US 20180037517A1

(19) United States
(12) Patent Application Publication
Zhang
(10) Pub. No.: US 2018/0037517 A1
(43) Pub. Date: Feb. 8, 2018

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

(71) Applicant: **RUTGERS, THE STATE UNIVERSITY OF NEW JERSEY**, New Brunswick, NJ (US)

(72) Inventor: **Ning Zhang**, East Brunswick, NJ (US)

(73) Assignee: **RUTGERS, THE STATE UNIVERSITY OF NEW JERSEY**, New Brunswick, NJ (US)

(21) Appl. No.: **15/509,355**

(22) PCT Filed: **Sep. 8, 2015**

(86) PCT No.: **PCT/US15/48889**

§ 371 (c)(1),
(2) Date: **Mar. 7, 2017**

Related U.S. Application Data

(60) Provisional application No. 62/047,226, filed on Sep. 8, 2014.

Publication Classification

(51) **Int. Cl.**

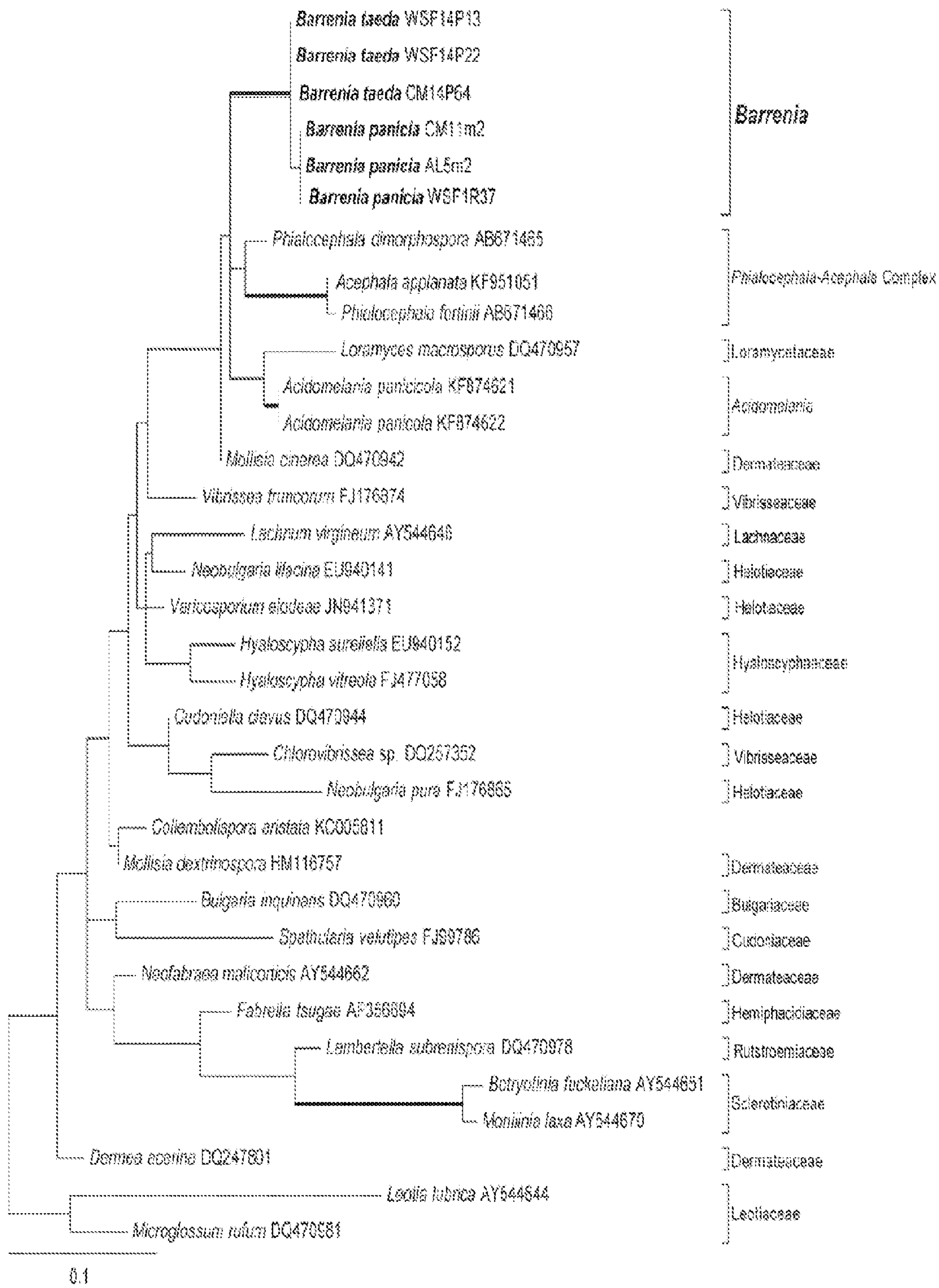
C05F 11/08 (2006.01)
C05G 3/00 (2006.01)
C05B 17/00 (2006.01)
C12N 1/14 (2006.01)
C12N 1/20 (2006.01)

(52) **U.S. Cl.**

CPC ***C05F 11/08*** (2013.01); ***C12N 1/14*** (2013.01); ***C12N 1/20*** (2013.01); ***C05B 17/00*** (2013.01); ***C05G 3/0029*** (2013.01)

(57) **ABSTRACT**

Compositions and methods for enhancing plant growth and resistance to adverse abiotic conditions are disclosed.



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Rutstroemiaceae
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Monilinia laxa AY544670
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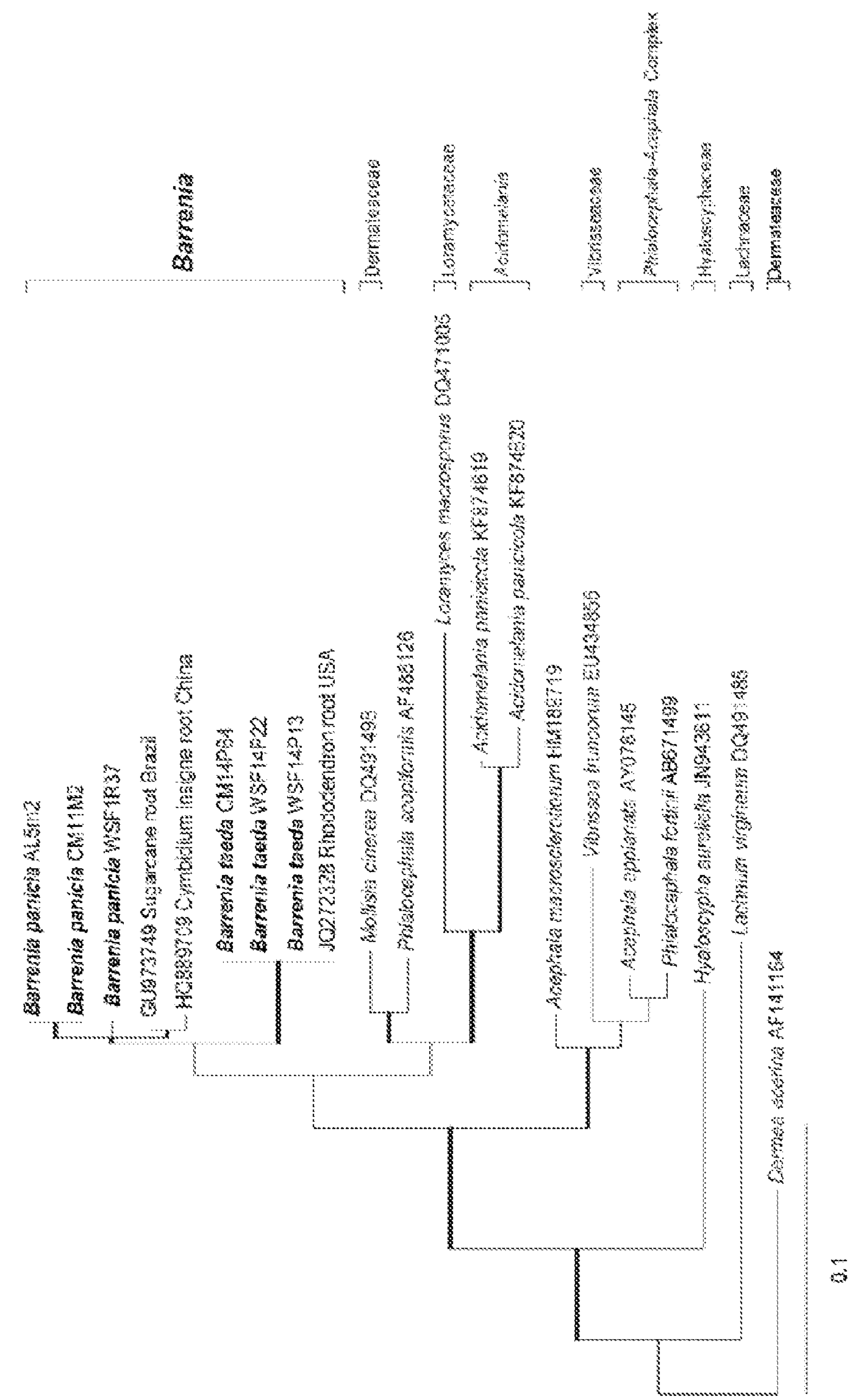
Figure 1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Barrenia taeda WSF14P22
Barrenia taeda WSF14P13
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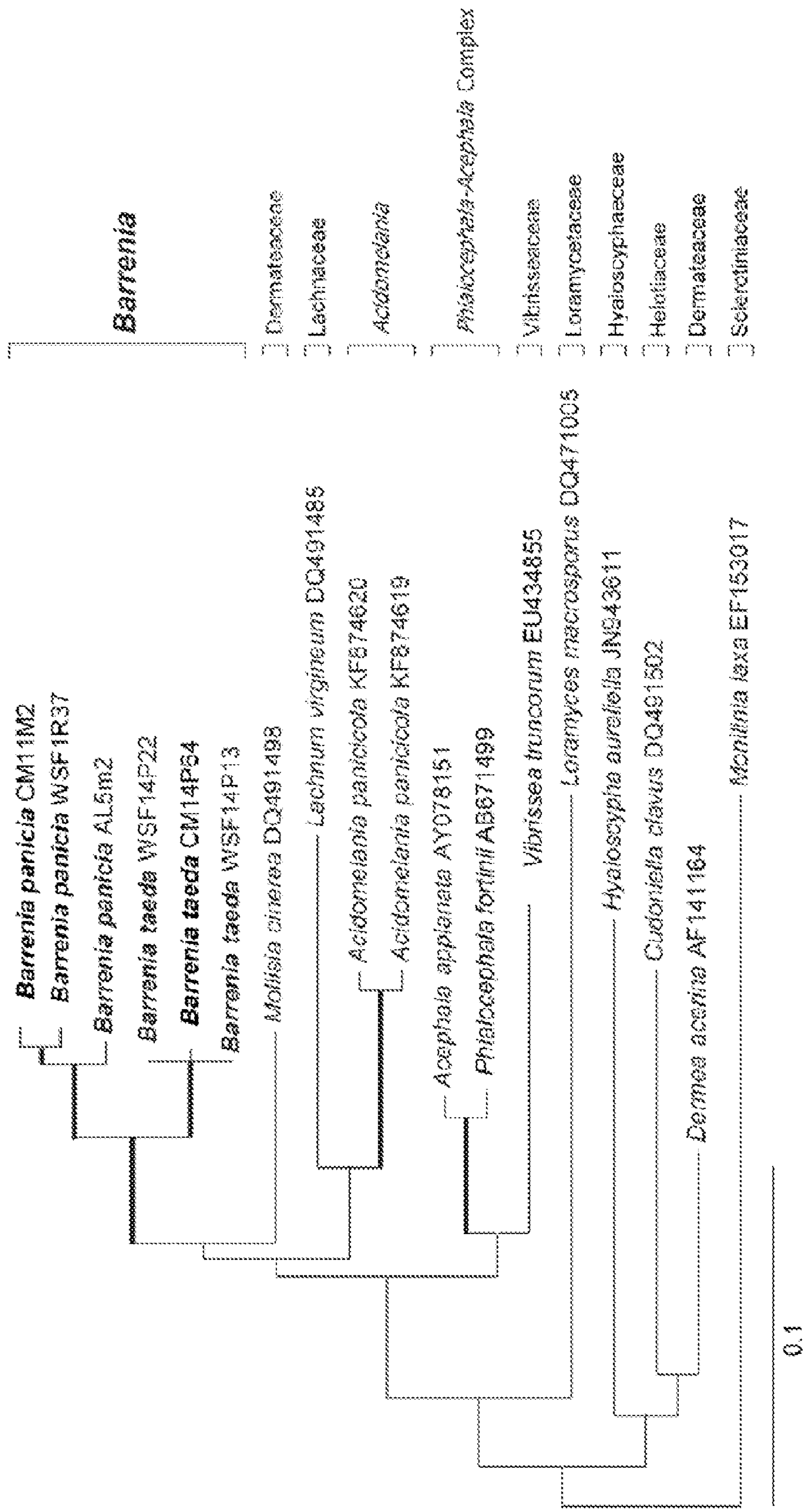
Acidomelania
Vibrisseaceae
Phialocephala-Acephala Complex
Hyaloscyphaceae
Lachnaceae
Dermateaceae

Figure 2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Mollisia cinerea DQ491498
Lachnum virgineum DQ491485
Acidomelania panicicola KF874620
Acidomelania panicicola KF874619
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Lachnaceae
Acidomelania
Phialocephala-Acephala Complex
Vibrisseaceae
Loramycetaceae
Hyaloscyphaceae
Helotiaceae
Dermateaceae
Sclerotiniaceae

Figure 3

Acephala_applanata_AY078151

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------CATACTATTGT-TGCTTTGGCGGGCCGTGA-CCT-CCAC--TGC----GGGCTC
TGCTCGT-----GTGTGCCCGCCAGAGGACC---AAACTCTGAATGTTAGTGATGTCTGA
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GGTGCCGGTG-GGCTCTAAGCGTAGTAC-ATACTCCCGCTATAGAGTTC-----------
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------------------------ACCCGCTGAACTTAAGCATATCAATAAGCGGAGGAA
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GGTGCGCCAGCAGGCTCTGCAGCTTTGGGGTACATGGAAGATGCCTAAGGACGAGGAGAA
CGAGGG------AAGCCAATCCGAGAAGAGACAAATCACTCCAGAGATGGCTCTGAACGT
CTTCCGAAGCATGTCTACTGCTGAGATTCGCGACCTTGGGTTGAGCAACGATTATGCCCG
ACCCGACTGGCTGATCATCACAGTCCTTCCAGTTCCTCCTCCGCCGGTTCGACCAAGTAT
CTCAATGGATGGCACAAGCACAGGCATGCGTGGAGARGATGATTTGACGTACAAGCTCGG
TGATATCATCCGTGCGAACGGCAATGTCAAGC-AGGCACAACAGGAAGG

Figure 4A

Acidomelania_panicicola_KF874620
GTGTCTA---

------CATACTCTTGT-TGCTTTGGCAGGCCGTGG-CCTCCCAC--TGT----GGGCTC
AGCCTGC-----ATGTGCCTGCCAGAGGACC---AAACTCTGAATGTTACTGATGTCTGA
GTACTATATAATAGTTAAAACTTTCAACAACGGATCTCTTGGTTCTGGCATCGATGAAGA
ACGCAGCGAAATGCGATAAGTAATGTGAATTGCAGAATTCAGTGAATCATCGAATCTTTG
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GTCACCTTTA-GGTCCTAAGCGTAGTAATTTCTCCTCGCTACAGAACCT-----------
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CGCGCTTC-GGCTAGGATGCTGGCGTAATGGTTGTAAGCGACCCGTCTTGAAACACGGAC
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AACGGAGGTGAGACCCCATTAGGGCGCATCATCGACCGATCCTGATGTCTTCGGATGGAT
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GGGTGGTGGCATCTCT--TGCAT-CTTGTGCTGACATGAAT-ATCTCAGAGTAACCCGCA
ATACAAGGCAGCTGTTTCTATTCGGGACCCAAAGCGTAGATTCGACACCATTTGGCGACT
TTGCAAGCCCAAGATGATCTGCGACAGTGATGTTCCTAATGACGAC---GAATTCGGAGG
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TGAGGGTGG--CAACACT----GAGAAGCGACAAATTACTCCAGAGATGGCTCTCAATGT
CTTCCGGTCCATGTCTTCCGATGAGATTCGCGATCTCGGTTTGAGCAACGACTATGCGCG
TCCTGACTGGTTGATCATCACTGTTCTTCCAGTTCCACCTCCTCCCGTTCGCCCCAGTAT
TTCTATGGATGGTACAAGCACAGGAATGCGCGGAGAGGATGATTTGACCTACAAGCTAGG
TGATATCATTCGTGCCAACGGCAATGTCAAGC-AGGCACAGCAAGAAGG

Figure 4B

```
Acidomelania_panicicola_KF874619
GTGTCTA-----------------------------------------------------
------------------------------------------------------------
------CATACTCTTGT-TGCTTTGGCAGGCCGTGG-CCTCCCAC--TGT----GGGCTC
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GTACTATATAATAGTTAAAACTTTCAACAACGGATCTCTTGGTTCTGGCATCGATGAAGA
ACGCAGCGAAATGCGATAAGTAATGTGAATTGCAGAATTCAGTGAATCATCGAATCTTTG
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TGATATCATTCGCGCCAACGGCAATGTCAAGC-AGGCACAGCAAGAAGG
```

Figure 4C

```
Acidoradicia_panicicola_AL5m2-2
GTGTCTA-----------------------------------------------------
------------------------------------------------------------
------TCTACTCTTGT-TGCTTTGGCAGGCCGTGG-CCT-CCAC--CGC----GGGCTC
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GTACTATATAATAGTTAAAACTTTCAACAACGGATCTCTTGGTTCTGGCATCGATGAAGA
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```

Figure 4D

Acidoradicia_panicicola_CM11M2
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GGTGCCGGTG-GGCTCTAAGCGTAGTAA-ATCTCCTCGCTATAGGGTCC-----------
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Figure 4E

Acidoradicia_panicicola_WSF1-R37
GTGTCTA---

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TGCCTGC-----GTGTGCCTGCCAGAGGACC---AAACTCTGAATTTTAGTGATGTCTGA
GTACTATATAATAGTTAAAACTTTCAACAACGGATCTCTTGGTTCTGGCATCGATGAAGA
ACGCAGCGAAATGCGATAAGTAATGTGAATTGCAGAATTCAGTGAATCATCGAATCTTTG
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ACTCAAGCCTGGCTTGGTATTGGGAC-TCGCGGT--TCCGCGGCCCCTAAAATCAGTGGC
GGTGCCGGTG-GGCTCTAAGCGTAGTAA-ATCTCCTCGCTATAGGGTCC-----------
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---------TGTAAAGCTCTTTCGACGAGTCGAGTTGTTTGGGAATGCAGCTCAAAATGG
GTGGTATATTTCATCTAAAGCTAAATATTGGCCAGAGACCGATAGCGCACAAGTAGAGTG
ATCGAAAGATGAAAAGCACTTTGGAAAGAGAGTTAAACAGTACGTGAAATTGTTGAAAGG
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CAAGGAGTCTAACATCTATGCGAGTGTTTGGGTGTCAAACCCATACGCGTAATGAAAGTG
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TTCCATGGATGGTACAAGCACAGGAATGCGCGGAGAGGATGATTTGACATACAAGCTTGG
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Figure 4F

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Acidoradicia_taeda_CM14-P64
GTGTCTA-----------------------------------------------------
------------------------------------------------------------
------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------GGAGTGTTATAGCCTAGGGTGCAATGCCGCCTACCGGACCGAGGAC
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

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
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GTCTAAGTTCCTTGGAACAGGACGTCATAGAGGGTGAGAATCCCGTATGTGACTGGTTGC
CTTCGCCCATGTGAAGCTCTTTCGACGAGTCGAGTTGTTTGGGAATGCAGCTCTAAATGG
GTGGTAAATTTCATCTAAAGCTAAATATTGGCCAGAGACCGATAGCGCACAAGTAGAGTG
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GAAGCGCTTGCAACCAGACTTGCACGTCGTCGATCATCCTCAGTTC-TCTGGGGTGCACT
CGGCGGTGT-TCAGGCCAGCATCGGTTTCGGTGGTGGGATAAAGGCCTTGGGAATGTGGC
TCCTCTC----GGGGAGTGTTATAGCCCTCGGTGCAATGCCGCCTACTGGGACCGAGGAC
CGCGCTTC-GGCTAGGATGCTGGCGTAATGGTTGTAAGCGACCCGTCTTGAAACACGGAC
CAAGGAGTCTAACATCTATGCGAGTGTTTGGGTGTTAAACCCATACGCGTAATGAAAGTG
AACGGAGGTGAGAACCCTTTAGGGTGCATCATCGACCGATCCTGATGTCTTCGGATGGAT
TTGAGTAAGAGCATAGCTGTTGGGACCCGAAAGATGGTGAACTATGCCTAAATAGGGTGA
AGCCAGAGGAAACTCTGGTGGAGGCTCGCAGCGGTTCTGACGTGCAAATCGATCGTC-AA
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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
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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
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AGGTGTTGGCTTCGCT--TGTTC-TTTTTGCTGACA-GAAT-ATCTCAGGGTAATCCCCA
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TTGCAAGCCCAAGATGATCTGCGATAGCGATGTCCCTAATGAAGAT---GAATTCGGTGG
TGATCCAAAGGAAGCTGTGAAG---CGTTCGCATGGAGGATGTGGAAATACACAACCTGA
GGTCCGCCAACAGGCATTGCAGCTCTGGGGAACATGGAAGATGCCAAAGGATGAGGAGAA
CGAGGGTGG--CAACTCG----GAGAAGAGACAAATTACACCAGAGATGGCTCTCAATGT
CTTCAGATCCATGTCTTCTGAAGAAATTCGCGACCTCGGTCTCAGCAACGATTATGCACG
TCCTGACTGGTTGATTATTACAGTTCTTCCAGTTCCGCCTCCTCCTGTTCGACCCAGTAT
TTCCGTGGACGGCACGAGCACAGGTATGCGCGGAGAGGATGATTTGACATACAAGCTTGG
TGATATCATTCGTGCCAACGGCAATGTGAAGC-AGGCTCAACAAGAAGG
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Figure 4M

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Loramyces_macrosporus_DQ471005
GTGTCTA-----------------------------------------------------
------------------------------------------------------------
------TATACTCTTGT-TGCTTTGGCAGGCCGTGG-TCT-CGACCCTGT----GGGCTT
TGCCTGC-----ATGTGCCTGCCAGAGGACC---AAACTCTGAATTTTAGTGATGTCTGA
GTACTATATAATAGTTAAAACTTTCAACAACGGATCTCTTGGTTCTGGCATCGATGAAGA
ACGCAGCGAAATGCGATAAGTAATGTGAATTGCAGAATTCAGTGAATCATCGAATCTTTG
AACGCACATTGCGCCCGGTGGTATTCCGCCGGGCATGCCTGTTCGAGCGTCTCTATCAAC
CTACACGCTCCGCGTGGAATTGGGGC-CTGCGGTCACCTGCAGCCCTAGAACCCAACAGC
GATACCGAGT-GGTCCTCAGCGTAGTAC--ATACCCCGCTACAGGCCTC-----------
-----------------CT---------------------------CTGGTGTTCTGC--
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-TGGTCTATATCATCTAAAGCTACATATTGGCCAGAGGCCGATAGCGCACAAGTAGAGTG
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GAAGCGCTTGCAATCAGACTTGCAGGCGGTTGATCATCCGGGGTTT-TCCCCGGTGCACT
CGATCGTCT-TCAG??CAGCATCAGTTCTCGTGGTGGGATAAAGGCTGTGAGAATGTGGC
TC--TTC------GGAGTGTTATAGCTCACGGTGCAATGCTGCCTACGGGGACTGAGGAC
CGCGCTTC-GGCTAGGATGCTGGCGTAATGGTTGTAAGCGACCCGTCTTGAAACACGGAC
CAAGGAGTCTAACATCTATGCGAGTGTTTGGGTGTCAAACCCATACGCGTAATGAAAGTG
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AGCCAGAGGAAACTCTGGTGGAGGCTCGCAGCGGTTCTGACGTGCAAATCGATCGTC-AA
ATTTGCGTATAGGGGC-GAAAGACTAATCGCCTTGACAGAGTTAGTCAG---CCCAGAAG
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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
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GAAGCGCTTGCAATCAGACTTGCAGGCAGTCGATCATCCGAGGTTC-TCCCCGGTGCACT
CGATTGTCT-TCAGGCCAGCATCGGTTTCGGTGGTGGGATAAAGGCTGTGGGAATGTGGC
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CAAGGAGTCTAACATCTATGCGAGTGTTTGGGTGTCAAACCCATACGCGTAATGAAAGTG
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TTGAGTAAGAGCATAGCTGTTGGGACCCGAAAGATGGTGAACTATGCGTGAATAGGGTGA
AGCCAGAGGAAACTCTGGTGGAGGCTCGCAGCGGTTCTGACGTGCAAATCGATCGTC-AA
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ATATGCAGCAGCTACAAGTATTCGCGACCCAAAGCGTAGGTTCGATACGATATGGCGACT
CTGCAAACCAAAAATGATCTGCGATAGCGATGTCCCAAATGAAGAT---GAATTCGGAGG
TGATCCTAAGGAAGCTGTCAAG---CGCTCACATGGAGGTTGTGGAAACACTCAGCCCGA
AGTGCGTCAACAATCTCTCCAACTTTGGGGTACATGGAAGATGCCAAAGGATGAGGAGAA
CGAGGGCGGTGCAACGCAG---GAGAAGAAACAAATTACTCCAGAGATGGCTCTCAATGT
CTTCAAAAGCATGTCCACCAAGGAGATCTACGATCTTGGCTTGAACAACGACTACGCTCG
TCCTGACTGGTTGATTATCACTGTTCTTCCAGTTCCACCTCCCCCAGTCCGACCAAGTAT
CTCCATGGATGGCACAAGTACCGGCATGCGTGGAGAGGATGATTTGACATACAAGCTTGG
TGATATCATTCGTGCAAATGGAAACGTTAAGC-AGGCACAACAGGAAGG

Figure 40

```
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
TTCCATGGATGCTACTGGTCAGGGTATGCGAGGAGAGGATGATTTGACATACAAGTTGGG
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
ATCGAAAGATGAAAAGCACTTTGGAAAGAGAGTTAAACAGTACGTGAAATTGTTGAAAGG
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CGGCCGTCT-TCAGGCCAGCATCAGTTTCGGTGGTGGGATAAAGGCCTTGGGAATGTAGC
TT--CTT----CGGGAGTGTTATAGCCCTCGGTGCAATGCCGCCTACCGGGACTGAGGAC
CGCGCTTC-GGCTAGGATGCTGGCGTAATGGTTGTAAGCGACCCGTCTTGAAACACGGAC
CAAGGAGTCTAACATCTATGCGAGTGTTTGGGTGTCAAACCCATACGCGGAATGAAAGTG
AACGGAGGTAAGAACCCTTTAGGGCGCATTATCGACCGATCCTGATGTCTTCGGATGGAT
TTGAGTAAGAGCATAGCTGTTGGGACCCGAAAGATGGTGAACTATGCGTGAATAGGGTGA
AGCCAGAGGAAACTCTGGTGGAGGCTCGCAGCGGTTCTGACGTGCAAATCGATCGTC-AA
ATTTGCGTATAGGGGC-GAAAGACTAATCGATTAGACAGGGTTTGTTTG---CCTGTTGA
AATGGG--AATCTAAC--AGTTCATTTGTGCTGACACGGATGAAAATAGAATAATCCTGC
ATTCAAGGCCGCTGTTAATATTCGAGACCCAAAGCGAAAATTCGATACGATATGGCGACT
CTGCAAGCCGAAGCTTGTTTGCGACAGTGACATCAATCCCGACGATCCAGAGTTCAACAG
CGATCCCAAGGAAGCAGCAAAG---CGTTCTCATGGTGGATGTGGCAATACTCAACCCGA
GGTGCGCCAACAGGCTTTACAACTTTGGGGTACCTGGAAGATGCCGAAGGATGAGGAGAA
CGATGGTGG---------ATCTGAGAAGAGACAAATCACTCCAGAGATGGCTCTGAACGT
TCTTCGAAGCATGTCTACTTCTGACATTCGGGATCTGGGACTCAGCGTCGATTATGCTCG
TCCTGAGTGGTTGATCATCACAGTTCTGCCAGTTCCTCCACCACCCGTCCGACCCAGTAT
TTCCATGGATGGCACAAGCACTGGTATGCGCGGAGAGGATGATTTGACCTATAAGCTTGG
TGATATTATCCGTGCAAATGGCAATGTGAAGC-AGGCACAACAGGAAGG

Figure 4R

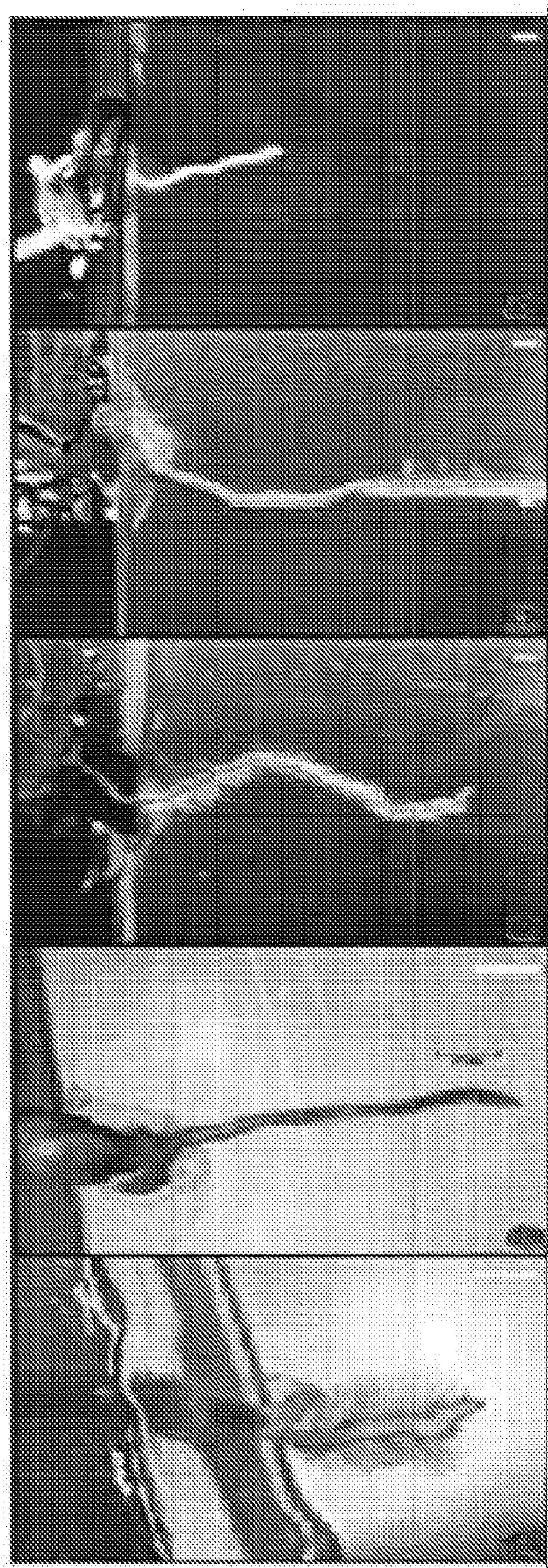

Fig. 5A Fig. 5B Fig. 5C Fig. 5D Fig. 5E

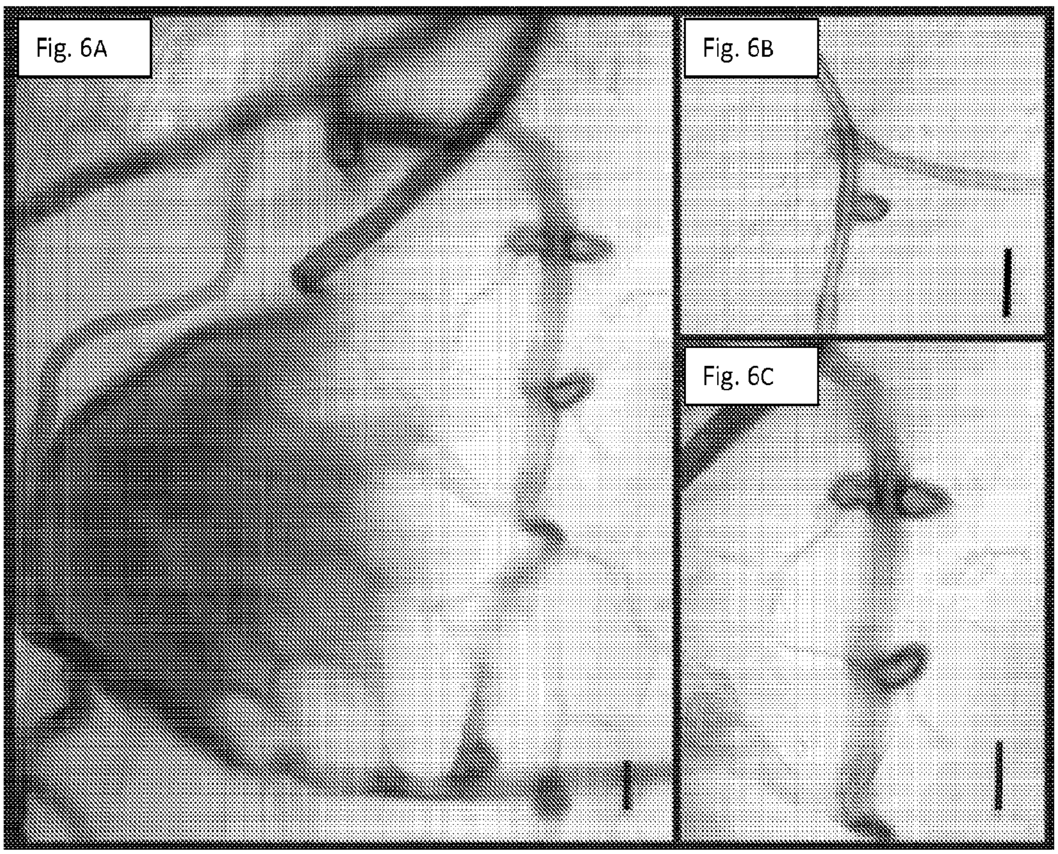
Fig. 6A
Fig. 6B
Fig. 6C

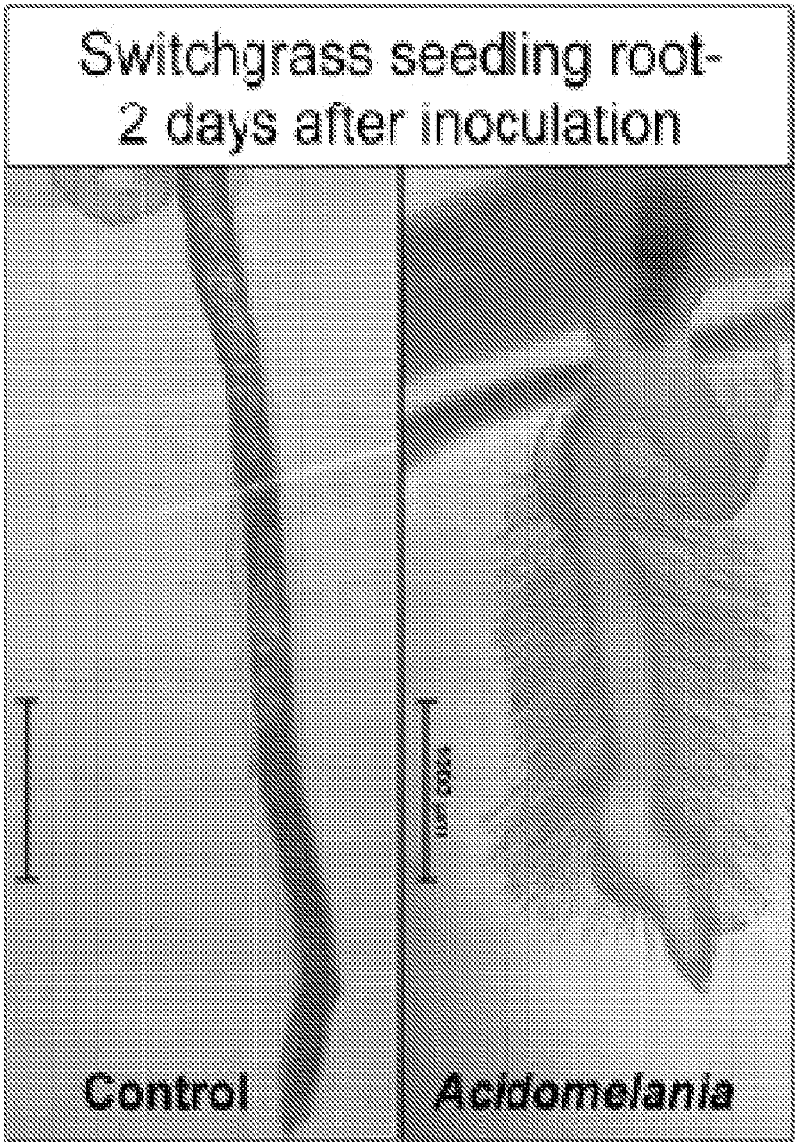
Switchgrass seedling root-
2 days after inoculation
Control
Acidomelania

Figure 7

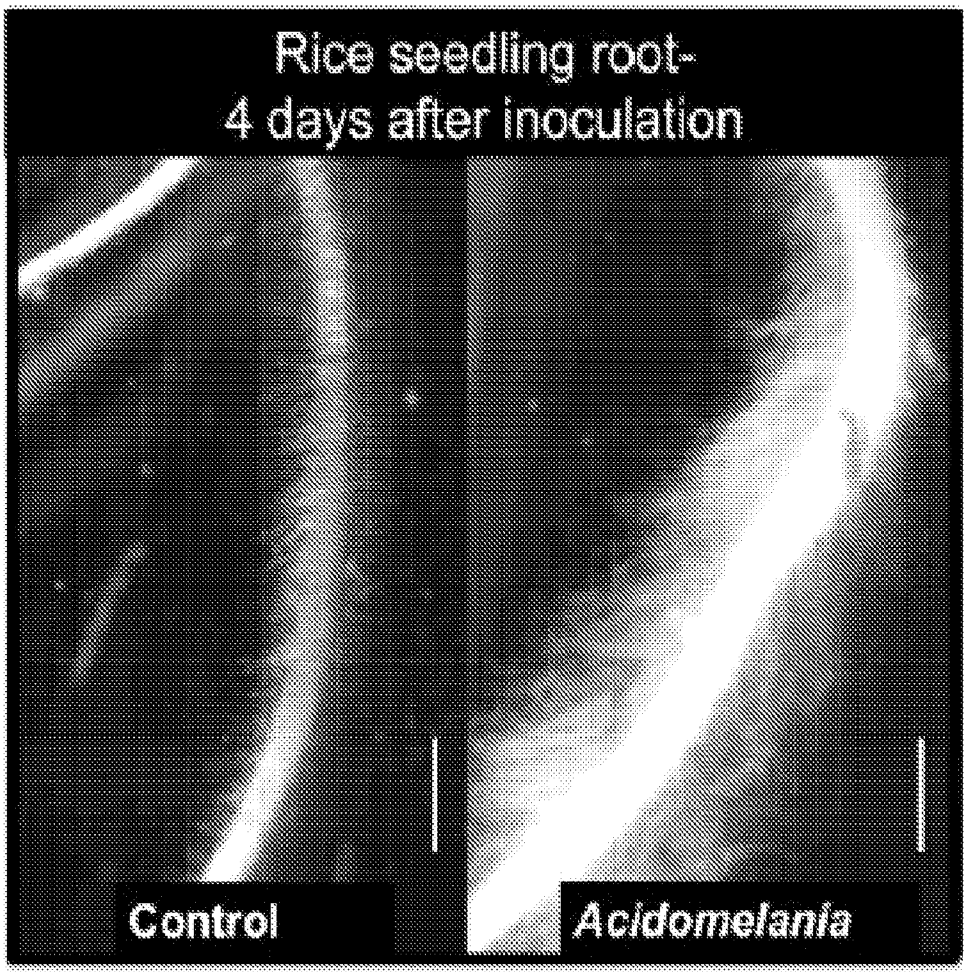
Rice seedling root-
4 days after inoculation
Control
Acidomelania

Figure 8

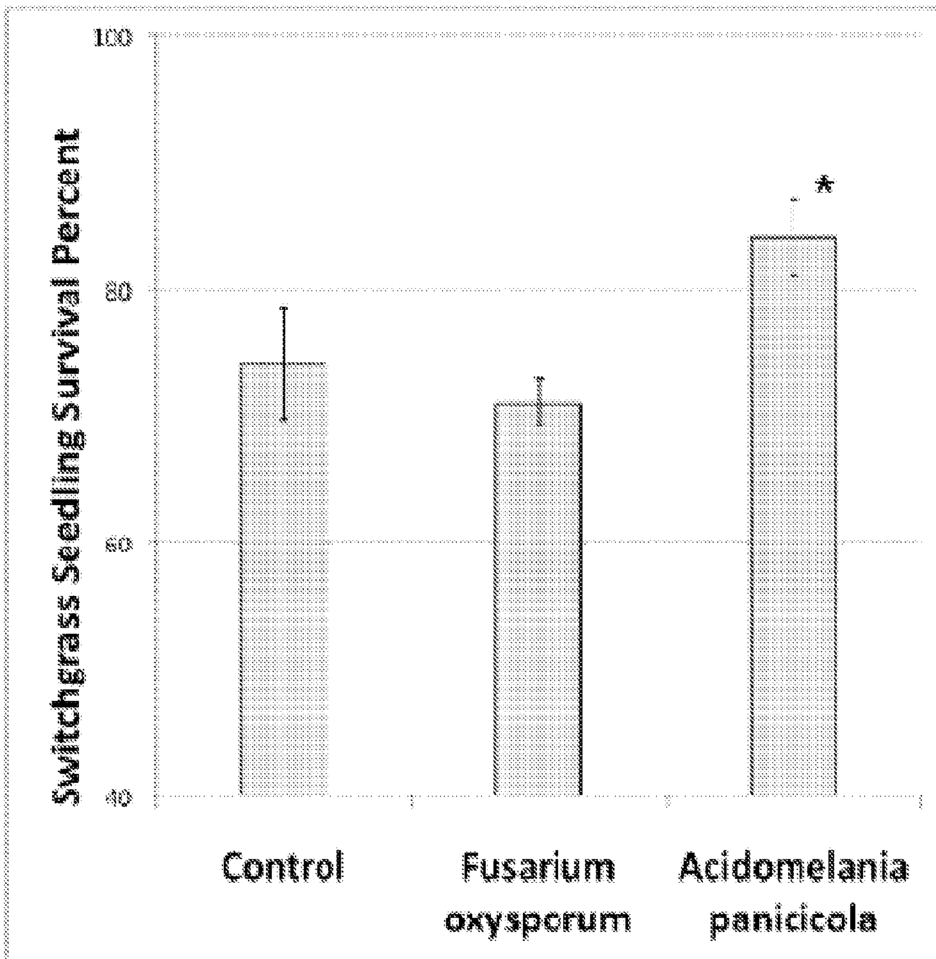
100
80
60
40
Switchgrass Seedling Survival Percent
*
Control
Fusarium oxysporum
Acidomelania panicicola

Figure 9

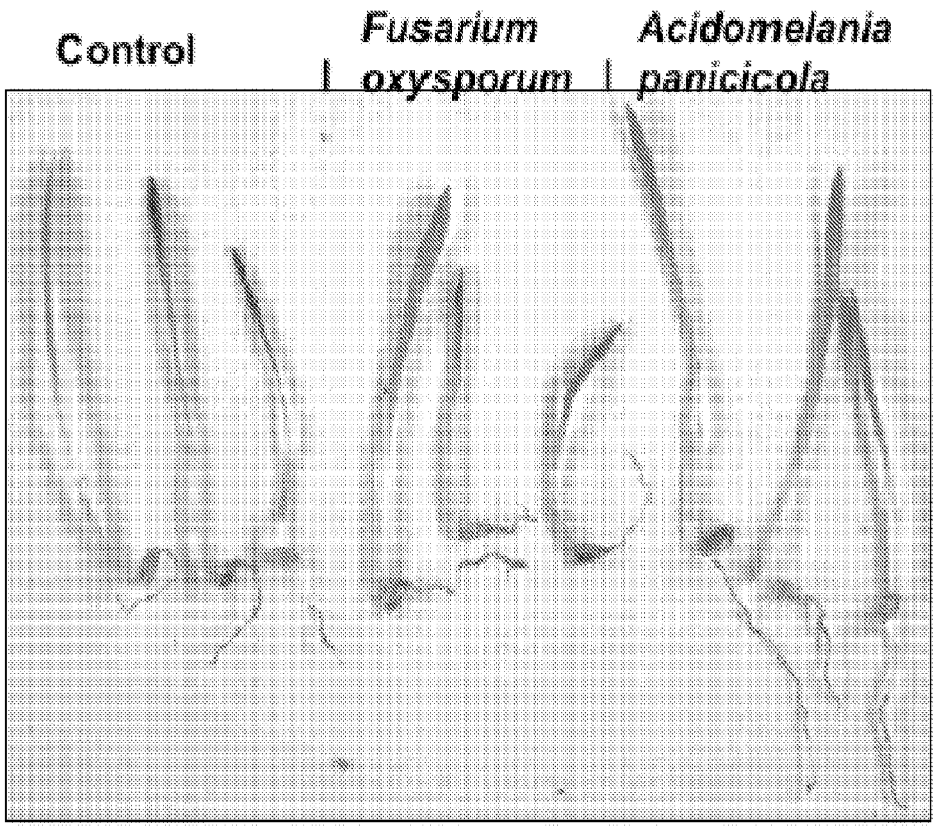

Figure 10

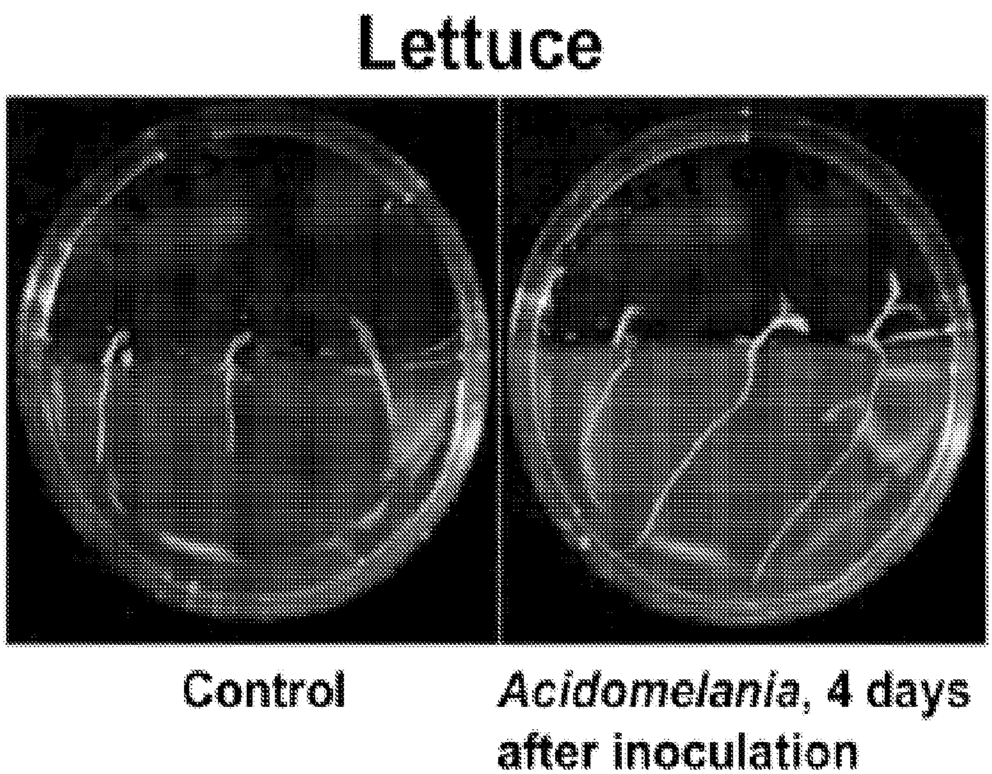

Figure 11

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

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Application No. 62/047,226 filed Sep. 8, 2014, the entire contents being incorporated herein by reference.

FIELD OF THE INVENTION

[0002] 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

[0003] 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.

[0004] 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.

[0005] 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).

[0006] 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

[0007] 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.

[0008] 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.

[0009] 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.

[0010] 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

[0011] FIG. **1**. Maximum likelihood phylogenetic tree inferred from the large subunit of rRNA gene sequence. Bootstraps higher than 70 have thickened branches.

[0012] FIG. **2**. Maximum likelihood phylogenetic tree inferred from the internal transcribed spacer sequences of rRNA gene. Bootstraps higher than 70 have thickened branches.

[0013] FIG. **3**. Maximum likelihood phylogenetic tree inferred from combined ITS, LSU, and RPB1 gene sequence datasets. Bootstraps higher than 70 have thickened branches.

[0014] FIG. **4**. DNA sequence for *A. applanata* AY078151; SEQ ID NO: 1 (FIG. **4**A), *A. panicicola* KF874620; SEQ ID NO: 2 (FIG. **4**B), *A. panicicola* KF874619; SEQ ID NO: 3 (FIG. **4**C), *A. panicicola* AL5m2-2; SEQ ID NO: 4 (FIG. **4**D), *A. panicicola* CM11M2; SEQ ID NO: 5 (FIG. **4**E), *A. panicicola* WSF1-R37; SEQ ID NO: 6 (FIG. **4**F), *A. taeda* CM14-P64; SEQ ID NO: 7 (FIG. **4**G), *A. taeda* WSF14-P22; SEQ ID NO: 8 (FIG. **4**H), *A. taeda* WSF14-P13; SEQ ID NO: 9 (FIG. **4**I), *C. clavus* DQ491502; SEQ ID NO: 10 (FIG. **4**J), *D. acerina* AF141164; SEQ ID NO: 11 (FIG. **4**K), *H. aureliella* JN943611; SEQ ID NO: 12 (FIG. **4**L), *L. virgineum* DQ491485; SEQ ID NO: 13 (FIG. **4**M), *L. macrospores* DQ471005; SEQ ID NO: 14 (FIG. **4**N), *M. cinerea* DQ491498; SEQ ID NO: 15 (FIG. **4**O), *M. laxa* EF153017; SEQ ID NO: 16 (FIG. **4**P), *P. fortinii* AB671499; SEQ ID NO: 17 (FIG. **4**Q), and *V. truncorum* EU434855; SEQ ID NO: 18 (FIG. **4**R).

[0015] FIGS. **5**A-**5**E. Switchgrass seedling two days after inoculation with *Acidomelania panicicola* holotype isolate 61R8 (FIG. **5**A); Control (FIG. **5**B); three days after inoculation with *Barrenia panicia* holotype isolate WSF1R37 (FIG. **5**C); Control (FIG. **5**D), *Barrenia taeda* holotype isolate WSF14P22 (FIG. **5**E). Bar=1 mm

[0016] FIGS. **6**A-**6**C. Representative image of morphological characters of *Barrenia panicia* holotype isolate WSF1R37 (FIG. **6**A); Representative image of morphological characters of *Barrenia panicia* holotype isolate WSF1R37 (FIG. **6**B); Representative image of morphological characters of *Barrenia panicia* holotype isolate WSF1R37 (FIG. **6**C). A-Bar=10 μm

[0017] FIG. **7**. Micrographs of control and *Acidomelania panicicola* inoculated switchgrass seedling roots 2 days post inoculation.

[0018] FIG. **8**. Micrographs of control and *Acidomelania panicicola* inoculated rice seedling roots 4 days post inoculation.

[0019] FIG. **9**. Micrographs showing control, *Fusarium oxysporum* inoculated and *Acidomelania panicicola* inoculated switchgrass seedling survival percentage.

[0020] FIG. **10**. Micrographs showing control, *Fusarium oxysporum* inoculated and *Acidomelania panicicola* inoculated switchgrass roots.

[0021] FIG. **11**. Micrographs showing control and *Acidomelania panicicola* inoculated lettuce roots 4 days post inoculation.

DETAILED DESCRIPTION OF THE INVENTION

[0022] 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).

[0023] 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.

[0024] *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.*

[0025] 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.

[0026] 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

[0027] 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.

[0028] 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).

[0029] 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.

[0030] 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.

[0031] The following materials and methods provided to facilitate the practice of the present invention.

Fungal Isolation

[0032] 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 30 s, 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 25 C., 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 25 C., *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 25 C., Buckthorn Brown, sparse aerial hyphae, reverse pigmented, Buckthorn Brown. Sporulation not observed	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. Zhang WSF14P22 (RUTPP-WSF14P22)	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. Zhang WFS14P13; Colliers Mills, N40 04.084 W74 26.696, 5 m alt., from

TABLE 2-continued

Species	MycoBank #	Etymology	Morphological Description	Holotype	Other materials examined
					roots of *Pinus rigida*, 4 Jun. 2014, E. Walsh & N. Zhang CM14P64

Morphological Study and Growth Rate

[0033] 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

[0034] 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 45 s, 54° C. for 45 s, 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, N.J.).

Sequence Alignment and Phylogenetic Analyses

[0035] 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 *Rhytismatales*. 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 lacrymajobi*, root	New Jersey Pine Barrens, USA	—	—	—
Barrenia panicia	WSF1R37	*Panicum virgatum*, root	New Jersey Pine Barrens, USA	—	—	—

TABLE 3-continued

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
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
Mollista 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		

TABLE 3-continued

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
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

[0036] 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 30 s, 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.

[0037] 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

[0038] 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

[0039] 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. **4**A-**4**R.

[0040] 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

[0041] 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 (FIGS. **5**A and **5**C). 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. **6**A-**6**C). 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. **5**E).

Discussion

[0042] 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.

[0043] 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.

[0044] 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).

[0045] 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).

[0046] 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.

[0047] 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

[0048] 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.

[0049] 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 (FIGS. **7** and **8**). These findings indicate that *Acidomelania panicicola* inoculation enhances root hair abundance.

[0050] 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 (FIG. **9**). Root and shoot length of switchgrass seedlings were visualized 8 days after inoculation when enhanced root and shoot length were observed (FIG. **10**). These results demonstrate that colonization of switchgrass seedlings with *Acidomelania panicicola* enhances switchgrass growth and survival.

[0051] 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 (FIG. **11**). These findings indicate that *Acidomelania panicicola* can enhance growth of edible plants.

B. Bacterial and Fungal Mixing and Inoculation of Seeds

[0052] 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

[0053] 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

[0054] 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

[0055] 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.

[0056] 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

[0057] 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.

[0058] 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).

[0059] 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.

[0060] 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

[0061] 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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[0100] 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.

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tgccgcctac cgggaccgag gaccgcgctt cggctaggat gctggcgtaa tggttgtaag    780
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tttccatgga tggtacaagc acaggaatgc gcggagagga tgatttgaca tacaagcttg   1620
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<210> SEQ ID NO 7
<211> LENGTH: 1448
<212> TYPE: DNA
<213> ORGANISM: Acidoradicia taeda

<400> SEQUENCE: 7

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aaaactttca acaacggatc tcttggttct ggcatcgatg aagaacgcag cgaaatgcga    180
taagtaatgt gaattgcaga attcagtgaa tcatcgaatc tttgaacgca cattgcgccc    240
ggtggtattc cgccgggcat gcctgttcga gcgtcattat aaccactcaa gcctggcttg    300
gtattggggt acgcggcttc gcggctccta aaatcagtgg cggtgccggt gggctctaag    360
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cgtagtaaat ctcctcgcta tagggttcct ctggttgctt gcggtgcact cgatcgtctt 420
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ttatagccta gggtgcaatg ccgcctaccg ggaccgagga ccgcgcttcg gctaggatgc 540
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cgagtgtttg ggtgtcaaac ccatacgcgt aatgaaagtg aacggaggtg agagcccttt 660
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cagagatggc tttaaatgtc ttccgaagca tgtcctcggc tgagattcgc gacctgggcc 1260
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caagaatg 1448

<210> SEQ ID NO 8
<211> LENGTH: 1493
<212> TYPE: DNA
<213> ORGANISM: Acidoradicia taeda

<400> SEQUENCE: 8

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aaaactttca acaacggatc tcttggttct ggcatcgatg aagaacgcag cgaaatgcga 180
taagtaatgt gaattgcaga attcagtgaa tcatcgaatc tttgaacgca cattgcgccc 240
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cgtagtaaat ctcctcgcta tagggttcct ctggttgctt gcgcttgcaa ccagacttgc 420
aggcggtcga tcatccgagg ttctccccgg tgcactcgat cgtcttcagg ccagcatcgg 480
tttcggtggc gggataaagg ctctaggaat gtggctcttc ggagtgttat agcctagggt 540
gcaatgccgc ctaccgggac cgaggaccgc gcttcggcta ggatgctggc gtaatggttg 600
taagcggccc gtcttgaaac acggaccaag gagtctaaca tctatgcgag tgtttgggtg 660
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accgatcctg atgtcttcgg atggatttga gtaagagcat agctgttggg acccgaaaga 780
tggtgaacta tgcgtgaata gggtgaagcc agaggaaact ctggtggagg ctcgcagcgg 840
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gatacgatat ggcgactttg caagcccaag atgatctgcg acagcgatgt ccctaacgac   1080
gatgaatttg gtggtgatcc aaaggaagct gtcaagcgtt ctcatggagg ttgtggtaat   1140
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gatgaagaaa atgaggggtc aagtcaagaa aagagacaaa tcactccaga gatggctcta   1260
aatgtcttcc gaagcatgtc ctcggctgag attcgcgacc tgggcctgag caacgactac   1320
gctcgtcccg actggctcat cattacagtc cttcctgttc ctcctccgcc cgttcgccct   1380
agtatttcta tggatggcac aagcacggga atgcgtggag aagatgattt gacctacaag   1440
cttggtgata taattcgtgc aaacggcaac gttaagcaag cacaacaaga agg          1493
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<210> SEQ ID NO 9
<211> LENGTH: 1493
<212> TYPE: DNA
<213> ORGANISM: Acidoradicia taeda

<400> SEQUENCE: 9

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aaaactttca acaacggatc tcttggttct ggcatcgatg aagaacgcag cgaaatgcga    180
taagtaatgt gaattgcaga attcagtgaa tcatcgaatc tttgaacgca cattgcgccc    240
ggtggtattc cgccgggcat gcctgttcga gcgtcattat aaccactcaa gcctggcttg    300
gtattggggt acgcggcttc gcggctccta aaatcagtgg cggtgccggt gggctctaag    360
cgtagtaaat ctcctcgcta tagggttcct ctggttgctt gcgcttgcaa ccagacttgc    420
aggcggtcga tcatccgagg ttctccccgg tgcactcgat cgtcttcagg ccagcatcgg    480
tttcggtggc gggataaagg ctctaggaat gtggctcttc ggagtgttat agcctagggt    540
gcaatgccgc ctaccgggac cgaggaccgc gcttcggcta ggatgctggc gtaatggttg    600
taagcggccc gtcttgaaac acggaccaag gagtctaaca tctatgcgag tgtttgggtg    660
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accgatcctg atgtcttcgg atggatttga gtaagagcat agctgttggg acccgaaaga    780
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cagggtcagt tcgcccgaat agggtggcag atctacttgt tctttgtgct gacatgagta    960
tctcagagta atccggcgta caaggcagct gtttcgattc gggacccgaa gcgtaggttc   1020
gatacgatat ggcgactttg caagcccaag atgatctgcg acagcgatgt ccctaacgac   1080
gatgaatttg gtggtgatcc aaaggaagct gtcaagcgtt ctcatggagg ttgtggtaat   1140
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gatgaagaaa atgaggggtc aagtcaagaa aagagacaaa tcactccaga gatggctcta   1260
aatgtcttcc gaagcatgtc ctcggctgag attcgcgacc tgggcctgag caacgactac   1320
gctcgtcccg actggctcat cattacagtc cttcctgttc ctcctccgcc cgttcgccct   1380
agtatttcta tggatggcac aagcacggga atgcgtggag aagatgattt gacctacaag   1440
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cttggtgata taattcgtgc aaacggcaac gttaagcaag cacaacaaga agg 1493

<210> SEQ ID NO 10
<211> LENGTH: 2027
<212> TYPE: DNA
<213> ORGANISM: Cudoniella clavus
<220> FEATURE:
<221> NAME/KEY: misc_feature
<222> LOCATION: (573)..(573)
<223> OTHER INFORMATION: n is a, c, g, or t
<220> FEATURE:
<221> NAME/KEY: misc_feature
<222> LOCATION: (1831)..(1831)
<223> OTHER INFORMATION: n is a, c, g, or t

<400> SEQUENCE: 10

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ttaggcactg gcttcggctg gctcgcgccc gccagagaac cccaaactct aaatgttagt 180

gtcgtctgag tactatctaa tagttaaaac tttcaacaac ggatctcttg gttctggcat 240

cgatgaagaa cgcagcgaaa tgcgataagt aatgtgaatt gcagaattca gtgaatcatc 300

gaatctttga acgcacattg cgccccttgg tattccgggg ggcatgcctg ttcgagcgtc 360

atttaaacca atccagcatg ctgggtcttg ggccttcgcc tctgggcggg cctcaaaatt 420

agtggcggtg ccacctggct ctacgcgtag taattcttct cgcgatggag tcccaggtgg 480

aagcttgcca acaaccccaa attcttttaa aggttgacct cggatcaggt agggataccc 540

gcctaagcat atcaataagc ggaggaaaag aanccaacag ggattacctc agtaacggcg 600

agtgaagcgg taacagctca aatttgaaat ctggctcttt cagggtccga gttgtaattt 660

gtagaagatg cttcgggtgt ggctccggtc taagttcctt ggaacaggac gtcatagagg 720

gtgagaatcc cgtatgtgac tggttgcctt cgcccatgtg aagctctttc gacgagtcga 780

gttgtttggg aatgcagctc taaatgggtg gtaaatttca tctaaagcta aatattggcc 840

agagaccgat agcgcacaag tagagtgatc gaaagatgaa aagcactttg gaaagagagt 900

taaacagtac gtgaaattgt tgaaagggaa gcgcttgcaa ccagacttgc acgtcgtcga 960

tcatcctcag ttctctgggg tgcactcggc ggtgttcagg ccagcatcgg tttcggtggt 1020

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acccgtcttg aaacacggac caaggagtct aacatctatg cgagtgtttg ggtgttaaac 1200

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cctgatgtct tcggatggat ttgagtaaga gcatagctgt tgggacccga aagatggtga 1320

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cgtgcaaatc gatcgtcaaa tttgggtata ggggcgaaag actaatcgac tagacagggt 1440

cagttggccc gcatagcgtg gcatgtcttt tgtgcctttg tgctaacaga atgatttcag 1500

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cccgaatgga tgatcataac ggttctccca gttcctccac cacctgttcg acccagtatt 1920

tcaatggatg gcactggtca gggcatgcgc ggagaggacg atttgacata taagttggga 1980

gatatcatcc gggcaaacgg caatgtgcgg caagctcagc aggaagg 2027

<210> SEQ ID NO 11
<211> LENGTH: 1818
<212> TYPE: DNA
<213> ORGANISM: Dermea acerina
<220> FEATURE:
<221> NAME/KEY: misc_feature
<222> LOCATION: (446)..(446)
<223> OTHER INFORMATION: n is a, c, g, or t

<400> SEQUENCE: 11

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acaatagtta aaactttcaa caacggatct cttggttctg gcatcgatga agaacgcagc 180

gaaatgcgat aagtaatgtg aattgcagaa ttcagtgaat catcgaatct ttgaacgcac 240

attgcgcccc ttggtattcc ggggggcatg cctgttcgag cgtcattaca accctcaagc 300

tctgcttggt attgggcgtc accgggttcg gtgtgcctta aatcagtggc ggcgccgtc 360

tggctctaag cgtagtacat actctcgcta tggacgcctg gcggatgctt gcgaaatctg 420

ggtcttttag gctccgagtt gtaatntgta gaagatgctt cgggtgcggc tccggtctaa 480

gttccttgga acaggacgtc atagagggtg agaatcccgt atgtgatcgg gggcttgcgc 540

ccatgtgaag ctctttcgac gagtcgagtt gtttgggaat gcagctcaaa atgggtggta 600

tatttcatct aaagctaaat attggccaga gaccgatagc gcacaagtag agtgatcgaa 660

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cttgcaacca gacttgggcg gggttgatca tctagggttc tccctagtgc actcgacctc 780

gcacaggcca gcatcggttc cggtggttgg ataaaggcct tgggaatgta gcttctttcg 840

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tctggtggag gctcgcagcg gttctgacgt gcaaatcgat cgtcaaattt gggtataggg 1200

gcgaaagact aatcggctag acagggtcag ttctcccacg tagcgtgggg agcatgattg 1260

tttctgtgtg ctaacgtcaa tatctcagag taatccagcg tacaaagcag ccgtttcgat 1320

tcgagacccg aagcgtaggt tcgatacgat ctggcgactt tgcaagccca agatgatctg 1380

tgatagcgat ttgactgccg ccgatgatga tttcaatgca gacccgaagg aagccgcaaa 1440

gcgctcgcac ggtggatgtg gaaatactca gcctgaggtg cgccagtcgg ccttgcagct 1500

gtggggtaca tggaaggttc caaaggatga agacaatgat ggtgctactg ccgaaaagaa 1560

gcagatcact gcagagatgg ccctgaatgt cttccgaagc atttccactt ctgagatcca 1620

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agttcctcct ccacctgttc gaccgagtat ttcgatggac ggcactgggc aaggcatgcg 1740

aggagaggat gatttgacat acaagcttgg cgatatcatt cgtgcgaatg gcaacgttcg 1800

acaggcccag caagaagg 1818

<210> SEQ ID NO 12
<211> LENGTH: 1947
<212> TYPE: DNA
<213> ORGANISM: Hyaloscypha aureliella

<400> SEQUENCE: 12

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gaatacctta cctttgtctg ctttggcggg ccacgtccgc gtgccggctc cggctggttg 180

cgcccgccag aggacccaaa ctcttttgtt tagtgatgtc tgagtactat ataatagtta 240

aaactttcaa caacggatct cttggttctg gcatcgatga agaacgcagc gaaatgcgat 300

aagtaatgtg aattgcagaa ttcagtgaat catcgaatct ttgaacgcac attgcgcccc 360

ttggtattcc gaggggcatg cctgttcgag cgtcattatg accactcaag cctggcttgg 420

tgttggggtc cgcggtcccg cggcccttaa aatcagtggc ggcgccatct ggctctcagc 480

gtagtaatac tcctcgctac agggtcccac ggcgagtgaa gcggcaacag ctcaaatttg 540

aaatctggct cctgcggggc ccgagttgta atttgtagaa gatgctttga gcgtggctcc 600

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cctccgttcg tgtaaagctc tttcgacgag tcgagttgtt tgggaatgca gctcaaaatg 720

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gatcgaaaga tgaaaagcac tttggaaaga gagttaaaca gtacgtgaaa ttgttgaaag 840

ggaagcgctt gcaaccagac ttgcccgctg ctgatcatcc gaggttctcc ccggtgcact 900

cggcagcgat caggccagca tcggttctgg tgggcggata aaggccttgg gaatgtagct 960

tccttcgggg agtgttatag ccctcggtgc aatgcgccct accgggaccg aggaccgcgc 1020

ttcggctagg atgctggcgt aatggttgta agcgacccgt cttgaaacac ggaccaagga 1080

gtctaacatc tatgcgagtg tttgggtgtt aaacccatac gcgtaatgaa agtgaacgga 1140

ggtgagaacc cttaagggtg catcatcgac cgatcctgat gtcttcggat ggatttgagt 1200

aagagcatag ctgttgggac ccgaaagatg gtgaactatg cctgaatagg gtgaagccag 1260

aggaaactct ggtggaggct cgcagcggtt ctgacgtgca aatcgatcgt caaatttggg 1320

tataggggcg aaagactaat cgacttgaca gagtcagtgt gcctgaactt gagggccgag 1380

tttcttgtgt gcctttatgc taacttcatg attgcagaac aatccggcgt acaaagctgc 1440

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aggtatgcga ggagaggatg atttgacata caaacttggt gacatcatcc gtgcgaatgg 1920

aaacgttcga caggcgcatc aagaggg 1947

<210> SEQ ID NO 13
<211> LENGTH: 1857
<212> TYPE: DNA
<213> ORGANISM: Lachnum virgineum

<400> SEQUENCE: 13

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tagttaaaac tttcaacaac ggatctcttg gttctggcat cgatgaagaa cgcagcgaaa 180

tgcgataagt aatgtgaatt gcagaattca gtgaatcatc gaatctttga acgcacattg 240

cgccccttgg tattccgggg ggcatgcctg ttcgagcgtc atttatacca atctarcctg 300

gctaggtgtt gggcctcgcc agttggcggg ccttaaaact agtggcggtg ctcttcagct 360

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tcgacgagtc gagttgtttg ggaatgcagc tcaaaatggg tggtaaattt catctaaagc 660

taaatattgg ccagagaccg atagcgcaca agtagagtga tcgaaagatg aaaagcactt 720

tggaaagaga gttaaacagt acgtgaaatt gttgaaaggg aagcgcttgc aaccagactt 780

agttgctgcc gatcatccag ggttctccct ggtgcactcg gtagtatcta ggccagcatc 840

ggtttgggtg gtgggataaa ggccttggga atgtagcttc tttcggggag tgttatagcc 900

ctcggtgcaa tgccgcctac ccggaccgag gaccgcgctt cggctaggat gctggcgtaa 960

tggttgtaag ccacccgtct tgaaacacag accaaggagt ctaacatcta tgcgagtatt 1020

tgggtgttaa acccatatgc gtaatgaaag tgaacggagg tgagaaccct taagggtgca 1080

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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

i) 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, or

ii) said composition is prepared before use by mixing said fungi and bacterial cultures with seeds, or

iii) said composition is prepared before use by mixing seeds with said fungi and bacterial cultures and drying said seeds to form a coating thereon.

5. (canceled)

6. (canceled)

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

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

9. The method of claim **2**, wherein the crop plants are dicotyledonous plants or monocotyledonous plants.

10. The method of claim **9**, wherein said plant is an edible plant selected from lettuce, corn, rice, soybeans, potatoes, barley, wheat, and carrots.

11. (canceled)

12. The method of claim **2** 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**, optionally for use as a seed coating.

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. (canceled)

18. The biofertilizer composition of claim **13**, wherein the composition is applied as a seed coating and improves seed germination.

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

20. (canceled)

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

i) inoculating said seeds with said endophyte on agar or growth medium and placing seeds and agar in the soil, or

ii) mixing seeds with said fungi and bacterial cultures and drying said seeds to form a coating thereon or,

iii) mixing seeds with said fungi and bacterial cultures and drying said seeds to form a coating thereon.

25. (canceled)

26. (canceled)

27. The method of claim **24** 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.

* * * * *