania panicicola*) is grown on water agar or other growth media under room temperature for 7 days. Bacterium (e.g. *Burkholderia* sp.) is cultured in Luria-

Bertani broth (LB) overnight at 28 °C. Seeds are mixed with the bacterial culture and the fungal cultures (ratio: 500 seeds: 10 mL overnight bacterial culture: 1 Petri dish 7 day old fungal culture) and placed on soil (e.g. Pine Barrens soil or other nutrient-poor soils). Seeds are then covered with top soil and grown under sufficient light.

C. Bacterial and Fungal Mixing, Inoculation and Drying of Seeds

Fungus (e.g. *Acidomelania panicicola*) is grown on water agar or other growth media under room temperature for 7 days. Bacteria (e.g. *Burkholderia* sp.) are grown in Luria-Bertani broth (LB) overnight at 28° C. Seeds are mixed with the bacterial culture and the fungal cultures (ratio: 500 seeds: 10 mL overnight bacterial culture: 1 Petri dish 7 day old fungal culture) and dried. Seeds are placed on soil (e.g. Pine Barrens soil or other nutrient-poor soils). Seeds are then covered with top soil and grown under sufficient light.

D. Bacterial and Fungal Mixing, Inoculation of Soil Formulated with Vermiculite and Rock Phosphate

Fungus (e.g. *Acidomelania panicicola*) is grown on water agar or other growth media under room temperature for 7 days. Bacterium (e.g. *Burkholderia* sp.) are grown in Luria-Bertani broth (LB) overnight at 28°C. Soil formulated with vermiculite and rock phosphate is inoculated with the fungal and bacterial cultures.

DISCUSSION

Roots were an early development in plant life evolving on land during the Devonian Period (416 to 360 million years ago; (von Uexkull et al. 1995)). The fossil record and molecular phylogenetic analysis suggest that from the outset, mycorrhizal fungi played a crucial role in facilitating plant invasion of land, which was dry and poor in nutrients at the time of colonization (Gensel et al. 2001). Such drought and low nutrient stress continue to challenge plants living in many extant habitats.

We describe herein a novel endophytic fungi, *Acidomelania panicicola,* for use alone, and optionally in the presence bacteria, which enter the root-interior and colonize the tissues of the plant, thereby effectively promoting plant growth and survival. Given that there are limited techniques—both time consuming and cost-intensive--to prevent adverse effects of abiotic stressors on plant growth, the present studies demonstrating that application of a biofertilizer comprising *Acidomelania* to seeds or seedlings results in increased seedling survival rate, root hair abundance, and root and shoot length will have great utility for promoting plant growth under adverse environmental conditions.

EXAMPLE III

Liquid Formulation of the BioFertilizer for Seed Coating

This example provides a liquid formulation of biofertilizer, where the formulation consists of two separate solutions that are combined before use as a seed coating.

For the first solution, the fungi are grown in a 1 L flask using an adequate medium and are concentrated by centrifugation in order to separate the solid. This solid is then suspended in a minimum amount of media. A sun protecting product, such as Congo red or green colorant can also be added to the media at 1% (w/v).

According to one preferred embodiment, *A. panicicola* only is used for the first solution in similar initial concentrations. In a second embodiment, the first solution contains a fungus from the genus *Barrenia* only (e.g. *B. panicia*). In another embodiment, the first solution is comprised of *A. panicicola* and at least one fungus from the genus *Barrenia* (e.g. *B. panicia*). In another embodiment, the first solution contains a mixture of *A. panicicola* and at least one bacteria from the genus *Burkholderia.* In another embodiment, a mixture of *B. panicia* and at least one bacteria from the genus *Burkholderia* is contained within the first solution.

For the second solution, a 1% (w/v) solution of a polysaccharide, such as guar gum, gelan gum, pectin, carboxymetil cellulose, agar-agar, xantan gum (or other food hydrocolloid) is prepared to be used as sticker. The two solutions are then mixed together to treat plant seeds as a coating. The seed should be dried before planting and it is preferable to wait at least two hours after application prior to planting.

EXAMPLE IV

Solid State Formulation of the Biofertilizer of the Invention

This example provides a liquid formulation of a biofertilizer where the fungi and optionally bacteria are encapsulated and the fertilizer is in solid form. Alginate beads were prepared as follows:

1 ml of 30% glycerol was added to 1, 1.5 or 2% sodium alginate solution, depending on the alginate properties (M/G ratio) to obtain a final volume of 25 ml. Then, 250 ml of culture (obtained from a culture of *A. panicicola* only, a fungus from the genus *Barrenia* only (e.g. *B. panicia)*, or a mixture of *A. panicicola* and *Burkholderia*, or a mixture of *A. panicicola* and *Barrenia* (e.g. *B. panicia)* was centrifuged, the cell pellet was washed with saline (0.85% NaCl, w/v) and suspended in 25 ml of alginate mixture and mixed thoroughly. This suspension was added drop wise into a pre-cooled sterile 1.5 or 2% (w/v) aqueous solution of $CaCl_2$ under mild agitation to obtain the fungal-alginate beads. These beads were allowed to harden for 2-4 h at room temperature. Beads were collected by sieving and were washed several times with sterile water and stored at 4° C. In order to preserve the formulation, the fresh wet beads were frozen at -80 °C prior to lyophilization at -45 ° C. for 15 h. The lyophilized dry beads were stored in sterile glass bottles.

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While certain of the preferred embodiments of the present invention have been described and specifically exemplified above, it is not intended that the invention be limited to such embodiments. Various modifications may be made thereto without departing from the scope and spirit of the present invention, as set forth in the following claims.

What is claimed is:

1. A method for enhancing overall plant growth and resistance to adverse abiotic conditions comprising contacting a plant or seed therefrom with a composition comprising a biofertilizer comprising at least one endophytic fungi and optionally bacteria.

2. The method of claim 1, wherein the fungi is *Acidomelania panicicola*.

3. The method of claim 2, wherein said composition contains bacteria selected from the *Burkholderia* genus.

4. The method of claim 1, wherein said composition is prepared before use by inoculating said seeds with said endophyte on agar or growth medium and placing seeds and agar in the soil.

5. The method of claim 1, wherein said composition is prepared before use by mixing said fungi and bacterial cultures with seeds.

6. The method of claim 1, wherein said composition is prepared before use by mixing seeds with said fungi and bacterial cultures and drying said seeds to form a coating thereon.

7. The method of claim 4-6 wherein said composition comprises vermiculite and rock phosphate.

8. The method of claim 4-6, wherein said biofertilizer is applicable to crop and forest plants.

9. The method of claim 4-6, wherein the crop plants are dicotyledonous plants.

10. The method of claim 4-6, wherein said plant is an edible plant including lettuce, corn, rice, soybeans, potatoes, barley, wheat, and carrots.

11. The method of claim 4-6, wherein the crop plants are monocotyledonous plants.

12. The method of claim 4-6 wherein said plant is a turfgrass plant selected from a Ryegrass, Kentucky Bluegrass, Tall Fescue, Bermuda, St. Augustine or Zoysia plant or any other turfgrass plant.

13. A biofertilizer composition, comprising an effective amount of *A. panicicola* and at least one agent or microorganism for promoting plant growth and resistance to abiotic stresses for use in the method of claim 1.

14. The biofertilizer composition of claim 13, wherein the composition contains *A. panicicola* and at least one *Burkholderia* species in equal concentrations.

15. The biofertilizer composition of claim 14, comprising a culture suspension comprising the fungal strain and optionally a bacterial strain, a sun protecting product and a polysaccharide solution.

16. The biofertilizer composition of claim 15, wherein the polysaccharide is selected from the group consisting of guar gum, gelan gum, pectin, carboxymetil cellulose, agar, and xantan gum and contains 1% w/v of polysaccharide.

17. The biofertilizer composition of claim 13, wherein the composition is for seed coating.

18. The biofertilizer composition of claim 13, wherein the composition improves seed germination.

19. The biofertilizer composition of claim 13, wherein the fungal strains are encapsulated in allignate beads.

20. The biofertilizer composition of claim 13, wherein the biofertilizer is applicable to edible and non edible plants.

21. The method of claim 1, wherein said composition contains fungi selected from the *Barrenia* genus.

22. The method of claim 21, wherein the fungi is *Barrenia panicia.*

23. The method of claim 21, wherein said composition contains bacteria selected from the *Burkholderia* genus.

24. The method of claim 21, wherein said composition is prepared before use by inoculating said seeds with said endophyte on agar or growth medium and placing seeds and agar in the soil.

25. The method of claim 1, wherein said composition is prepared before use by mixing said fungi and bacterial cultures with seeds.

26. The method of claim 1, wherein said composition is prepared before use by mixing seeds with said fungi and bacterial cultures and drying said seeds to form a coating thereon.

27. The method of claims 24-66 wherein said composition comprises vermiculite and rock phosphate.

28. The biofertilizer composition, according to claim 13, wherein said at least one microorganism is of the genus *Barrenia*.

29. The biofertilizer of claim 28, wherein the fungi is *Barrenia panicia*.

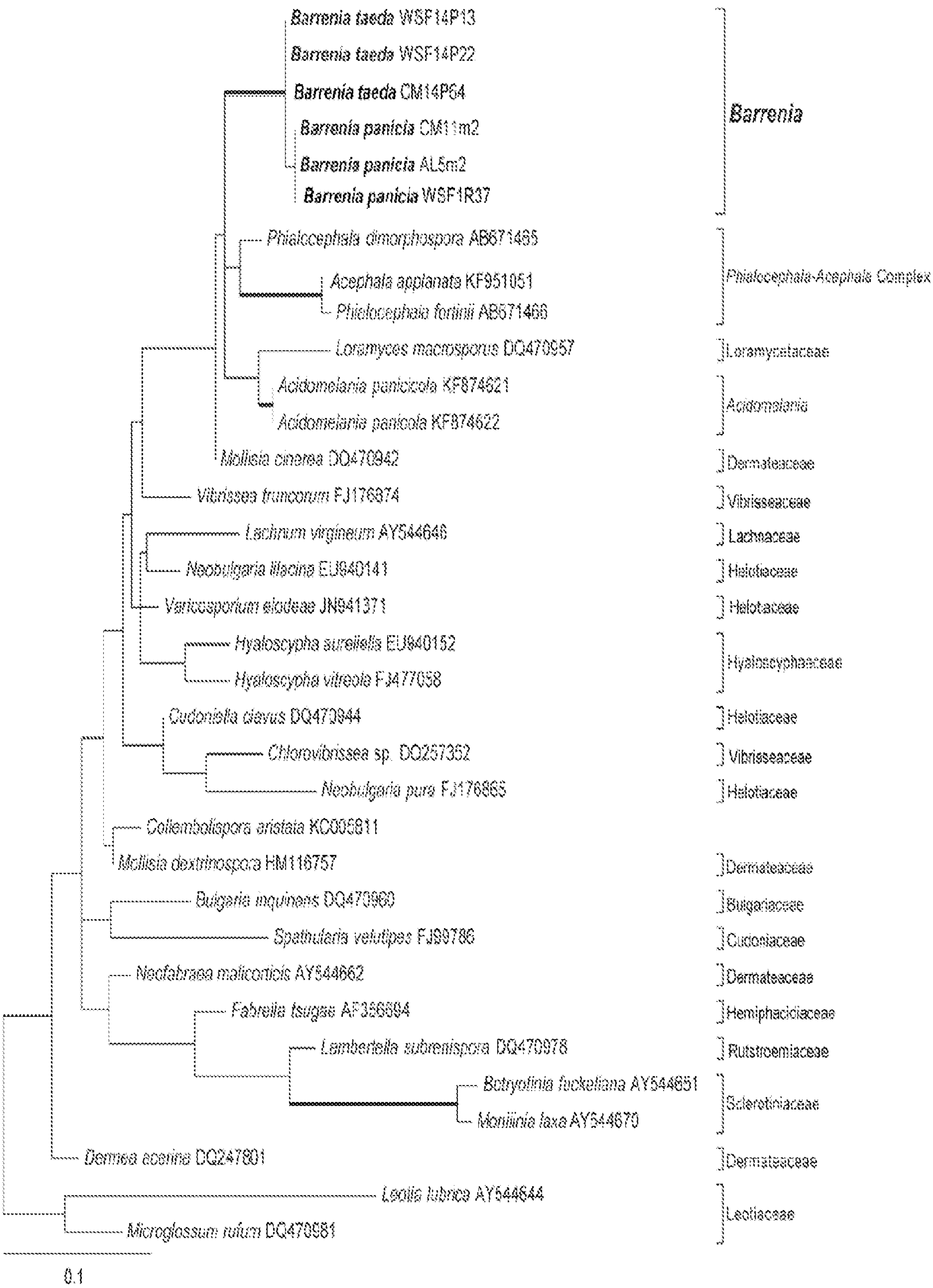
30. The biofertilizer composition of claim 13, wherein the composition contains *A. panicicola* and at least one *Barrenia* species in equal concentrations.

31. The biofertilizer composition of claim 28, further comprising a sun protecting product and a polysaccharide solution.

32. The biofertilizer composition of claim 26, wherein the polysaccharide is selected from the group consisting of guar gum, gelan gum, pectin, carboxymetil cellulose, agar, and xantan gum and contains 1% w/v of a polysaccharide.

33. The biofertilizer composition of claim 32 applied to seeds as a coating

34. The biofertilizer composition of claim 28, wherein the fungal strains are encapsulated in allignate beads.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Barrenia taeda WSF14P22
Barrenia taeda CM14P54
Barrenia panicia CM11m2
Barrenia panicia AL5m2
Barrenia panicia WSF1R37
Barrenia
Phialocephala dimorphospora AB671465
Acephala applanata KF951051
Phialocephala fortinii AB671466
Phialocephala-Acephala Complex
Loramyces macrosporus DQ470957
Loramycetaceae
Acidomelania panicicola KF874621
Acidomelania panicola KF874622
Acidomelania
Mollisia cinerea DQ470942
Dermateaceae
Vibrissea truncorum FJ176874
Vibrisseaceae
Lachnum virgineum AY544646
Lachnaceae
Neobulgaria lilacina EU940141
Helotiaceae
Varicosporium elodeae JN941371
Helotiaceae
Hyaloscypha aureliella EU940152
Hyaloscypha vitreola FJ477058
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Mollisia dextrinospora HM116757
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Cudoniaceae
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Dermateaceae
Fabrella tsugae AF356694
Hemiphacidiaceae
Lambertella subrenispora DQ470978
Rutstroemiaceae
Botryotinia fuckeliana AY544651
Monilinia laxa AY544670
Sclerotiniaceae
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Dermateaceae
Leotia lubrica AY544644
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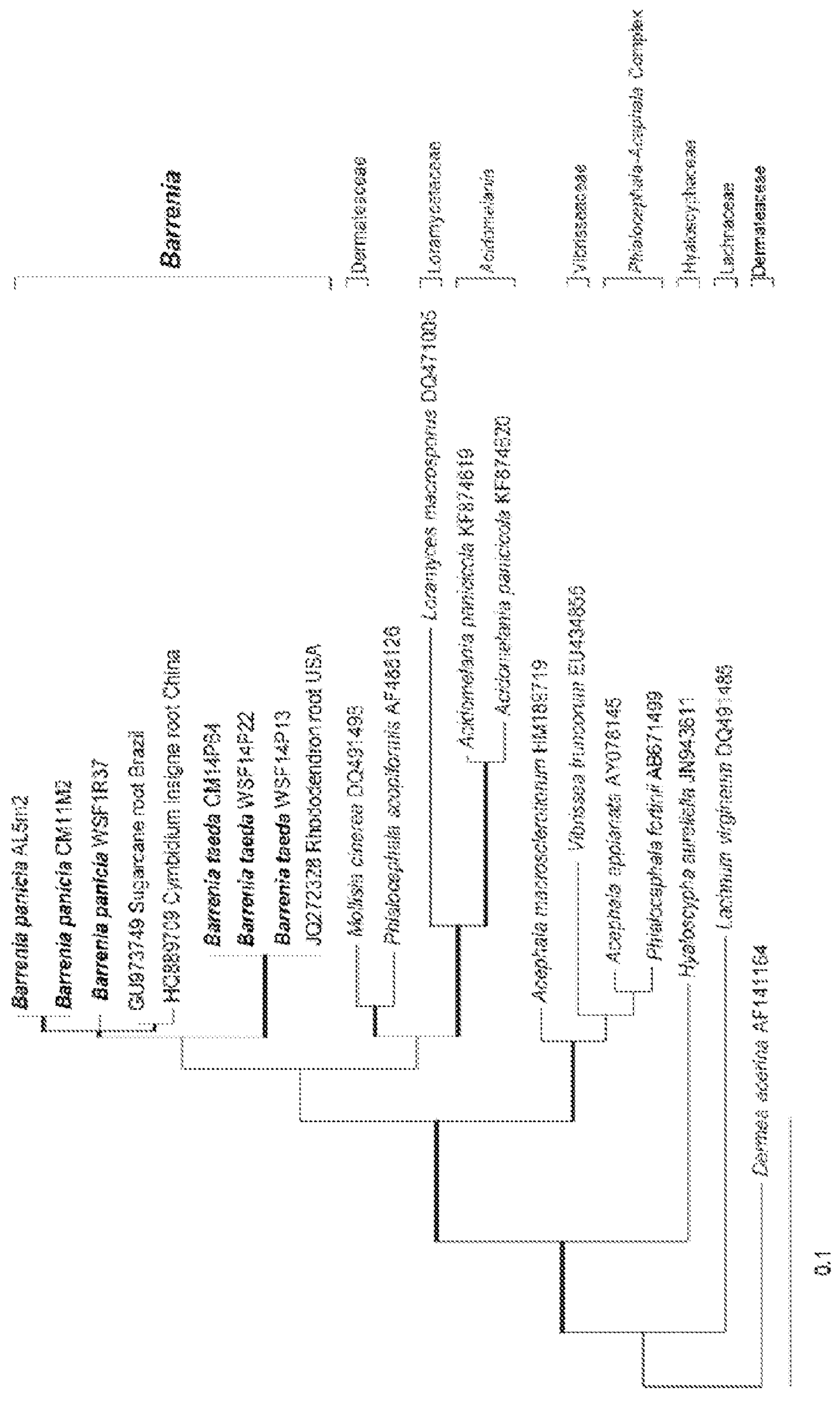
Leotiaceae
0.1

Figure 1


Barrenia panicia AL5m2
Barrenia panicia CM11M2
Barrenia panicia WSF1R37
GU973749 Sugarcane root Brazil
HC889709 Cymbidium insigne root China
Barrenia taeda CM14P54
Barrenia taeda WSF14P22
Barrenia taeda WSF14P13
JQ272328 Rhododendron root USA
Mollisia cinerea DQ491498
Phialocephala scopiformis AF486126
Loramyces macrosporus DQ471005
Acidomelania panicicola KF874619
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Vibrissea truncorum EU434856
Acephala applanata AY078145
Phialocephala fortinii AB671499
Hyaloscypha aureliella JN943611
Lachnum virgineum DQ491485
Dermea acerina AF141164
0.1
Barrenia
Dermateaceae
Loramycetaceae
Acidomelania
Vibrisseaceae
Phialocephala-Acephala Complex
Hyaloscyphaceae
Lachnaceae
Dermateaceae

Figure 2

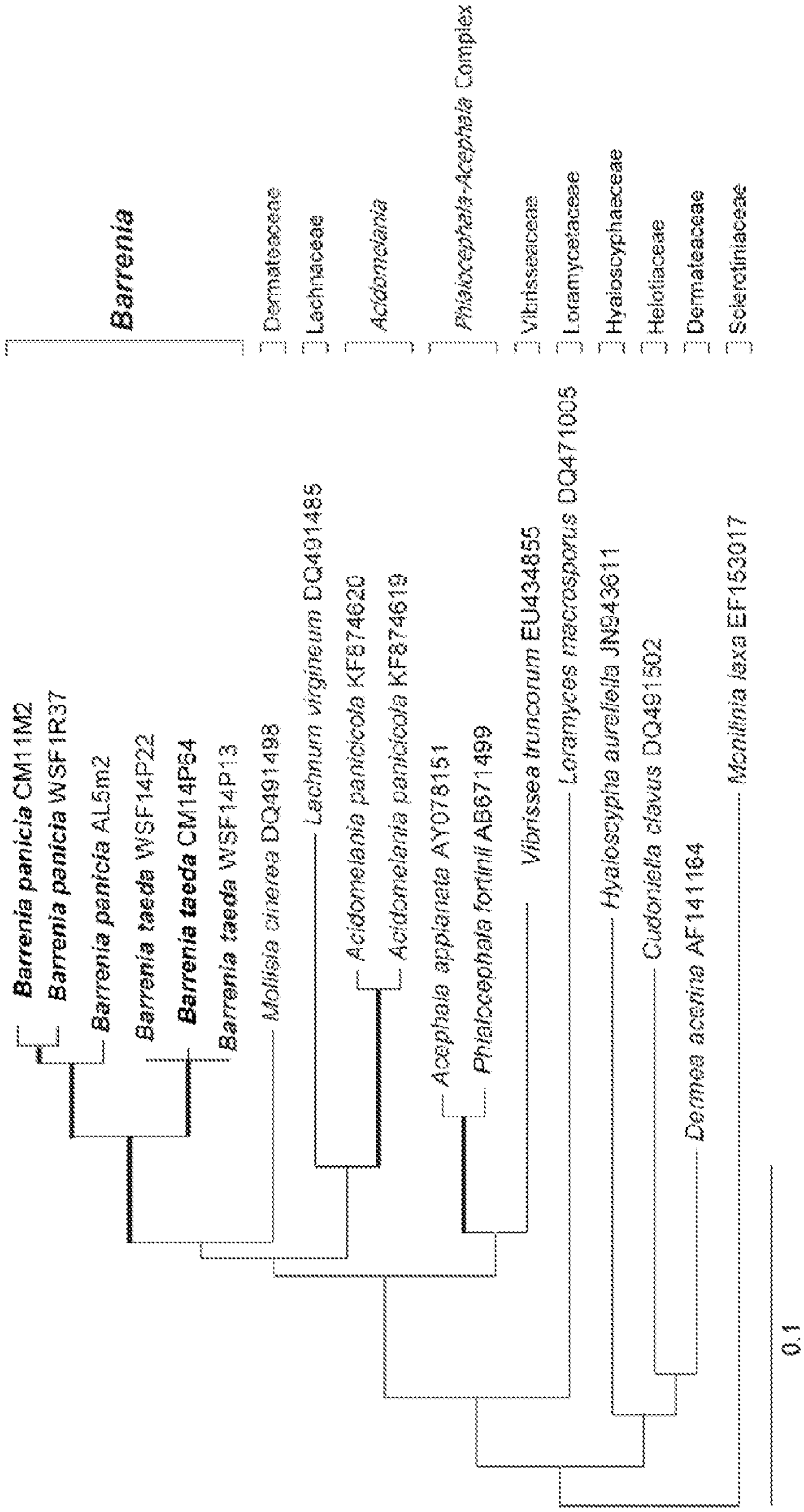
Barrenia panicia CM11M2
Barrenia panicia WSF1R37
Barrenia panicia AL5m2
Barrenia taeda WSF14P22
Barrenia taeda CM14P54
Barrenia taeda WSF14P13
Mollisia cinerea DQ491498
Lachnum virgineum DQ491485
Acidomelania panicicola KF874620
Acidomelania panicicola KF874619
Acephala applanata AY078151
Phialocephala fortinii AB671499
Vibrissea truncorum EU434855
Loramyces macrosporus DQ471005
Hyaloscypha aureliella JN943611
Cudoniella clavus DQ491502
Dermea acerina AF141164
Monilinia laxa EF153017
0.1
Barrenia
Dermateaceae
Lachnaceae
Acidomelania
Phialocephala-Acephala Complex
Vibrisseaceae
Loramycetaceae
Hyaloscyphaceae
Helotiaceae
Dermateaceae
Sclerotiniaceae

Figure 3

Acephala_applanata_AY078151

GTGTTTA---

------CATACTATTGT-TGCTTTGGCGGGCCGTGA-CCT-CCAC--TGC----GGGCTC
TGCTCGT-----GTGTGCCCGCCAGAGGACC---AAACTCTGAATGTTAGTGATGTCTGA
GTACTATCTAATAGTTAAAACTTTCAACAACGGATCTCTTGGTTCTGGCATCGATGAAGA
ACGCAGCGAAATGCGATAAGTAATGTGAATTGCAGAATTCAGTGAATCATCGAATCTTTG
AACGCACATTGCGCCCTGTGGTATTCCGCAGGGCATGCCTGTTCGAGCGTCATT-TAACC
ACTCACGCCTGGCGTGGTATTGGGGT-ACGCGGT--CTCGCGGCCCTCAAAATCAGTGGC
GGTGCCGGTG-GGCTCTAAGCGTAGTAC-ATACTCCCGCTATAGAGTTC-----------
-----------------CC---------------------------CCGGTGGCTCGC--
------------------------ACCCGCTGAACTTAAGCATATCAATAAGCGGAGGAA
AAGAAACCAACAGGGATTACCTCAGTAACGGCGAGTGAAGCGGTAACAGCTCAAATTTGA
AAGCTGCC-----AACAGGCCGCGTTGTAATTTGTAGARGCTGCTTTGGGTGTCGGCCCG
GTCTAAGTTCCTTGGAACAGGACGTCATAGAGGGTGAGAATCCCGTATGTGATCGG-TGC
CGTTGCCCGTGTAAAGCGCTTTCGACGAGTCGAGTTGTTTGGGAATGCAGCTCAAAATGG
GTGGTAAATTTCATCTAAAGCTAAATATTGGCCAGAGACCGATAGCGCACAAGTAGAGTG
ATCGAAAGATGAAAAGCACTTTGGAAAGAGAGTTAAACAGTACGTGAAATTGTTGAAAGG
GAAGCGCTTGCAACCAGACTTGCGGGCGGTCGATCATCCGAGGTTC-TCCCCGGTGCACT
CGATCGTTC-TCAGGCCAGCATCGGTTTCCGGGGTGGGATAAAGGCGGTGGGAATGTGGC
TC--TTC------GGAGTGTTATAGCCCACCGTGCAATGCCGCCACCGGGGACCGAGGAC
CGCGCTTC-GGCTAGGATGCTGGCGTAATGGTTGTAAGCGACCCGTCTTGAAACACGGAC
CAAGGAGTCTAACATCTATGCGAGTGTTTGGGTGTCAAACCCATACGCGTAATGAAAGTG
AACGGAGGTAAGAGCCCTTTAGGGTGCATTATCGACCGATCCTGATGTCTTCGGATGGAT
TTGAGTAAGAGCATAGCTGTTGGGACCCGAAAGATGGTGAACTATGCGTGAATAGGGTGA
AGCCAGAGGAAACTCTGGTGGAGGCTCGCAGCGGTTCTGACGTGCAAATCGATCGTC-AA
ATTTGCGTATAGGGGC-GAAAGACTAATCGGCTAGACAGAGTCAGTTCG---CCCGATGA
GGGTGGCAGATCTACT--TGTTC--TYGTGCTGACATGAGT-ATCTCAGAGTAATCCGGC
CTTCAAAGCAGCTGTTTCCATTCGAGACCCGAAGCGTAGGTTCGATACGATTTGGCGACT
TTGCAAGCCCAAGATGATCTGCGATAGCGACGTTTCTGCGGACGATCAAGAATTCGGTGG
CGATCCAAAGGAAGCCGTGAAG---CGCTCTCATGGAGGCTGTGGAAATACTCAGCCCGA
GGTGCGCCAGCAGGCTCTGCAGCTTTGGGGTACATGGAAGATGCCTAAGGACGAGGAGAA
CGAGGG------AAGCCAATCCGAGAAGAGACAAATCACTCCAGAGATGGCTCTGAACGT
CTTCCGAAGCATGTCTACTGCTGAGATTCGCGACCTTGGGTTGAGCAACGATTATGCCCG
ACCCGACTGGCTGATCATCACAGTCCTTCCAGTTCCTCCTCCGCCGGTTCGACCAAGTAT
CTCAATGGATGGCACAAGCACAGGCATGCGTGGAGARGATGATTTGACGTACAAGCTCGG
TGATATCATCCGTGCGAACGGCAATGTCAAGC-AGGCACAACAGGAAGG

Figure 4A

Acidomelania_panicicola_KF874620
GTGTCTA---

------CATACTCTTGT-TGCTTTGGCAGGCCGTGG-CCTCCCAC--TGT----GGGCTC
AGCCTGC-----ATGTGCCTGCCAGAGGACC---AAACTCTGAATGTTACTGATGTCTGA
GTACTATATAATAGTTAAAACTTTCAACAACGGATCTCTTGGTTCTGGCATCGATGAAGA
ACGCAGCGAAATGCGATAAGTAATGTGAATTGCAGAATTCAGTGAATCATCGAATCTTTG
AACGCACATTGCACCCGGTGGTATTCCGCCGGGTATGCCTGTTCGAGCGTCATTACAACC
ACTCAAGCCTGTCTTGGTGTTGGGGA-TTGCGAAT-CTCGCAGCCCTAGAGTCCAGTAGC
GTCACCTTTA-GGTCCTAAGCGTAGTAATTTCTCCTCGCTACAGAACCT-----------
-----------------GCCGGTGGATAGTATAAATCCAGTTAAGTCTGGTATCCCGC-G
GTTGACCTCGGATCAAGTAGGGATACCCGCTGAACTTAAGCATATCAATAAGCGGAGGAA
AAGAAACCAACAGGGATTACTTTAGTAACGGCGAGTGAAGCGGTAACTGCTCAAATTTGA
AAGCTGCC-----AACAGGCCGCGTTGTAATTTGTAGAAGATGCTTTGGGTGTCGGCCCA
GTCTAAGTTCCTTGGAACAGGACGTCATAGAGGGTGAGAATCCCGTATGTGATTGG-TGC
CGTCCCCCGTGTAAAGCTCTTTCGACGAGTCGAGTTGTTTGGGAATGCAGCTCAAAATGG
GTGGTAAATTTCATCTAAAGCTAAATATTGGCCAGAGACCGATAGCGCACAAGTAGAGTG
ATCGAAAGATGAAAAGCACTTTGGAAAGAGAGTTAAACAGTACGTGAAATTGTTGAAAGG
GAAGCGCTTGCAATCAGACTTGCAGGCGGTTGATCATCCGAGGTTC-TCCCCGGTGCACT
CGATCGTCT-TCAGGCCAGCATCGGTTTCAGTGGTGGGATAAAGGCTGTGAGAACGTGGC
TC--TTC------GGAGTGTTATAGCTCACGGTGCAATGCCGCCTACTGGGACCGAGGAC
CGCGCTTC-GGCTAGGATGCTGGCGTAATGGTTGTAAGCGACCCGTCTTGAAACACGGAC
CAAGGAGTCTAACATCTATGCGAGTGTTTGGGTGTCAAACCCATACGCGTAATGAAAGTG
AACGGAGGTGAGACCCCATTAGGGCGCATCATCGACCGATCCTGATGTCTTCGGATGGAT
TTGAGTAAGAGCATAGCTGTTGGGACCCGAAAGATGGTGAACTATGCGTGAATAGGGTGA
AGCCAGAGGAAACTCTGGTGGAGGCTCGCAGCGGTTCTGACGTGCAAATCGATCGTC-AA
ATTTGCGTATAGGGGC-GAAAGACTAATCGGTTAGACAGGGTCAGTTCA---CCCGTATA
GGGTGGTGGCATCTCT--TGCAT-CTTGTGCTGACATGAAT-ATCTCAGAGTAACCCGCA
ATACAAGGCAGCTGTTTCTATTCGGGACCCAAAGCGTAGATTCGACACCATTTGGCGACT
TTGCAAGCCCAAGATGATCTGCGACAGTGATGTTCCTAATGACGAC---GAATTCGGAGG
TGATCCAAAGGAGGCTGTGAAG---CGTTCGCATGGAGGATGTGGAAATACGCAACCTGA
GGTGCGCCAGCAAGCTTTGCAGCTTTGGGGAACATGGAAGATGCCAAAAGATGAAGAGAA
TGAGGGTGG--CAACACT----GAGAAGCGACAAATTACTCCAGAGATGGCTCTCAATGT
CTTCCGGTCCATGTCTTCCGATGAGATTCGCGATCTCGGTTTGAGCAACGACTATGCGCG
TCCTGACTGGTTGATCATCACTGTTCTTCCAGTTCCACCTCCTCCCGTTCGCCCCAGTAT
TTCTATGGATGGTACAAGCACAGGAATGCGCGGAGAGGATGATTTGACCTACAAGCTAGG
TGATATCATTCGTGCCAACGGCAATGTCAAGC-AGGCACAGCAAGAAGG

Figure 4B

Acidomelania_panicicola_KF874619
GTGTCTA---

------CATACTCTTGT-TGCTTTGGCAGGCCGTGG-CCTCCCAC--TGT----GGGCTC
AGCCTGC-----ATGTGCCTGCCAGAGGACC---AAACTCTGAATGTTAGTGATGTCTGA
GTACTATATAATAGTTAAAACTTTCAACAACGGATCTCTTGGTTCTGGCATCGATGAAGA
ACGCAGCGAAATGCGATAAGTAATGTGAATTGCAGAATTCAGTGAATCATCGAATCTTTG
AACGCACATTGCACCCGGTGGCATTCCGCCGGGTATGCCTGTTCGAGCGTCATTATAACC
ACTCAAGCCTGTCTTGGTGTTGGGGA-TTGCGAAT-CTCGCAGCCCTAGAGTCCAGTAGC
GTCACCTGTG-GGTCCTAAGCGTAGTAATTTCTCCTCGCTACAGAGCCT-----------
-----------------GCTCGTGGATAGTGTAAATCCAGTTCGGTCTGGTATCCCGC-G
GTTGACCTCGGATCAAGTAGGGATACCCGCTGAACTTAAGCATATCAATAAGCGGAGGAA
AAGAAACCAACAGGGATTAC--TAGTAACGGCGAGTGAAGCGGTAACTGCTCAAATTTGA
AAGCTGCC-----AACAGGCCGCGTTGTAATTTGTAGAAGATGCTTTGGGTGTCGGCCCA
GTCTAAGTTCCTTGGAACAGGACGTCATAGAGGGTGAGAATCCCGTATGTGATTGG-TGC
CGTCCCCCGTGTAAAGCTCTTTCGACGAGTCGAGTTGTTTGGGAATGCAGCTCAAAATGG
GTGGTAAATTTCATCTAAAGCTAAATATTGGCCAGAGACCGATAGCGCACAAGTAGAGTG
ATCGAAAGATGAAAAGCACTTTGGAAAGAGAGTTAAACAGTACGTGAAATTGTTGAAAGG
GAAGCGCTTGCAATCAGACTTGCAGGCGGTTGATCATCCGAGGTTC-TCCCCGGTGCACT
CGATCGTCT-TCAGGCCAGCATCGGTTTCAGTGGTGGGATAAAGGCTGTGAGAACGTGGC
TC--TTC------GGAGTGTTATAGCTCACGGTGCAATGCCGCCTACTGGGACCGAGGAC
CGCGCTTC-GGCTAGGATGCTGGCGTAATGGTTGTAAGCGACCCGTCTTGAAACACGGAC
CAAGGAGTCTAACATCTATGCGAGTGTTTGGGTGTCAAACCCATACGCGTAATGAAAGTG
AACGGAGGTGAGACCCCATTAGGGCGCATCATCGACCGATCCTGATGTCTTCGGATGGAT
TTGAGTAAGAGCATAGCTGTTGGGACCCGAAAGATGGTGAACTATGCGTGAATAGGGTGA
AGCCAGAGGAAACTCTGGTGGAGGCTCGCAGCGGTTCTGACGTGCAAATCGATCGTC-AA
ATTTGCGTATAGGGGC-GAAAGACTAATCGGTTAGACAGGGTCAGTTCA---CCCGTATA
GGGTGGTGGCATCTCT--TGCAT-CTTGTGCTGACATGAGT-ATCTCAGAGTAACCCGCA
ATACAAGGCAGCTGTTTCTATTCGGGATCCAAAGCGTAGATTCGACACCATTTGGCGACT
TTGCAAGCCCAAGATGATCTGCGACAGTGATGTTCCTAATGACGAC---GAATTCGGAGG
TGATCCAAAGGAGGCTGTGAAG---CGTTCCCATGGAGGATGTGGAAATACGCAACCTGA
GGTGCGCCAGCAAGCCTTGCAGCTTTGGGGAACATGGAAAATGCCAAAGGATGAAGAGAA
TGAGAGTGG--CAACACT----GAGAAGCGACAAATTACTCCAGAGATGGCTCTCAATGT
CTTCCGGTCCATGTCTTCCGATGAGATTCGCGATCTCGGTTTGAGCAACGACTATGCGCG
TCCTGACTGGTTGATCATCACTGTTCTTCCAGTTCCACCTCCTCCTGTTCGCCCCAGTAT
TTCTATGGATGGTACAAGCACAGGAATGCGCGGAGAGGATGATTTGACCTACAAGCTGGG
TGATATCATTCGCGCCAACGGCAATGTCAAGC-AGGCACAGCAAGAAGG

Figure 4C

```
Acidoradicia_panicicola_AL5m2-2
GTGTCTA-----------------------------------------------------
------------------------------------------------------------
------TCTACTCTTGT-TGCTTTGGCAGGCCGTGG-CCT-CCAC--CGC----GGGCTC
TGCCTGC-----GTGTGCCTGCCAGAGGACC---AAACTCTGAATTTTAGTGATGTCTGA
GTACTATATAATAGTTAAAACTTTCAACAACGGATCTCTTGGTTCTGGCATCGATGAAGA
ACGCAGCGAAATGCGATAAGTAATGTGAATTGCAGAATTCAGTGAATCATCGAATCTTTG
AACGCACATTGCGCCCGGTGGTATTCCGCCGGGCATGCCTGTTCGAGCGTCATTATAACC
ACTCAAGCCTAGCTTGGTATTGGGGT-TCGCGGT--CCCGCGGCCCCTAAAATCAGTGGC
GGTGCCGGTG-GGCTCTAAGCGTAGTAA-ATCTCCTCGCTATAGGGTCC-----------
-----------------CC---------------------------CCGGTTGCCCGC-G
GTTGACCTCGGATCAGGTAGGGATACCCGCTGAACTTAAGCATATCAATAAGCGGAGGAA
AAGAAACCAACAGGGATTAC-TCAGTAACGGCGAGTGAAGCGGTAACAGCTCAAATT-GA
AAGCTGCC-----AACAGGCCGCGTTGTAATTTGTAGAAGATGCTTTGGGGGTAGGCCTA
GTCTAAGTTCCTTGGAACAGGACGTCATAGAGGGTGAGAATCCCGTATGTGATTAG-TGC
CTGCTCCCGTGTAAAGCTCTTTCGACGAGTCGAGTTGTTTGGGAATGCAGCTCAAAATGG
GTGGTATATTTCATCTAAAGCTAAATATTGGCCAGAGACCGATAGCGCACAAGTAGAGTG
ATCGAAAGATGAAAAGCACTTTGGAAAGAGAGTTAAACAGTACGTGAAATTGTTGAAAGG
GAAGCGCTTGCAACCAGACTTGCAGGCGGTCGATCATCCGAGGTTC-TCCCCGGTGCACT
CGATCGTCT-TCAGGCCAGCATCGGTTTTGGTGGCGGGATAAAGGCTCTAGGAATGTGGC
TC--TTC------GGAGTGTTATAGCCTAGGGTGCAATGCCGCCTACCGGGACCGAGGAC
CGCGCTTC-GGCTAGGATGCTGGCGTAATGGTTGTAAGCGGCCCGTCTTGAAACACGGAC
CAAGGAGTCTAACATCTATGCGAGTGTTTGGGTGTCAAACCCATACGCGTAATGAAAGTG
AACGGAGGTGAGAGCCCTTTAGGGCGCATCATCGACCGATCCTGATGTCTTCGGATGGAT
TTGAGTAAGAGCATAGCTGTTGGGACCCGAAAGATGGTGAACTATGCGTGAATAGGGTGA
AGCCAGAGGAAACTCTGGTGGAGGCTCGCAGCGGTTCTGACGTGCAAATCGATCGTC-AA
ATTTGCGTATAGGGGC-GAAAGACTAATCGGCTAGACAGGGTCAGTTCG---CCCGAAAA
GGGTGGCGGATCTACT--TGTTC-TTTGTGCTGACATGAGT-TTCTCAGAGTAATCCGGC
ATACAAGGCAGCCGTTTCGATTCGAGACCCGAAGCGTAAGTTCGATACCATATGGCGACT
TTGCAAGCCCAAGATGATCTGCGACAGCGATGTCCCTAACGACGAT---GAATTTGGTGG
TGATCCAAAGGAAGCTGTTAAA---CGTTCTCATGGAGGTTGTGGCAATACTCAACCCGA
GGTTCGCCAACAAGCTTTACAGCTCTGGGGAACATGGAAGATGCCCAAGGATGAAGAAAA
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CTTCCGCAGCATGTCCTCGGCTGAGATTCGCGATTTGGGCTTGAGCAATGACTATGCACG
CCCTGACTGGCTTATCATTACTGTCCTTCCTGTTCCTCCCCCGCCTGTTCGACCGAGTAT
CTCCATGGATGGTACAAGCACAGGAATGCGCGGAGAGGATGATTTGACATACAAGCTTGG
TGATATTATTCGTGCAAACGGAAACGTTAAGC-AAGCCCAACAAGAGGG
```

Figure 4D

```
Acidoradicia_panicicola_CM11M2
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------------------------------------------------------------
------TCTACTCTTGT-TGCTTTGGCAGGCCGTGG-CCT-CCAC--CGC----GGGCTC
TGCCTGC-----GTGTGCCTGCCAGAGGACC---AAACTCTGAATTTTAGTGATGTCTGA
GTACTATATAATAGTTAAAACTTTCAACAACGGATCTCTTGGTTCTGGCATCGATGAAGA
ACGCAGCGAAATGCGATAAGTAATGTGAATTGCAGAATTCAGTGAATCATCGAATCTTTG
AACGCACATTGCGCCCGGTGGTATTCCGCCGGGCATGCCTGTTCGAGCGTCATTATAACC
ACTCAAGCCTAGCTTGGTATTGGGGT-TCGCGGT--CCCGCGGCCCCTAAAATCAGTGGC
GGTGCCGGTG-GGCTCTAAGCGTAGTAA-ATCTCCTCGCTATAGGGTCC-----------
-----------------CC---------------------------CCGGTTGCCCGC-G
GTTGACCTCGGATCAGGTAGGGATACCCGCTGAACTTAAGCATATCAATAAGCGGAGGAA
AAGAAACCAACAGGGATTACCTCAGTAACGGCGAGTGAAGCGGTAACAGCTCAAATTTGA
AAGCTGCC-----AACAGGCCGCGTTGTAATTTGTAGAAGATGCTTTGGGGGTCGGCCTA
GTCTAAGTTCCTTGGAACAGGACGTCATAGAGGGTGAGAATCCCGTATGTGATTAG-TGC
CGGCTCCCGTGTAAAGCTCTTTCGACGAGTCGAGTTGTTTGGGAATGCAGCTCAAAATGG
GTGGTATATTTCATCTAAAGCTAAATATTGGCCAGAGACCGATAGCGCACAAGTAGAGTG
ATCGAAAGATGAAAAGCACTTTGGAAAGAGAGTTAAACAGTACGTGAAATTGTTGAAAGG
GAAGCGCTTGCAACCAGACTTGCAGGCGGTCGATCATCCGAGGTTC-TCCCCGGTGCACT
CGATCGTCT-TCAGGCCAGCATCGGTTTTGGTGGCGGGATAAAGGCTCTAGGAATGTGGC
TC--TTC------GGAGTGTTATAGCCTAGGGTGCAATGCCGCCTACCGGGACCGAGGAC
CGCGCTTC-GGCTAGGATGCTGGCGTAATGGTTGTAAGCGGCCCGTCTTGAAACACGGAC
CAAGGAGTCTAACATCTATGCGAGTGTTTGGGTGTCAAACCCATACGCGTAATGAAAGTG
AACGGAGGTGAGAGCCCTTTAGGGCGCATCATCGACCGATCCTGATGTCTTCGGATGGAT
TTGAGTAAGAGCATAGCTGTTGGGACCCGAAAGATGGTGAACTATGCGTGAATAGGGTGA
AGCCAGAGGAAACTCTGGTGGAGGCTCGCAGCGGTTCTGACGTGCAAATCGATCGTC-AA
ATTTGCGTATAGGGGC-GAAAGACTAATCG------------------------------
--------------------------------GACATGAGT-TTCTCAGAGCAATCCGGC
ATACAAGGCAGCCGTTTCAATTCGAGACCCGAAGCGTAGGTTCGATACGATATGGCGACT
TTGCAAGCCCAAGATGATCTGCGACAGCGATGTCCCTAATGATGAT---GAATTTGGTGG
TGATCCAAAAGAAGCTGTTAAA---CGTTCTCATGGAGGTTGTGGCAATACTCAACCCGA
GGTTCGCCAGCAAGCTTTACAGCTCTGGGGAACATGGAAGATGCCCAAGGATGAAGAAAA
CGAGGGTG---CGACTCAA---GAAAAGAGACAGATTACTCCAGAGATGGCTCTGAACGT
CTTCCGCAGCATGTCCTCGGCTGAGATTCGCGATTTGGGCTTGAGCAATGACTATGCACG
CCCTGACTGGCTTATCATTACTGTCCTTCCCGTTCCTCCCCCACCTGTTCGACCAAGTAT
TTCCATGGATGGTACAAGCACAGGAATGCGCGGAGAGGATGATTTGACATACAAGCTTGG
TGATATTATCCGTGCAAATGGTTTCATTAAGC-AAGCCCAACAAGAGGG
```

Figure 4E

Acidoradicia_panicicola_WSF1-R37
GTGTCTA---

------TCTACTCTTGT-TGCTTTGGCAGGCCGTGG-CCT-CCAC--CGC----GGGCTC
TGCCTGC-----GTGTGCCTGCCAGAGGACC---AAACTCTGAATTTTAGTGATGTCTGA
GTACTATATAATAGTTAAAACTTTCAACAACGGATCTCTTGGTTCTGGCATCGATGAAGA
ACGCAGCGAAATGCGATAAGTAATGTGAATTGCAGAATTCAGTGAATCATCGAATCTTTG
AACGCACATTGCGCCCGGTGGTATTCCGCCGGGCATGCCTGTTCGAGCGTCATTATAACC
ACTCAAGCCTGGCTTGGTATTGGGAC-TCGCGGT--TCCGCGGCCCCTAAAATCAGTGGC
GGTGCCGGTG-GGCTCTAAGCGTAGTAA-ATCTCCTCGCTATAGGGTCC-----------
-----------------CT---------------------------CCGGTTGCCTGC--

---------TGTAAAGCTCTTTCGACGAGTCGAGTTGTTTGGGAATGCAGCTCAAAATGG
GTGGTATATTTCATCTAAAGCTAAATATTGGCCAGAGACCGATAGCGCACAAGTAGAGTG
ATCGAAAGATGAAAAGCACTTTGGAAAGAGAGTTAAACAGTACGTGAAATTGTTGAAAGG
GAAGCGCTTGCAACCAGACTTGCAGGCGGTCGATCATCCGAGGTTC-TCCCCGGTGCACT
CGATCGTCT-TCAGGCCAGCATCGGTTTTGGTGGCGGGATAAAGGCTCTAGGAATGTGGC
TC--TTC------GGAGTGTTATAGCCTAGGGTGCAATGCCGCCTACCGGGACCGAGGAC
CGCGCTTC-GGCTAGGATGCTGGCGTAATGGTTGTAAGCGGCCCGTCTTGAAACACGGAC
CAAGGAGTCTAACATCTATGCGAGTGTTTGGGTGTCAAACCCATACGCGTAATGAAAGTG
AACGGAGGTGAGAGCCCTTTAGGGCGCATCATCGACCGATCCTGATGTCTTCGGATGGAT
TTGAGTAAGAGCATAGCTGTTGGGACCCGAAAGATGGTGAACTATGCGTGAATAGGGTGA
AGCCAGAGGAAACTCTGGTGGAGGCTCGCAGCGGTTCTGACGTGCAAATCGATCGTC-AA
ATTTGCGTATAGGGGC-GAAAGACTAATCGGCTAGACAGGGTCAGTTCG---CCCGAAAA
GGGTGGCGGATCTACT--TGTTC-TTTGTGCTGACATGAGT-TTCTCAGAGCAATCCGGC
ATACAAGGCAGCCGTTTCAATTCGAGACCCGAAGCGTAGGTTCGATACGATATGGCGACT
TTGCAAGCCCAAGATGATCTGCGACAGCGATGTCCCTAATGATGAT---GAATTTGGTGG
TGATCCAAAGGAAGCTGTTAAA---CGTTCTCATGGAGGTTGTGGCAATACTCAACCCGA
GGTTCGCCAGCAAGCTTTACAGCTCTGGGGAACATGGAAGATGCCCAAGGATGAAGAAAA
CGAGGGTG---CGACTCAA---GAAAAGAGACAGATTACTCCAGAGATGGCTTTGAATGT
CTTCCGCAGCATGTCCTCGGCTGAGATTCGCGATTTGGGCTTGAGCAATGACTATGCACG
CCCTGATTGGCTTATCATTACTGTCCTTCCCGTTCCTCCCCCACCTGTTCGACCAAGTAT
TTCCATGGATGGTACAAGCACAGGAATGCGCGGAGAGGATGATTTGACATACAAGCTTGG
TGATATTATCCGTGCAAACGGCAACGTTAAGC-AAGCCCAACAAGAGGG

Figure 4F

```
Acidoradicia_taeda_CM14-P64
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------------------------------------------------------------
------TTTACTCTTGT-TGCTTTGGCAGGCCGTGG-CCT-CCAC--CGT----GGGCTC
TGTCTAC-----GCGTGTCTGCCAGAGGACC---AAACTCTGAATTTTAGTGATGTCTGA
GTACTATACAATAGTTAAAACTTTCAACAACGGATCTCTTGGTTCTGGCATCGATGAAGA
ACGCAGCGAAATGCGATAAGTAATGTGAATTGCAGAATTCAGTGAATCATCGAATCTTTG
AACGCACATTGCGCCCGGTGGTATTCCGCCGGGCATGCCTGTTCGAGCGTCATTATAACC
ACTCAAGCCTGGCTTGGTATTGGGGT-ACGCGGC--TTCGCGGCTCCTAAAATCAGTGGC
GGTGCCGGTG-GGCTCTAAGCGTAGTAA-ATCTCCTCGCTATAGGGTTC-----------
-----------------CT---------------------------CTGGTTGCTTGC--
------------------------------------------------------------
------------------------------------------------------------
------------------------------------------------------------
------------------------------------------------------------
------------------------------------------------------------
------------------------------------------------------------
------------------------------------------------------------
----------------------------------------------------GGTGCACT
CGATCGTCT-TCAGGCCAGCATCGGTTTCGGTGGCGGGATAAAGGCTCTAGGAATGTGGC
TC--TTC------GGAGTGTTATAGCCTAGGGTGCAATGCCGCCTACCGGGACCGAGGAC
CGCGCTTC-GGCTAGGATGCTGGCGTAATGGTTGTAAGCGGCCCGTCTTGAAACACGGAC
CAAGGAGTCTAACATCTATGCGAGTGTTTGGGTGTCAAACCCATACGCGTAATGAAAGTG
AACGGAGGTGAGAGCCCTTTAGGGCGCATCATCGACCGATCCTGATGTCTTCGGATGGAT
TTGAGTAAGAGCATAGCTGTTGGGACCCGAAAGATGGTGAACTATGCGTGAATAGGGTGA
AGCCAGAGGAAACTCTGGTGGAGGCTCGCAGCGGTTCTGACGTGCAAATCGATCGTC-AA
ATTTGCGTATAGGGGC-GAAAGACTAATCGGCTAGACAGGGTCAGTTCG---CCCGAATA
GGGTGGCAGATCTACT--TGTTC-TTTGTGCTGACATGAGT-ATCTCAGAGTAATCCGGC
GTACAAGGCAGCTGTTTCGATTCGGGACCCGAAGCGTAGGTTCGATACGATATGGCGACT
TTGCAAGCCCAAGATGATCTGCGACAGCGATGTCCCTAACGACGAT---GAATTTGGTGG
TGATCCAAAGGAAGCTGTCAAG---CGTTCTCATGGAGGTTGTGGTAATACTCAGCCCGA
GGTTCGTCAGCAGGCTCTACAGCTCTGGGGTACATGGAAGATGCCAAAGGATGAAGAAAA
TGAGGGGT---CAAGTCAA---GAAAAGAGACAAATCACTCCAGAGATGGCTTTAAATGT
CTTCCGAAGCATGTCCTCGGCTGAGATTCGCGACCTGGGCCTGAGCAACGACTACGCTCG
TCCCGACTGGCTCATCATTACAGTCCTTCCTGTTCCTCCTCCGCCCGTTCGCCCTAGTAT
TTCTATGGATGGCACAAGCACGGGAATGCGTGGAGAAGATGATTTGACCTACAAGCTTGG
TGATATAATTCGTGCCTACGGCAACGTTATGCAAAGCACAACAAGAATG
```

Figure 4G

Acidoradicia_taeda_WSF14-P22
GTGTCTA---

------TTTACTCTTGT-TGCTTTGGCAGGCCGTGG-CCT-CCAC--CGT----GGGCTC
TGTCTAC-----GCGTGTCTGCCAGAGGACC---AAACTCTGAATTTTAGTGATGTCTGA
GTACTATACAATAGTTAAAACTTTCAACAACGGATCTCTTGGTTCTGGCATCGATGAAGA
ACGCAGCGAAATGCGATAAGTAATGTGAATTGCAGAATTCAGTGAATCATCGAATCTTTG
AACGCACATTGCGCCCGGTGGTATTCCGCCGGGCATGCCTGTTCGAGCGTCATTATAACC
ACTCAAGCCTGGCTTGGTATTGGGGT-ACGCGGC--TTCGCGGCTCCTAAAATCAGTGGC
GGTGCCGGTG-GGCTCTAAGCGTAGTAA-ATCTCCTCGCTATAGGGTTC-----------
-----------------CT---------------------------CTGGTTGCTTGC--

-----GCTTGCAACCAGACTTGCAGGCGGTCGATCATCCGAGGTTC-TCCCCGGTGCACT
CGATCGTCT-TCAGGCCAGCATCGGTTTCGGTGGCGGGATAAAGGCTCTAGGAATGTGGC
TC--TTC------GGAGTGTTATAGCCTAGGGTGCAATGCCGCCTACCGGGACCGAGGAC
CGCGCTTC-GGCTAGGATGCTGGCGTAATGGTTGTAAGCGGCCCGTCTTGAAACACGGAC
CAAGGAGTCTAACATCTATGCGAGTGTTTGGGTGTCAAACCCATACGCGTAATGAAAGTG
AACGGAGGTGAGAGCCCTTTAGGGCGCATCATCGACCGATCCTGATGTCTTCGGATGGAT
TTGAGTAAGAGCATAGCTGTTGGGACCCGAAAGATGGTGAACTATGCGTGAATAGGGTGA
AGCCAGAGGAAACTCTGGTGGAGGCTCGCAGCGGTTCTGACGTGCAAATCGATCGTC-AA
ATTTGCGTATAGGGGC-GAAAGACTAATCGGCTAGACAGGGTCAGTTCG---CCCGAATA
GGGTGGCAGATCTACT--TGTTC-TTTGTGCTGACATGAGT-ATCTCAGAGTAATCCGGC
GTACAAGGCAGCTGTTTCGATTCGGGACCCGAAGCGTAGGTTCGATACGATATGGCGACT
TTGCAAGCCCAAGATGATCTGCGACAGCGATGTCCCTAACGACGAT---GAATTTGGTGG
TGATCCAAAGGAAGCTGTCAAG---CGTTCTCATGGAGGTTGTGGTAATACTCAGCCCGA
GGTTCGTCAGCAGGCTCTACAGCTCTGGGGTACATGGAAGATGCCAAAGGATGAAGAAAA
TGAGGGGT---CAAGTCAA---GAAAAGAGACAAATCACTCCAGAGATGGCTCTAAATGT
CTTCCGAAGCATGTCCTCGGCTGAGATTCGCGACCTGGGCCTGAGCAACGACTACGCTCG
TCCCGACTGGCTCATCATTACAGTCCTTCCTGTTCCTCCTCCGCCCGTTCGCCCTAGTAT
TTCTATGGATGGCACAAGCACGGGAATGCGTGGAGAAGATGATTTGACCTACAAGCTTGG
TGATATAATTCGTGCAAACGGCAACGTTAAGC-AAGCACAACAAGAAGG

Figure 4H

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Acidoradicia_taeda_WSF14-P13
GTGTCTA-----------------------------------------------------
------------------------------------------------------------
------TTTACTCTTGT-TGCTTTGGCAGGCCGTGG-CCT-CCAC--CGT----GGGCTC
TGTCTAC-----GCGTGTCTGCCAGAGGACC---AAACTCTGAATTTTAGTGATGTCTGA
GTACTATACAATAGTTAAAACTTTCAACAACGGATCTCTTGGTTCTGGCATCGATGAAGA
ACGCAGCGAAATGCGATAAGTAATGTGAATTGCAGAATTCAGTGAATCATCGAATCTTTG
AACGCACATTGCGCCCGGTGGTATTCCGCCGGGCATGCCTGTTCGAGCGTCATTATAACC
ACTCAAGCCTGGCTTGGTATTGGGGT-ACGCGGC--TTCGCGGCTCCTAAAATCAGTGGC
GGTGCCGGTG-GGCTCTAAGCGTAGTAA-ATCTCCTCGCTATAGGGTTC-----------
-----------------CT---------------------------CTGGTTGCTTGC--
------------------------------------------------------------
------------------------------------------------------------
------------------------------------------------------------
------------------------------------------------------------
------------------------------------------------------------
------------------------------------------------------------
------------------------------------------------------------
-----GCTTGCAACCAGACTTGCAGGCGGTCGATCATCCGAGGTTC-TCCCCGGTGCACT
CGATCGTCT-TCAGGCCAGCATCGGTTTCGGTGGCGGGATAAAGGCTCTAGGAATGTGGC
TC--TTC------GGAGTGTTATAGCCTAGGGTGCAATGCCGCCTACCGGGACCGAGGAC
CGCGCTTC-GGCTAGGATGCTGGCGTAATGGTTGTAAGCGGCCCGTCTTGAAACACGGAC
CAAGGAGTCTAACATCTATGCGAGTGTTTGGGTGTCAAACCCATACGCGTAATGAAAGTG
AACGGAGGTGAGAGCCCTTTAGGGCGCATCATCGACCGATCCTGATGTCTTCGGATGGAT
TTGAGTAAGAGCATAGCTGTTGGGACCCGAAAGATGGTGAACTATGCGTGAATAGGGTGA
AGCCAGAGGAAACTCTGGTGGAGGCTCGCAGCGGTTCTGACGTGCAAATCGATCGTC-AA
ATTTGCGTATAGGGGC-GAAAGACTAATCGGCTAGACAGGGTCAGTTCG---CCCGAATA
GGGTGGCAGATCTACT--TGTTC-TTTGTGCTGACATGAGT-ATCTCAGAGTAATCCGGC
GTACAAGGCAGCTGTTTCGATTCGGGACCCGAAGCGTAGGTTCGATACGATATGGCGACT
TTGCAAGCCCAAGATGATCTGCGACAGCGATGTCCCTAACGACGAT---GAATTTGGTGG
TGATCCAAAGGAAGCTGTCAAG---CGTTCTCATGGAGGTTGTGGTAATACTCAGCCCGA
GGTTCGTCAGCAGGCTCTACAGCTCTGGGGTACATGGAAGATGCCAAAGGATGAAGAAAA
TGAGGGGT---CAAGTCAA---GAAAAGAGACAAATCACTCCAGAGATGGCTCTAAATGT
CTTCCGAAGCATGTCCTCGGCTGAGATTCGCGACCTGGGCCTGAGCAACGACTACGCTCG
TCCCGACTGGCTCATCATTACAGTCCTTCCTGTTCCTCCTCCGCCCGTTCGCCCTAGTAT
TTCTATGGATGGCACAAGCACGGGAATGCGTGGAGAAGATGATTTGACCTACAAGCTTGG
TGATATAATTCGTGCAAACGGCAACGTTAAGC-AAGCACAACAAGAAGG
```

Figure 4I

Cudoniella_clavus_DQ491502
----------------------------------AAAAGTCGTAACAAGGTTTCCGTAG
GTGAACCTGCGGAAGGATCATTACAGTGTTCCCTGCCCTCACGGGTAGAAACGCCACCCT
TGTATATATTATCTTGT-TGCTTTGGCGGGCCGCCT-TTAGGCAC----T----GGCTTC
GGCTGGC-----TCGCGCCCGCCAGAGAACCCC-AAACTCTAAATGTTAGTGTCGTCTGA
GTACTATCTAATAGTTAAAACTTTCAACAACGGATCTCTTGGTTCTGGCATCGATGAAGA
ACGCAGCGAAATGCGATAAGTAATGTGAATTGCAGAATTCAGTGAATCATCGAATCTTTG
AACGCACATTGCGCCCCTTGGTATTCCGGGGGGCATGCCTGTTCGAGCGTCATTTAAACC
AATCCAGCAT-GCTGGGTCTTGGGCCTTCGCCTC--TGGGCGGGCCTCAAAATTAGTGGC
GGTGCCACCT-GGCTCTACGCGTAGTAA-TTCTTCTCGCGATGGAGTCCCAGGTGGAAGC
TTGCCAACAACCCCAAATTCTTTTAAAGGTTGACCTCGGATCAGGTAGGGATACCCGC--
----------------------------------CTAAGCATATCAATAAGCGGAGGAA
AAGAA?CCAACAGGGATTACCTCAGTAACGGCGAGTGAAGCGGTAACAGCTCAAATTTGA
AATCTGGCTCTTTCAGGGTCCGAGTTGTAATTTGTAGAAGATGCTTCGGGTGTGGCTCCG
GTCTAAGTTCCTTGGAACAGGACGTCATAGAGGGTGAGAATCCCGTATGTGACTGGTTGC
CTTCGCCCATGTGAAGCTCTTTCGACGAGTCGAGTTGTTTGGGAATGCAGCTCTAAATGG
GTGGTAAATTTCATCTAAAGCTAAATATTGGCCAGAGACCGATAGCGCACAAGTAGAGTG
ATCGAAAGATGAAAAGCACTTTGGAAAGAGAGTTAAACAGTACGTGAAATTGTTGAAAGG
GAAGCGCTTGCAACCAGACTTGCACGTCGTCGATCATCCTCAGTTC-TCTGGGGTGCACT
CGGCGGTGT-TCAGGCCAGCATCGGTTTCGGTGGTGGGATAAAGGCCTTGGGAATGTGGC
TCCTCTC----GGGGAGTGTTATAGCCCTCGGTGCAATGCCGCCTACTGGGACCGAGGAC
CGCGCTTC-GGCTAGGATGCTGGCGTAATGGTTGTAAGCGACCCGTCTTGAAACACGGAC
CAAGGAGTCTAACATCTATGCGAGTGTTTGGGTGTTAAACCCATACGCGTAATGAAAGTG
AACGGAGGTGAGAACCCTTTAGGGTGCATCATCGACCGATCCTGATGTCTTCGGATGGAT
TTGAGTAAGAGCATAGCTGTTGGGACCCGAAAGATGGTGAACTATGCCTAAATAGGGTGA
AGCCAGAGGAAACTCTGGTGGAGGCTCGCAGCGGTTCTGACGTGCAAATCGATCGTC-AA
ATTTGGGTATAGGGGC-GAAAGACTAATCGACTAGACAGGGTCAGTTGG---CCCGCATA
GCGTGGCATGTCT-TT--TGTGCCTTTGTGCTAACA-GAATGATTTCAGAGCAATCCAGC
GTACAAGGCAGCTGTTTCTATCCGAGATCCAAAGCGTAGATTTGATACAATATGGCGACT
GTGCAAGCCGAAGATGATTTGCGAGGGTGATGTGCAGGCGAATGAGGAAGAATTTGATCC
CAACCAAAAAGAACC---GAAG---CCGTCGCACGGAGGGTGTGGTAATTCTCAGCCTGA
AGTGCGTCAGACTGCTTTGCAACTATGGGGAACATGGAAAGTGCCTAAGGACGAAGATAA
CGAGAGTCAGTCGCCG------GAAAAGAGGCAGATTACTCCCGAAATGGCTCTGGCTGT
CTTCCGAAGCATTTCCACGGAAGAAATCTTC?ACCTTGGCCTGAGTAATGATTATGCGCG
TCCCGAATGGATGATCATAACGGTTCTCCCAGTTCCTCCACCACCTGTTCGACCCAGTAT
TTCAATGGATGGCACTGGTCAGGGCATGCGCGGAGAGGACGATTTGACATATAAGTTGGG
AGATATCATCCGGGCAAACGGCAATGTGCGGC-AAGCTCAGCAGGAAGG

Figure 4J

Dermea_acerina_AF141164
GTGTCGT---

------TATACCTTCGT-TGCTTTGGTGGGCCGCTGGGCTTCGGCCTGGCTCCTGGCTCC
GGCTAGG-----GAGTGCCCGCCAGAGGACC-TTAAAACCTGAA-GTTAGTGTCGTCTGA
GTACTATACAATAGTTAAAACTTTCAACAACGGATCTCTTGGTTCTGGCATCGATGAAGA
ACGCAGCGAAATGCGATAAGTAATGTGAATTGCAGAATTCAGTGAATCATCGAATCTTTG
AACGCACATTGCGCCCCTTGGTATTCCGGGGGGCATGCCTGTTCGAGCGTCATTACAACC
-CTCAAGCTCTGCTTGGTATTGGGCG-TCACCGGGTTCGGTGTGCCTTAAAATCAGTGGC
GGCGCCGTCT-GGCTCTAAGCGTAGTAC-ATACTCTCGCTATGGACGCC-----------
-----------------TG---------------------------GCGGATGCTTGC--

--GA
AATCTGGGTCTTTTAGGCTCCGAGTTGTAAT?TGTAGAAGATGCTTCGGGTGCGGCTCCG
GTCTAAGTTCCTTGGAACAGGACGTCATAGAGGGTGAGAATCCCGTATGTGATCGGGGGC
TTGCGCCCATGTGAAGCTCTTTCGACGAGTCGAGTTGTTTGGGAATGCAGCTCAAAATGG
GTGGTATATTTCATCTAAAGCTAAATATTGGCCAGAGACCGATAGCGCACAAGTAGAGTG
ATCGAAAGATGAAAAGCACTTTGGAAAGAGAGTTAAACAGTACGTGAAATTGTTGAAAGG
GAAGCGCTTGCAACCAGACTTGGGCGGGGTTGATCATCTAGGGTTC-TCCCTAGTGCACT
CGACCTCGC-ACAGGCCAGCATCGGTTCCGGTGGTTGGATAAAGGCCTTGGGAATGTAGC
TTCTTTC----GGGGAGTGTTATAGCCCTCGGTGCAATGCAGCCTACTGGGACCGAGGAC
CGCGCTTC-GGCTAGGATGCTGGCGTAATGGTTGTAAGCGACCCGTCTTGAAACACGGAC
CAAGGAGTCTAACATCTATGCGAGTGTTTGGGTGTCAAACCCATACGCGTAATGAAAGTG
AACGGAGGTGAGAACCCTTAAGGGTGCATCATCGACCGATCCTGATGTCTTCGGATGGAT
TTGAGTAAGAGCATAGCTGTTGGGACCCGAAAGATGGTGAACTATGCCTGAATAGGGTGA
AGCCAGAGGAAACTCTGGTGGAGGCTCGCAGCGGTTCTGACGTGCAAATCGATCGTC-AA
ATTTGGGTATAGGGGC-GAAAGACTAATCGGCTAGACAGGGTCAGTTCT---CCCACGTA
GCGTGGGGAGCATGAT--TGTTTCTGTGTGCTAACGTCAAT-ATCTCAGAGTAATCCAGC
GTACAAAGCAGCCGTTTCGATTCGAGACCCGAAGCGTAGGTTCGATACGATCTGGCGACT
TTGCAAGCCCAAGATGATCTGTGATAGCGATTTGACTGCCGCCGATGATGATTTCAATGC
AGACCCGAAGGAAGCCGCAAAG---CGCTCGCACGGTGGATGTGGAAATACTCAGCCTGA
GGTGCGCCAGTCGGCCTTGCAGCTGTGGGGTACATGGAAGGTTCCAAAGGATGAAGACAA
TGATGGTGCTACTGCC------GAAAAGAAGCAGATCACTGCAGAGATGGCCCTGAATGT
CTTCCGAAGCATTTCCACTTCTGAGATCCAAGACCTTGGCTTGAGTACTGACTATGCGCG
ACCTGAATGGATGATCATTACGGTTCTTCCAGTTCCTCCTCCACCTGTTCGACCGAGTAT
TTCGATGGACGGCACTGGGCAAGGCATGCGAGGAGAGGATGATTTGACATACAAGCTTGG
CGATATCATTCGTGCGAATGGCAACGTTCGAC-AGGCCCAGCAAGAAGG

Figure 4K

Hyaloscypha_aureliella_JN943611
GTGCCTGGTCTAAGATATAGTCGGTCCCGGCCCGAAAGGGCCGGGGAACAGCGTCCGTAG
GTGAACCTGCGGAAGGATCATTACAGAGTTCATGCCCTCACGGGTAGATCTCCCACCCTT
GAATACCTTACCTTTGTCTGCTTTGGCGGGCCACGT-----CCGCG-TGC----CGGCTC
CGGCTGG-----TTGCGCCCGCCAGAGGACC--CAAACTCTTTTGTTTAGTGATGTCTGA
GTACTATATAATAGTTAAAACTTTCAACAACGGATCTCTTGGTTCTGGCATCGATGAAGA
ACGCAGCGAAATGCGATAAGTAATGTGAATTGCAGAATTCAGTGAATCATCGAATCTTTG
AACGCACATTGCGCCCCTTGGTATTCCGAGGGGCATGCCTGTTCGAGCGTCATTATGACC
ACTCAAGCCTGGCTTGGTGTTGGGGT-CCGCGGT--CCCGCGGCCCTTAAAATCAGTGGC
GGCGCCATCT-GGCTCTCAGCGTAGTAA-TACTCCTCGCTACAGGGTCC-----------
---C--

---------------------------ACGGCGAGTGAAGCGGCAACAGCTCAAATTTGA
AATCTGGCTCCTGCGGGGCCCGAGTTGTAATTTGTAGAAGATGCTTTGAGCGTGGCTCCG
GTCTAAGTTCCTTGGAACAGGACGTCATAGAGGGTGAGAATCCCGTATGTGACTGGGTGC
CTCCGTTCGTGTAAAGCTCTTTCGACGAGTCGAGTTGTTTGGGAATGCAGCTCAAAATGG
GTGGTAAATTTCATCTAAAGCTAAATATTGGCCAGAGACCGATAGCGCACAAGTAGAGTG
ATCGAAAGATGAAAAGCACTTTGGAAAGAGAGTTAAACAGTACGTGAAATTGTTGAAAGG
GAAGCGCTTGCAACCAGACTTGCCCGCTGCTGATCATCCGAGGTTC-TCCCCGGTGCACT
CGGCAGCGA-TCAGGCCAGCATCGGTTCTGGTGGGCGGATAAAGGCCTTGGGAATGTAGC
TTCCTTC----GGGGAGTGTTATAGCCCTCGGTGCAATGCGCCCTACCGGGACCGAGGAC
CGCGCTTC-GGCTAGGATGCTGGCGTAATGGTTGTAAGCGACCCGTCTTGAAACACGGAC
CAAGGAGTCTAACATCTATGCGAGTGTTTGGGTGTTAAACCCATACGCGTAATGAAAGTG
AACGGAGGTGAGAACCCTTAAGGGTGCATCATCGACCGATCCTGATGTCTTCGGATGGAT
TTGAGTAAGAGCATAGCTGTTGGGACCCGAAAGATGGTGAACTATGCCTGAATAGGGTGA
AGCCAGAGGAAACTCTGGTGGAGGCTCGCAGCGGTTCTGACGTGCAAATCGATCGTC-AA
ATTTGGGTATAGGGGC-GAAAGACTAATCGACTTGACAGAGTCAGTGTG---CCTGAACT
TGAGGGCCGAGTTTCTTGTGTGCCTTTATGCTAACTTCATG-ATTGCAGAACAATCCGGC
GTACAAAGCTGCTGTGAGCATTCGAGACCCGAAACGTCGGTTCGATGCGATATGGCGACT
TTGCAAACCGAAATTGATCTGCGACAGTGATTTGAGTGCAGGGGACGAGGGCTTCGACGC
TGACCCAAAGGAACTTGCGAAA---CGCTCGCATGGAGGATGTGGAAATAAACAACCAGA
AGTGCGCCAGAGCGCCCTTCAGCTCACCGGCACTTTTAAGCCTTCGAAGGAAGAACTCAG
CGAGGGC------ATGCAGCCAGAAAAGAAGTTAATCACCCCAGAGGCAGCTCTGCACAT
CTTCCGAAGCATTTCCTCCGACGAGATTCGCGACTTAGGCCTGAGCAATGATTATGCGCG
CCCGGAATGGATGATCATCACAGTCCTTCCCGTGCCTCCTCCTCCTGTTCGGCCCAGTAT
TTCTATGGATGGCACTGGTCAAGGTATGCGAGGAGAGGATGATTTGACATACAAACTTGG
TGACATCATCCGTGCGAATGGAAACGTTCGAC-AGGCGCATCAAGAGGG

Figure 4L

Lachnum_virgineum_DQ491485
GTATCAT---

------TATAGAAT-GT-TGCTTTGGCGGGCTGCGTGCCTAGCAC----------GCCTC
GATTCGCGTCGAGCGCGCCCGCCAGAGGACCCCTAAACTSTGAATGTTAGTGTCGTCTGA
GTACTATTAAATAGTTAAAACTTTCAACAACGGATCTCTTGGTTCTGGCATCGATGAAGA
ACGCAGCGAAATGCGATAAGTAATGTGAATTGCAGAATTCAGTGAATCATCGAATCTTTG
AACGCACATTGCGCCCCTTGGTATTCCGGGGGGCATGCCTGTTCGAGCGTCATTTATACC
AATCTARCCTGGCTAGGTGTTGGGCC-TCGCCAG--TTGGCGGGCCTTAAAACTAGTGGC
GGTGCTCTTC-AGCTCTACGCGTAGTAA--TTTTCTCGCTATAGGGTCT-----------
--GGGGAGATGCTTGC--

-------CCACAGGGATTACCTCAGTAACGGCGAGTGAAGCGGTAACAGCTCAAATTTGA
AATCTGGCTCTTTTAGGGTCCGAGTTGTAATTTGTAGAAGATGCTTTGGGTGTGGCCCTG
GTCTAAGTTCCTTGGAACAGGACGTCATAGAGGGTGAGAATCCCGTATGTGACTAGGTGC
CTTCGCCCGTGTAAAGCTCTTTCGACGAGTCGAGTTGTTTGGGAATGCAGCTCAAAATGG
GTGGTAAATTTCATCTAAAGCTAAATATTGGCCAGAGACCGATAGCGCACAAGTAGAGTG
ATCGAAAGATGAAAAGCACTTTGGAAAGAGAGTTAAACAGTACGTGAAATTGTTGAAAGG
GAAGCGCTTGCAACCAGACTTAGTTGCTGCCGATCATCCAGGGTTC-TCCCTGGTGCACT
CGGTAGTAT-CTAGGCCAGCATCGGTTTGGGTGGTGGGATAAAGGCCTTGGGAATGTAGC
TTCTTTC----GGGGAGTGTTATAGCCCTCGGTGCAATGCCGCCTACCCGGACCGAGGAC
CGCGCTTC-GGCTAGGATGCTGGCGTAATGGTTGTAAGCCACCCGTCTTGAAACACAGAC
CAAGGAGTCTAACATCTATGCGAGTATTTGGGTGTTAAACCCATATGCGTAATGAAAGTG
AACGGAGGTGAGAACCCTTAAGGGTGCATCATCGACCGATCCTGATGTCTTCGGATGGAT
TTGAGTAAGAGCATAGCTGTTGGGACCCGAAAGATGGTGAACTATGCCTAAATAGGGTGA
AGCCAGAGGAAACTCTGGTGGAGGCTCGCAGCGGTTCTGACGTGCAAATCGATCGTC-AA
ATTTGGGTATAGGGGC-GAAAGACTAATCGGCTTGACAGGGTCAGTTCA----CCGTAAA
AGGTGTTGGCTTCGCT--TGTTC-TTTTTGCTGACA-GAAT-ATCTCAGGGTAATCCCCA
GTACAAGGCAGCTGTTTCTATTCGTGATCCAAAGCGTAGATTCGATACAATCTGGCGACT
TTGCAAGCCCAAGATGATCTGCGATAGCGATGTCCCTAATGAAGAT---GAATTCGGTGG
TGATCCAAAGGAAGCTGTGAAG---CGTTCGCATGGAGGATGTGGAAATACACAACCTGA
GGTCCGCCAACAGGCATTGCAGCTCTGGGGAACATGGAAGATGCCAAAGGATGAGGAGAA
CGAGGGTGG--CAACTCG----GAGAAGAGACAAATTACACCAGAGATGGCTCTCAATGT
CTTCAGATCCATGTCTTCTGAAGAAATTCGCGACCTCGGTCTCAGCAACGATTATGCACG
TCCTGACTGGTTGATTATTACAGTTCTTCCAGTTCCGCCTCCTCCTGTTCGACCCAGTAT
TTCCGTGGACGGCACGAGCACAGGTATGCGCGGAGAGGATGATTTGACATACAAGCTTGG
TGATATCATTCGTGCCAACGGCAATGTGAAGC-AGGCTCAACAAGAAGG

Figure 4M

Loramyces_macrosporus_DQ471005
GTGTCTA--

------TATACTCTTGT-TGCTTTGGCAGGCCGTGG-TCT-CGACCCTGT----GGGCTT
TGCCTGC-----ATGTGCCTGCCAGAGGACC---AAACTCTGAATTTTAGTGATGTCTGA
GTACTATATAATAGTTAAAACTTTCAACAACGGATCTCTTGGTTCTGGCATCGATGAAGA
ACGCAGCGAAATGCGATAAGTAATGTGAATTGCAGAATTCAGTGAATCATCGAATCTTTG
AACGCACATTGCGCCCGGTGGTATTCCGCCGGGCATGCCTGTTCGAGCGTCTCTATCAAC
CTACACGCTCCGCGTGGAATTGGGGC-CTGCGGTCACCTGCAGCCCTAGAACCCAACAGC
GATACCGAGT-GGTCCTCAGCGTAGTAC--ATACCCCGCTACAGGCCTC-----------
-----------------CT---------------------------CTGGTGTTCTGC--

-TGGTCTATATCATCTAAAGCTACATATTGGCCAGAGGCCGATAGCGCACAAGTAGAGTG
ATCGAAAGATG?AAAGCACTTTGGAAAGAGAGTTAAACAGTACGTGAAATTGTTGAAAGG
GAAGCGCTTGCAATCAGACTTGCAGGCGGTTGATCATCCGGGGTTT-TCCCCGGTGCACT
CGATCGTCT-TCAG??CAGCATCAGTTCTCGTGGTGGGATAAAGGCTGTGAGAATGTGGC
TC--TTC------GGAGTGTTATAGCTCACGGTGCAATGCTGCCTACGGGGACTGAGGAC
CGCGCTTC-GGCTAGGATGCTGGCGTAATGGTTGTAAGCGACCCGTCTTGAAACACGGAC
CAAGGAGTCTAACATCTATGCGAGTGTTTGGGTGTCAAACCCATACGCGTAATGAAAGTG
AACGGAGGTGAGAACCCTTTAGGGCGCATCATCGACCGATCCTGATGTCTTCGGATGGAT
TTGAGTAAGAGCATAGCTGTTGGGACCCGAAAGATGGTGAACTATGCGTGAATAGGGTGA
AGCCAGAGGAAACTCTGGTGGAGGCTCGCAGCGGTTCTGACGTGCAAATCGATCGTC-AA
ATTTGCGTATAGGGGC-GAAAGACTAATCGCCTTGACAGAGTTAGTCAG---CCCAGAAG
GCGTGACGTTTCTTGT--TCCTCATTTATGCTAACGTAATGGCCATCAGACCAATCCTCA
GTATAAGGCGGCTCTTTCTATTCGTGATCCAAAGCGTAGATTCGATACGATCTGGCGGCT
CTGCAAACCTAAGATGATTTGCGAGATTGATAGCACACCGGAAGATCTAGATTTCGAAGG
AAAGCCAACGGATGCCGGGAAAGTCCGAAGTCATGGTGGATGCGGAAATATTCAACCGGA
AGTTCGCCAGACCGCGCTTCAACTTTGGGGCACTTGGAAGGTACCAAAGGATGAGGATAA
TGAGG------CACAACAACCTGAGAAGAAGCAGATCTCACCTGAGATGGCATTGCAGGT
CTTCCGTAGCATCTCAAATGAGGAGATTCACGATCTTGGTCTGAACAATGATTATGCTCG
GCCAGAGTGGATGATTATCACCGTTCTTCCCGTACCTCCACCACCTGTCCGACCAAGTAT
TTCGATGGACGGCACTGGACAGGGCATGCGAGGAGAGGATGATTTGACTTATAAGCTTGG
CGATATCATCCGCGCGAATGGTAACGTCCGTC-AAGCACAGCAGGAAGG

Figure 4N

```
Mollisia_cinerea_DQ491498
GTGTCTA-----------------------------------------------------
------------------------------------------------------------
------CATACTCTTGT-TGCTTTGGCAGGCCGTGG-TCT-CCAC--TGT----GGGCTC
TGCCTAC-----ATGTGCCTGCCAGAGGACC---AAAATCTGAATTTTAGTGATGTCTGA
GTACTATATAATAGTTAAAACTTTCAACAACGGATCTCTTGGTTCTGGCATCGATGAAGA
ACGCAGCGAAATGCGATAAGTAATGTGAATTGCAGAATTCAGTGAATCATCGAATCTTTG
AACGCACATTGCGCCCTGTGGTATTCCGCAGGGCATGCCTGTTCGAGCGTCATTATAACC
ACTCAAGCCTGGCTTGGTATTGGAGT-TTGCGGT--TCCGCAGCTCCTAAAATCAGTGGC
GGTGCCGGTGTGGCTCTACGCGTAGTAA-TTCTTCTCGCGATGGAGTTC-----------
-----------------CC---------------------------CTGGTTGCTTGC--
------------------------------------------------------------
-------------------------TAACGGCGAGTGAAGCGGTAACAGCTCAAATTTGA
AAGCTACC-----AACAGGTCGCATTGTAATTTGTAGAAGATGCTTTGGGTGTTGACCTA
GTCTAAGTTCCTTGGAACAGGACGTCATAGAGGGTGAGAATCCCGTATGTGATTAG-TGT
CAGCCCCCGTGTAAAGCTCTTTCGACGAGTCGAGTTGTTTGGGAATGCAGCTCAAAATGG
GTGGTAAATTTCATCTAAAGCTAAATATTGGCCAGAGACCGATAGCGCACAAGTAGAGTG
ATCGAAAGATGAAAAGCACTTTGGAAAGAGAGTTAAACAGTACGTGAAATTGTTGAAAGG
GAAGCGCTTGCAATCAGACTTGCAGGCAGTCGATCATCCGAGGTTC-TCCCCGGTGCACT
CGATTGTCT-TCAGGCCAGCATCGGTTTCGGTGGTGGGATAAAGGCTGTGGGAATGTGGC
TC--TTC------GGAGTGTTATAGCCCACGGTGCAATGCCGCCTACCGGGACCGAGGAC
CGCGCTTC-GGCTAGGATGCTGGCGTAATGGTTGTAAGCGACCCGTCTTGAAACACGGAC
CAAGGAGTCTAACATCTATGCGAGTGTTTGGGTGTCAAACCCATACGCGTAATGAAAGTG
AACGGAGGTGAGAACCCTTTAGGGTGCATCATCGACCGATCCTGATGTCTTCGGATGGAT
TTGAGTAAGAGCATAGCTGTTGGGACCCGAAAGATGGTGAACTATGCGTGAATAGGGTGA
AGCCAGAGGAAACTCTGGTGGAGGCTCGCAGCGGTTCTGACGTGCAAATCGATCGTC-AA
ATTTGCGTATAGGGGC-GAAAGACTAATCGGCTAGACAGGGTCAGTTCG---CCCGAAGA
GGGTGGCAGATCTACT--TGTTC-TTTGTGCTGACATGAGT-ATCTCAGAGTAATCCGGC
ATATGCAGCAGCTACAAGTATTCGCGACCCAAAGCGTAGGTTCGATACGATATGGCGACT
CTGCAAACCAAAAATGATCTGCGATAGCGATGTCCCAAATGAAGAT---GAATTCGGAGG
TGATCCTAAGGAAGCTGTCAAG---CGCTCACATGGAGGTTGTGGAAACACTCAGCCCGA
AGTGCGTCAACAATCTCTCCAACTTTGGGGTACATGGAAGATGCCAAAGGATGAGGAGAA
CGAGGGCGGTGCAACGCAG---GAGAAGAAACAAATTACTCCAGAGATGGCTCTCAATGT
CTTCAAAAGCATGTCCACCAAGGAGATCTACGATCTTGGCTTGAACAACGACTACGCTCG
TCCTGACTGGTTGATTATCACTGTTCTTCCAGTTCCACCTCCCCCAGTCCGACCAAGTAT
CTCCATGGATGGCACAAGTACCGGCATGCGTGGAGAGGATGATTTGACATACAAGCTTGG
TGATATCATTCGTGCAAATGGAAACGTTAAGC-AGGCACAACAGGAAGG
```

Figure 4O

```
Monilinia_laxa_EF153017
GTGGAAGT---------------------------AAAAGTCGTAACAAGGTTTCCGTAG
GTGAACCTGCGGAAGGATCATTACAGAGTTCATGCCCGAAAGGGTAGACCTCCCACCCTT
GTGTATTATTACTTTGT-TGCTTTGGCGAGCTG----CC--------TTC----GGGCCT
TG-----------TATGCTCGCCAGAGAATAATCAAACTCTTTTTATTAATGTCGTCTGA
GTACTATATAATAGTTAAAACTTTCAACAACGGATCTCTTGGTTCTGGCATCGATGAAGA
ACGCAGCGAAATGCGATAAGTAATGTGAATTGCAGAATTCAGTGAATCATCGAATCTTTG
AACGCACATTGCGCCCCTTGGTATTCCGGGGGGCATGCCTGTTCGAGCGTCATTTCAACC
-CTCAAGCACAGCTTGGTATTGAGTCTATGTCAGCAATGGCAGGCTCTAAAATCAGTGGC
GGCGCCGCTG-GGTCCTGAA-----------------------------------------
------------------------------------------------------------
------------------------------------------------------------
------------GGGATTACCTCAGTAACGGCGAGTGAAGCGGTAAAAGCTCAAATTTGA
AATCTGGCTCTTTTAGAGTCCGAGTTGTAATTTGTAGAAGATGCTTCGGGTGTGGTTCCG
GTCTAAGTTCCTTGGAACAGGACGTCATAGAGGGTGAGAATCCCGTATGTGACTGGATAC
CTATGCTCATGTGAAGCTCTTTCGACGAGTCGAGTTGTTTGGGAATGCAGCTCAAAATGG
GTGGTATATTTCATCTAAAGCTAAATATTGGCCAGAGACCGATAGCGCACAAGTAGAGTG
ATCGAAAGATGAAAAGCACTTTGGAAAGAGAGTTAAACAGTACGTGAAATTGTTGAAAGG
GAAGCGCTTGCAATCAGACTTGCACTTGGT-GTTCATCGGGGTTTC-TACCCCGTGTACT
TCATCAAGT-TCAGGCCAGCATCAGTTTGGGTGGTTAGATAAAGGCTTAGAGAATGTGGC
CCTCTTC----GGGGGGTGTTATAGCTCTAGGTGCAATGTAGCCTACCTGG??TGAGG?C
CGCGCTTC-GGCTA?GATGCTGGCGTAATGGTTGTAAGCGACCCGTCTTGAAACACGGAC
CAAGGAGTGTACCTAATATGCGAGTGTTTGGGTGTT-AACCCATACGCGTAATGAAAGTG
AACGGAGGTGAGAGCCCTTAAGGGTGCATCATCGACCGATCCTGATGTCTTCGGATGGAT
TTGAGTAAGAGCATATTGGGTGCGACCCGAAAGATGGTGATCTATACGTGAATAGGGTGA
AGCCAGAGGAAACTCTGGTGGAGGCTCGCAGCGGTTCTGACGTGCAAATCGATCGTC-AA
ATTTGCGTATAGGGGC-GAAAGACTAATCGACTAGACAGGGTTAGTTTGCAACCAACTTG
AGGTGGTTTGTTT-CA--TGTGCCTTGATGCTAACACCAAA-GTATCAGAGTAATCCAGC
TTACAAGGCAGCCGTTTCCATCCGTGATCCTAAGCGCAGATTCGAAGCAATATGGAAACT
CTGCAAGTCCAAGATGATTTGTGATAGTGACGTCCAGGCGAACGAGGAGGAATTCAATGG
AGATCCAAAGGAAGCTGCAAAG---CGATCGCATGGAGGATGCGGCAATACTCAACCTGA
AGTCCGTCAAACTGCTCTGGCCCTCTGGGGTACGTGGAAGCCGCCCAAGGATGAAGACGG
AGAGGCTGT------GCAACCTGACAAGAGACAAATCACTCCGGAGATGGCTCTTAACGT
CTTTCGCAGCATGACCACTGCAGAAATCCAGGATGTTGGATTGAACGCAGATTATGCTCG
CCCAGAATGGATGATTATTACCGTTCTACCAGTACCACCGCCTCCCGTTCGACCAAGTAT
TTCCATGGATGGTACTGGTCAGGGTATGCGAGGAGAGGATGATTTGACATACAAGTTGGG
TGATATCATTCGTGCCAATGGTAACGTTCGTC-AAGCACAACAAGAAGG
```

Figure 4P

```
Phialocephala_fortinii_AB671499
GTGTTTA-----------------------------------------------------
------------------------------------------------------------
------CATACTATTGT-TGCTTTGGCGGGCCGTGG-CCT-CCAC--TGC----GGGCTC
TGCTCGT-----GTGTGCCCGCCAGAGAACC---AAACTCTGAATGTTAGTGATGTCTGA
GTACTATCTAATAGTTAAAACTTTCAACAACGGATCTCTTGGTTCTGGCATCGATGAAGA
ACGCAGCGAAATGCGATAAGTAATGTGAATTGCAGAATTCAGTGAATCATCGAATCTTTG
AACGCACATTGCGCCCTGTGGTATTCCGCAGGGCATGCCTGTTCGAGCGTCATT-TAACC
ACTCACGCCTAGCGTGGTATTGGGGC-ACGCGGTC-TCCGCGGCCCTCAAAATGAGTGGC
GGCGCCGGTG-GGCTCTAAGCGTAGTAC-ATACTCCCGCTATAGAGTTC-----------
-----------------CC---------------------------CCGGTGGCTCGC--
------------------------------------------------------------
------------------------GTAACGGCGAGTGAAGCGGTAACAGCTCAAATTTGA
AAGCTGCC-----AACAGGCCGCGTTGTAATTTGTAGAAGCTGCTTTGGGTGTCGGCCCG
GTCTAAGTTCCTTGGAACAGGACGTCATAGAGGGTGAGAATCCCGTATGTGATCGG-TGC
CGTTGCCCGTGTAAAGCGCTTTCGACGAGTCGAGTTGTTTGGGAATGCAGCTCAAAATGG
GTGGTAAATTTCATCTAAAGCTAAATATTGGCCAGAGACCGATAGCGCACAAGTAGAGTG
ATCGAAAGATGAAAAGCACTTTGGAAAGAGAGTTAAACAGTACGTGAAATTGTTGAAAGG
GAAGCGCTTGCAACCAGACTTGCGGGCGGTCGATCATCCGAGGTTC-TCCCCGGTGCACT
CGATCGTTC-TCAGGCCAGCATCGGTTTCCGGGGTGGGATAAAGGCGGTGGGAATGTGGC
TC--TTC------GGAGTGTTATAGCCCACCGTGCAATGCCGCCACTGGGGACCGAGGAC
CGCGCTTC-GGCTAGGATGCTGGCGTAATGGTTGTAAGCGACCCGTCTTGAAACACGGAC
CAAGGAGTCTAACATCTATGCGAGTGTTTGGGTGTCAAACCCATACGCGTAATGAAAGTG
AACGGAGGTAAGAGCCCTTTAGGGTGCATTATCGACCGATCCTGATGTCTTCGGATGGAT
TTGAGTAAGAGCATAGCTGTTGGGACCCGAAAGATGGTGAACTATGCGTGAATAGGGTGA
AGCCAGAGGAAACTCTGGTGGAGGCTCGCAGCGGTTCTGACGTGCAAATCGATCGTC-AA
ATTTGCGTATAGGGGC-GAAAGACTAATCGGCTAGACAGAGTCAGTTCG---CCCGATGA
GGGTGGCAGATCTACT--TGTTC--TTGTGCTGACATGAGT-ATCTCAGAGTAATCCGGC
CTTCAAAGCAGCTGTTTCCATTCGAGACCCGAAGCGTAGGTTCGATACGATTTGGCGACT
TTGCAAGCCCAAGATGATCTGCGATAGCGACGTTTCTGCGGACGATCAGGAATTCGGTGG
CGATCCAAGGGAAGCTGTGAAG---CGCTCTCATGGAGGTTGTGGAAATACTCAGCCCGA
GGTGCGCCAGCAGGCTCTGCAGCTTTGGGGTACATGGAAGATGCCTAAGGACGAGGAGAA
CGAGGG------AAACCAATCCGAGAAGAGACAAATCACTCCAGAGATGGCTCTGAACGT
CTTCCGAAGCATGTCTACTGCTGAGATTCGCGACCTTGGGTTGAGCAACGATTATGCCCG
TCCCGACTGGCTGATCATCACAGTCCTTCCAGTTCCTCCTCCGCCGGTTCGACCAAGTAT
TTCTATGGATGGCACAAGCACTGGAATGCGTGGAGAAGATGATTTGACATACAAGCTCGG
TGATATCATTCGTGCGAATGGAAATGTCAAGC-AGGCACAACAGGAAGG
```

Figure 4Q

Vibrissea_truncorum_EU434855
GTGTTTA---

------CATACTCTTGT-TGCTTTGGCAGGCCGTGG-CCT-CCAC--TGC----GGGCTC
TGCTCGT-----ACGTGCCCGCCAGAGGACC---AAACTCTGAATGTTAGTGATGTCTGA
GTACTATATAATAGTTAAAACTTTCAACAACGGATCTCTTGGTTCTGGCATCGATGAAGA
ACGCAGCGAAATGCGATAAGTAATGTGAATTGCAGAATTCAGTGAATCATCGAATCTTTG
AACGCACATTGCGCCCGGTGGTATTCCGCCGGGCATGCCTGTTCGAGCGTCATTATAACC
AATCACGCCTGGCGTGGTGTTGGGGC-ACACGGC--TCCGTGGCCCTCAAAATCAGTGGC
GATGCCGGTT-GGCTCTAAGCGTAGTAA-CTTCTCTCGCTATAGATGTC-----------
--TGCTGGTTGCTCGC--

-------------------CCTCAGTAACGGCGAGTGAAGCGGTAACAGCTCAAATTTGA
AAGCTGCC-----AACAGGCCGCATTGTAATTTGTAGAGGATGCTTTGGGGGTTGGCCCG
GTCTAAGTTCCTTGGAACAGGACGTCATAGAGGGTGAGAATCCCGTATGTGCCCGG-TGC
CCGCCCCCGTGTAAAGCTCCTTCAACGAGTCGAGTTGTTTGGGAATGCAGCTCAAAATGG
GTGGTATATTTCATCTAAAGCTAAATATTGGCCAGAGACCGATAGCGCACAAGTAGAGTG
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GAAGCGCTTGCAATCAGACTTGCAGGCGGTCGATCATCCGGGGTTC-TCCTCGGTGCACT
CGGCCGTCT-TCAGGCCAGCATCAGTTTCGGTGGTGGGATAAAGGCCTTGGGAATGTAGC
TT--CTT----CGGGAGTGTTATAGCCCTCGGTGCAATGCCGCCTACCGGGACTGAGGAC
CGCGCTTC-GGCTAGGATGCTGGCGTAATGGTTGTAAGCGACCCGTCTTGAAACACGGAC
CAAGGAGTCTAACATCTATGCGAGTGTTTGGGTGTCAAACCCATACGCGGAATGAAAGTG
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AGCCAGAGGAAACTCTGGTGGAGGCTCGCAGCGGTTCTGACGTGCAAATCGATCGTC-AA
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AATGGG--AATCTAAC--AGTTCATTTGTGCTGACACGGATGAAAATAGAATAATCCTGC
ATTCAAGGCCGCTGTTAATATTCGAGACCCAAAGCGAAAATTCGATACGATATGGCGACT
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CGATCCCAAGGAAGCAGCAAAG---CGTTCTCATGGTGGATGTGGCAATACTCAACCCGA
GGTGCGCCAACAGGCTTTACAACTTTGGGGTACCTGGAAGATGCCGAAGGATGAGGAGAA
CGATGGTGG---------ATCTGAAGAGACAAATCACTCCAGAGATGGCTCTGAACGT
TCTTCGAAGCATGTCTACTTCTGACATTCGGGATCTGGGACTCAGCGTCGATTATGCTCG
TCCTGAGTGGTTGATCATCACAGTTCTGCCAGTTCCTCCACCACCCGTCCGACCCAGTAT
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Figure 4R

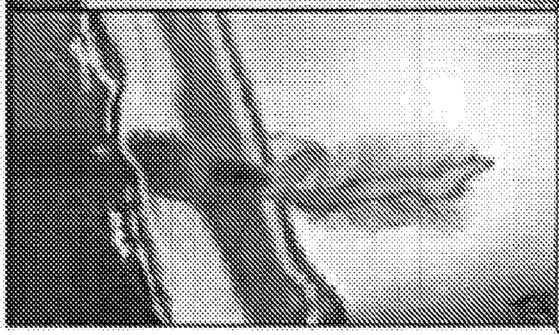
Fig. 5A

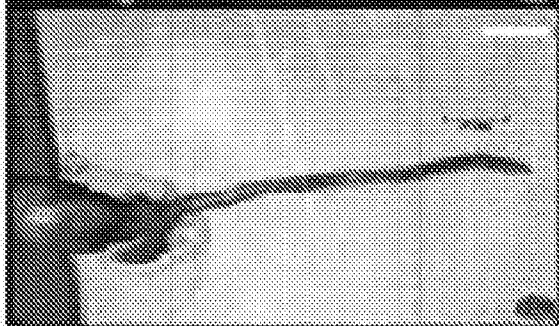
Fig. 5B

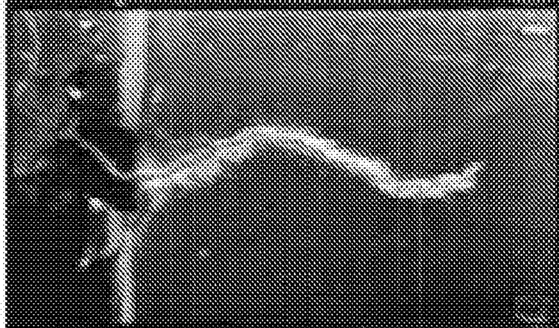
Fig. 5C

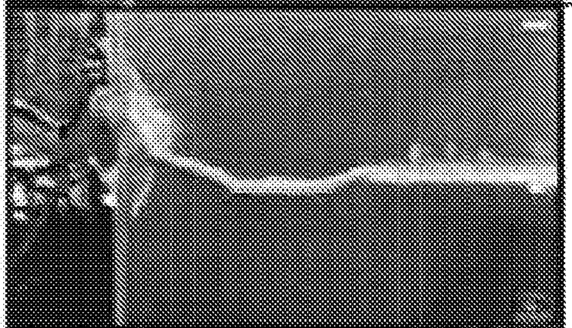
Fig. 5D

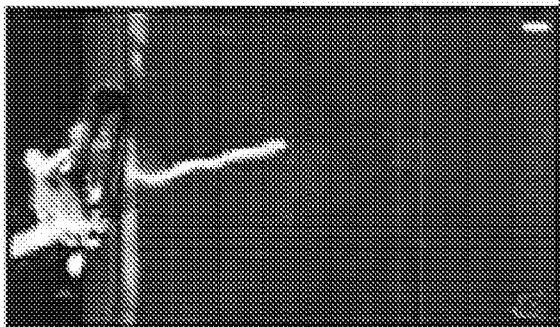
Fig. 5E

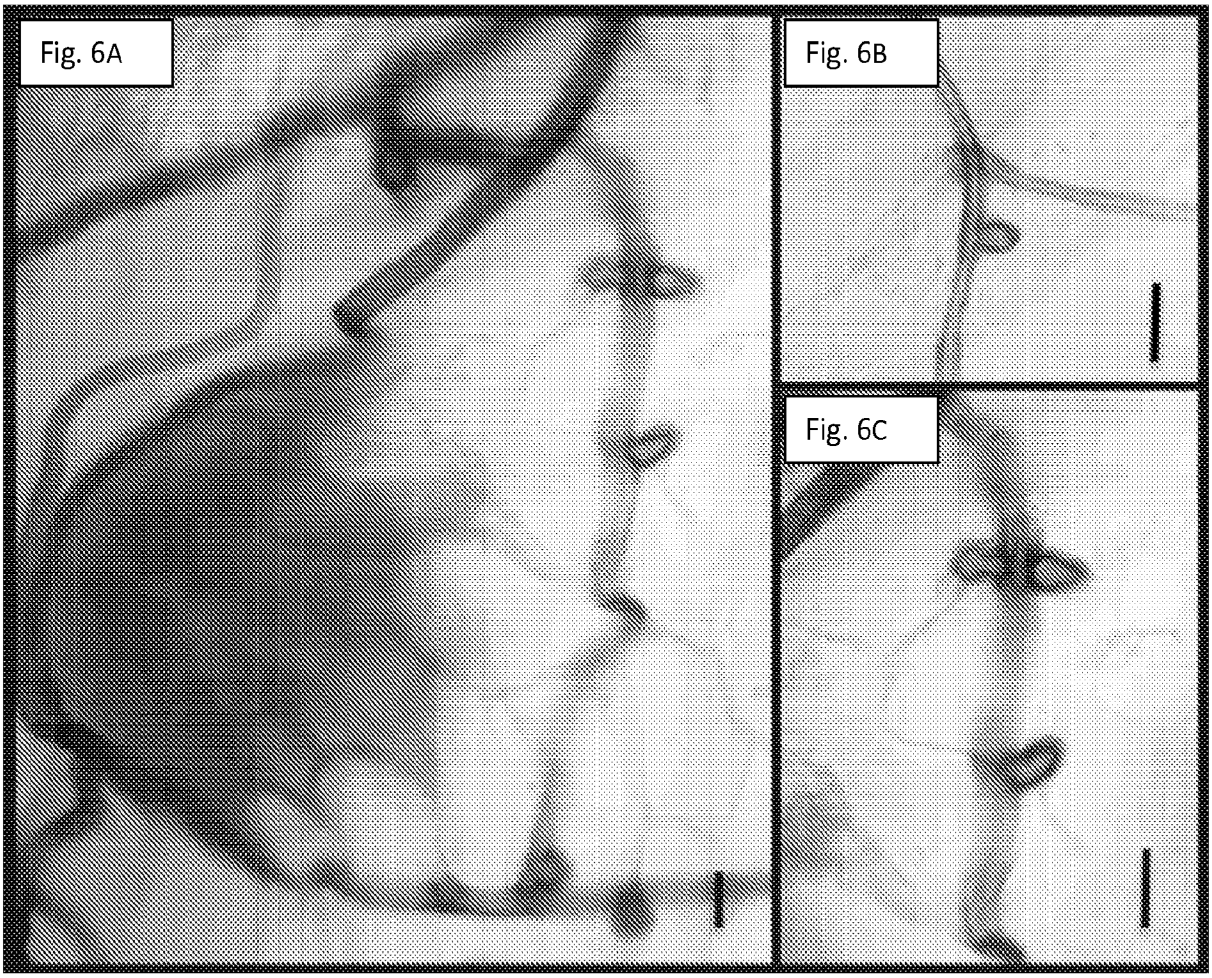
Fig. 6A
Fig. 6B
Fig. 6C

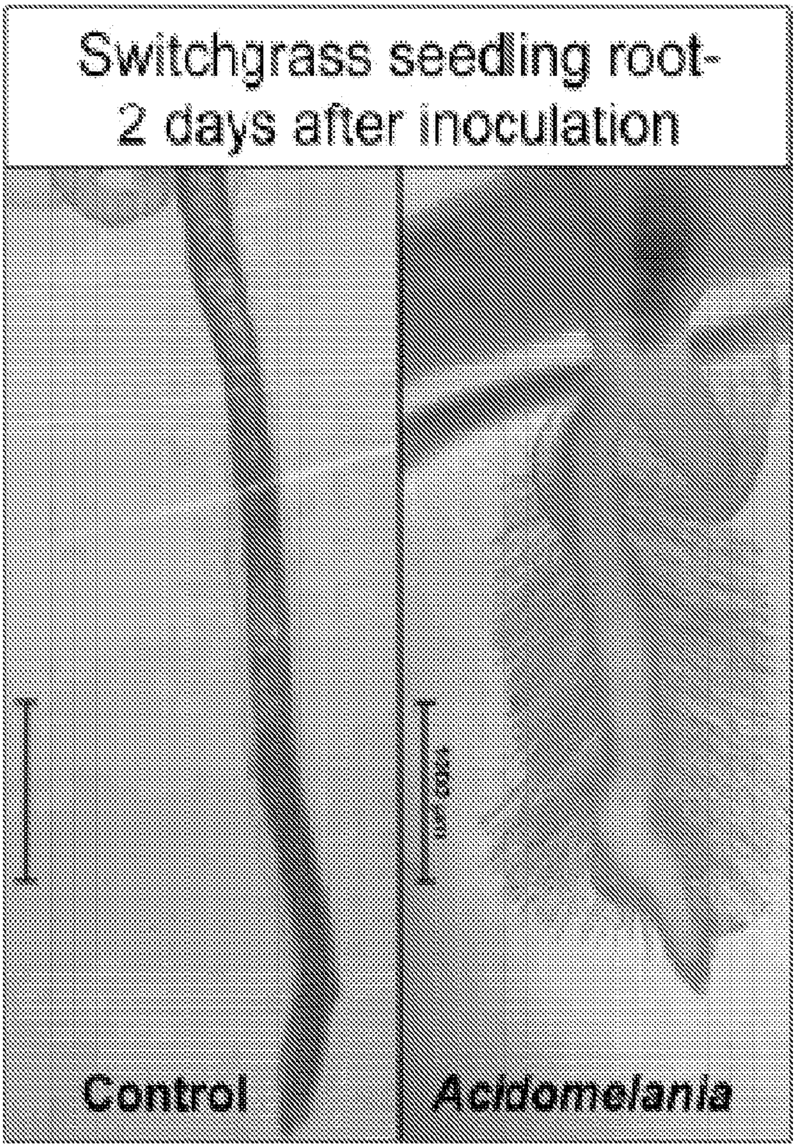
Switchgrass seedling root-
2 days after inoculation
Control
Acidomelania

Figure 7

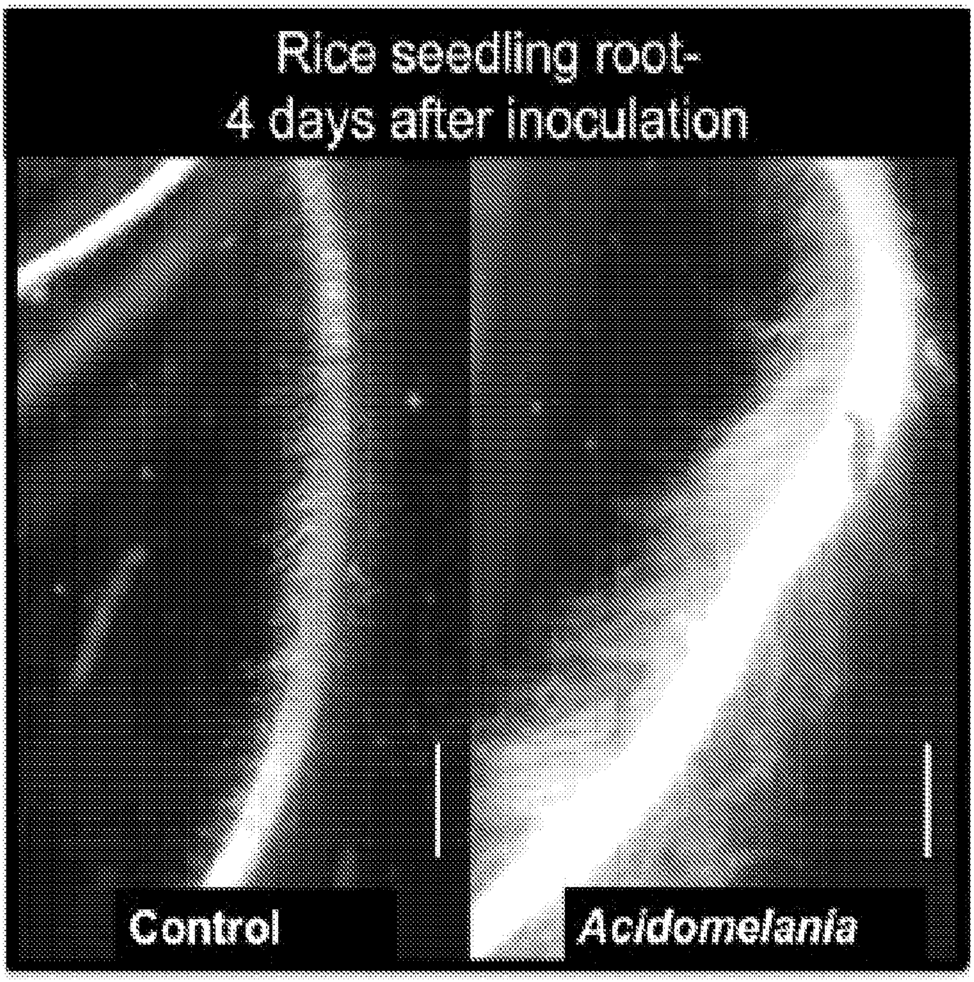
Rice seedling root-
4 days after inoculation
Control
Acidomelania

Figure 8

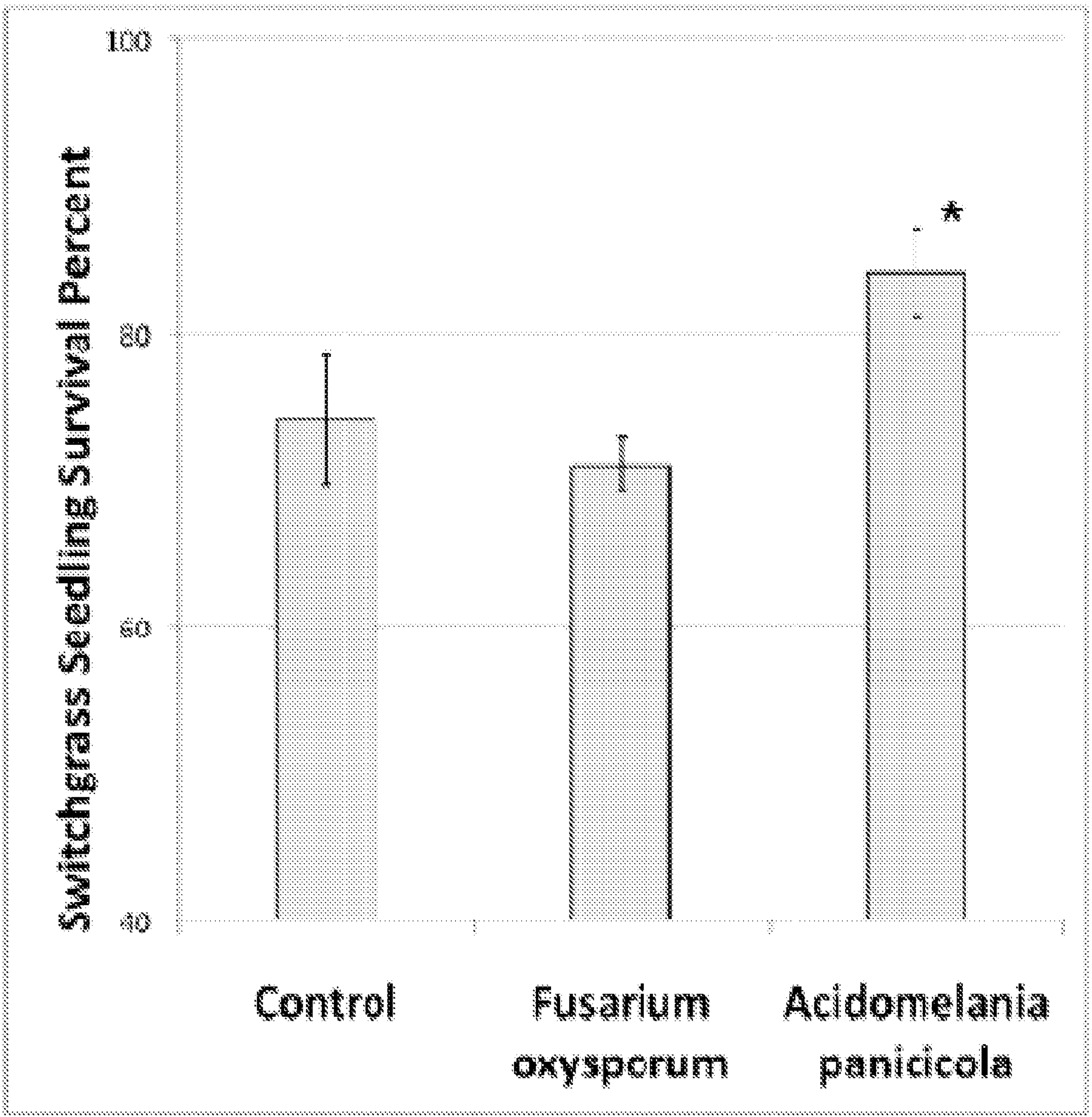
100
80
60
40
Switchgrass Seedling Survival Percent
*
Control
Fusarium oxysporum
Acidomelania panicicola

Figure 9

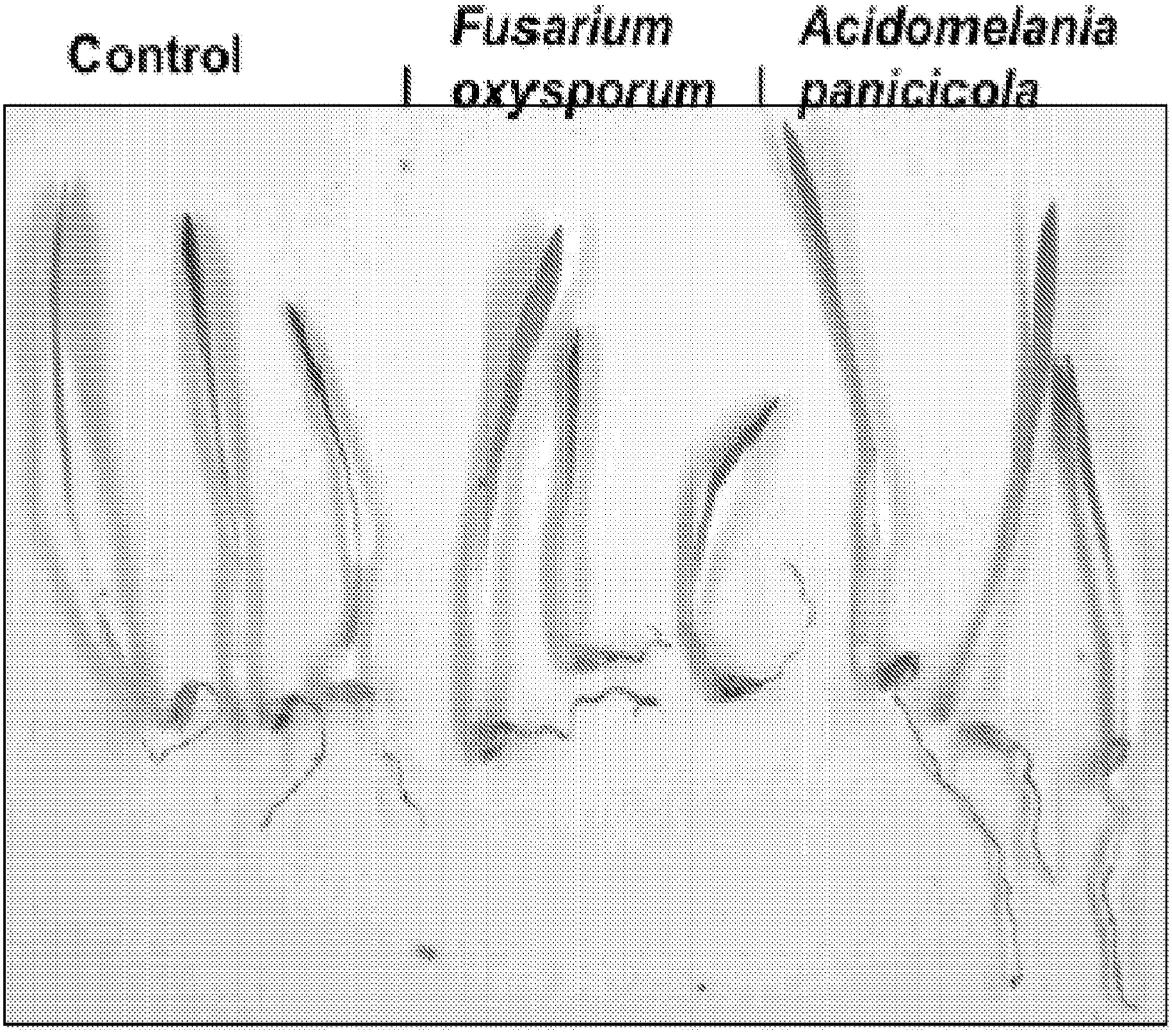

Figure 10

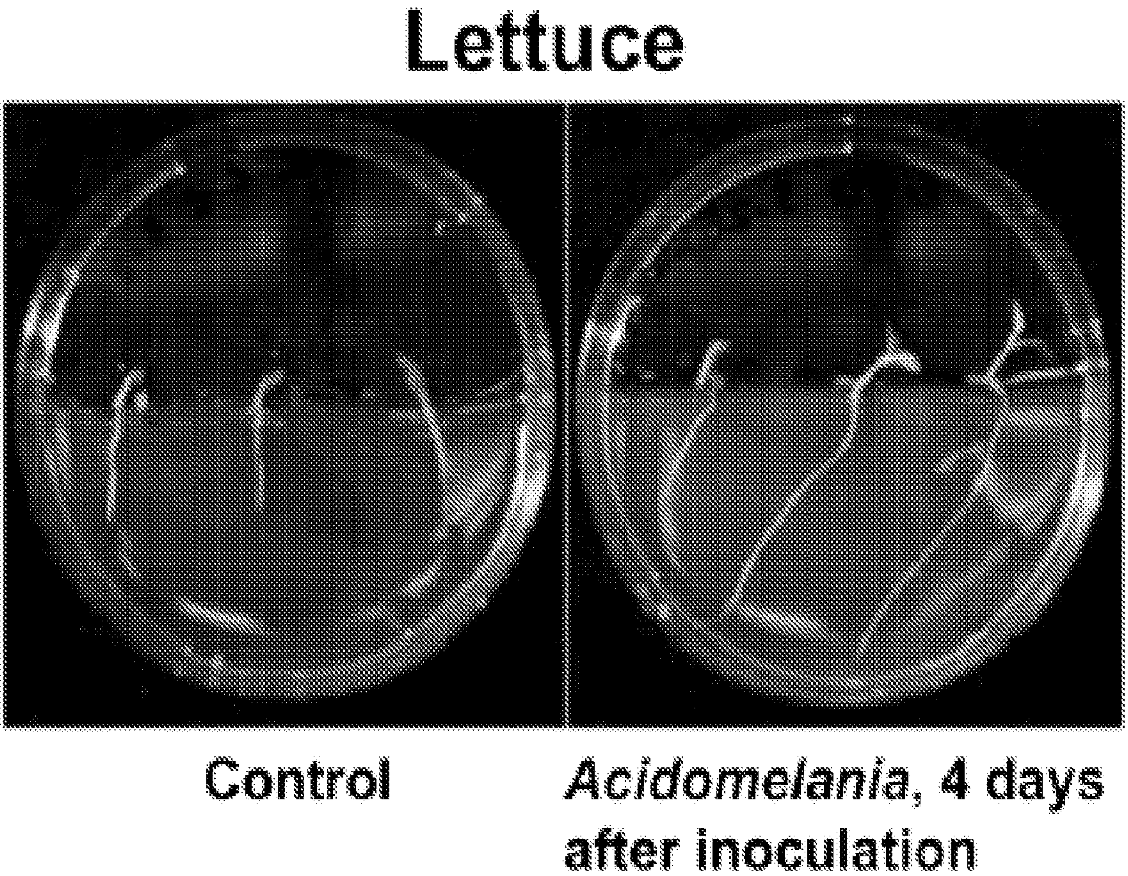

Figure 11

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US15/48889

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - C05F 11/08; C12N 1/14; C08L 5/06 (2015.01)
CPC - C05F 11/08; C12N 1/14; C08L 5/06
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8): C05F 11/08; A01C 21/00; C12N 1/14, 1/20; A01H 17/00; C08L 5/04, 5/06, 5/12; A01N 63/04 (2015.01)
CPC: C05F 11/08; C12N 1/14, 1/20; A01G 1/048; C08L 5/04, 5/06, 5/12; A01C 21/00; A01N 63/04

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Patseer (US, EP, WO, JP, DE, GB, CN, FR, KR, ES, AU, IN, CA, INPADOC, RU, AT, CH, TH, BR, PH); PubMed; EBSCO; Google; Google Scholar; Google Patents: biofertilizer, fertilizer, bacteria, fungi, endophytic, 'Acidomelania panicicola',' 'Acidomelania,' 'Burkholderia,' 'Barrenia panicia,' 'Barrenia,' 'dark septate,' symbiotic, mycorrhizae

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- A	WO 2013/090628 A1 (SYNTHETIC GENOMICS, INC.) June 20, 2013; paragraphs [0010]-[0012], [0059], [0060], [0070]-[0077], [00164]-[00166]	1, 4-6, 25, 26 ----- 2, 3, 13-24, 28-34
A	WALSH, E et al. Acidomelania panicicola gen. et sp. nov. from Switchgrass Roots In Acidic New Jersey Pine Barrens. Mycologia. 02 June 2014, Vol. 106, No. 4; pages 856-864; abstract; DOI: 10.3852/13-377.	2, 3, 13-24, 28-34
A	ZIJLSTRA, JD et al. Diversity Of Symbiotic Root Endophytes Of The Helotiales In Ericaceous Plants And The Grass, Deschampsia flexuosa. Studies in Mycology. 2005, Vol. 53; pages 147-162; abstract; page 158, first column, third paragraph; DOI: 10.3114/sim.53.1.147.	2, 3, 13-24, 28-34
A	MATHEW, A et al. The Evidence Of Mycorrhizal Fungi And Dark Septate Endophytes In Roots Of Chlorophytum borivillianum. Acta Botanica Croatica. 2008 [retrieved on 12 November 2015], Vol. 67, No. 1; pages 91-96; Retrieved from the Internet: <URL: http://hrcak.srce.hr/file/35449>.	1-6, 13-26, 28-34
A	WO 2013/098829 A1 (THE ENERGY AND RESOURCES INSTITUTE (TERI)) July 04, 2013; abstract	1-6, 13-26, 28-34

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 November 2015 (13.11.2015)	14 DEC 2015

Name and mailing address of the ISA/	Authorized officer
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Shane Thomas PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US15/48889

Box No. I Nucleotide and/or amino acid sequence(s) (Continuation of item 1.c of the first sheet)

1. With regard to any nucleotide and/or amino acid sequence disclosed in the international application, the international search was carried out on the basis of a sequence listing:

   a. ☐ forming part of the international application as filed:
      - ☐ in the form of an Annex C/ST.25 text file.
      - ☐ on paper or in the form of an image file.

   b. ☐ furnished together with the international application under PCT Rule 13*ter*.1(a) for the purposes of international search only in the form of an Annex C/ST.25 text file.

   c. ☒ furnished subsequent to the international filing date for the purposes of international search only:
      - ☒ in the form of an Annex C/ST.25 text file (Rule 13*ter*.1(a)).
      - ☐ on paper or in the form of an image file (Rule 13*ter*.1(b) and Administrative Instructions, Section 713).

2. ☒ In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that forming part of the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

3. Additional comments:

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US15/48889

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☒ Claims Nos.: 7-12, 27
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.