Supporting Information

Biodegradation of the Allelopathic Chemical, Pterostilbene, by *Sphingobium* sp. from Peanut Rhizosphere

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Supplemental figures: Figure S1 – S6

Supplemental tables: Table S1 –S2

Materials and Methods –Extra LCMS methods for sample analysis

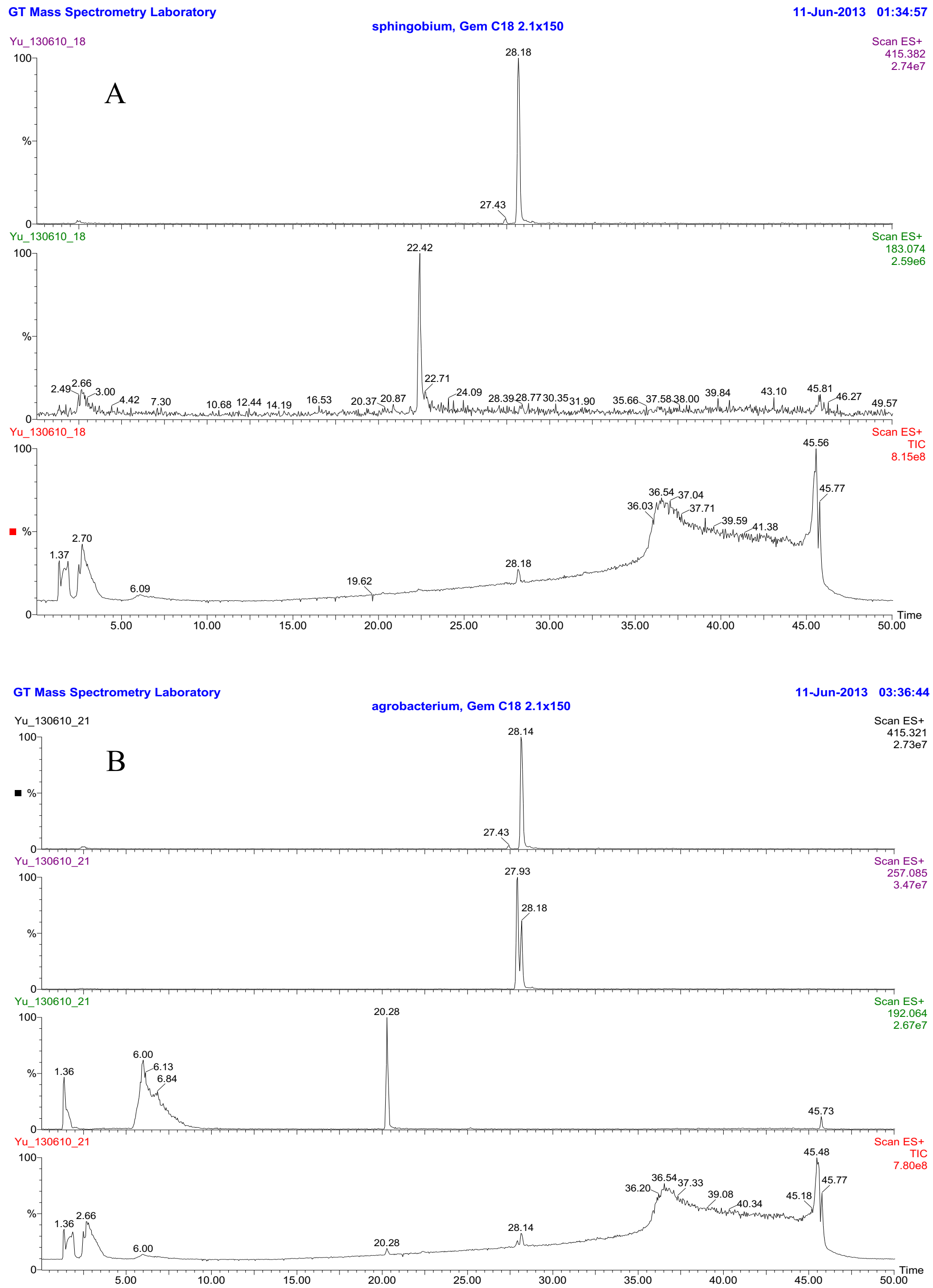

Figure S1. LC-MS analyses of novel products from pterostilbene metabolism by *Sphingobium* sp. JS1018 (**panel A**) at HPLC RT 6.23 min (or RT 28.18 min on LC-MS with an m/z value of 415); and novel products from pterostilbene metabolism by *Agrobacterium tumefaciens* JS1013 (**panel B**) at HPLC RT 6.23 min (or RT 28.14 min on LC-MS with an m/z value of 415) and RT

5.57 min (or RT 20.28 on LC-MS with an m/z value of 192) with pterostilbene as a reference (m/z of 257).

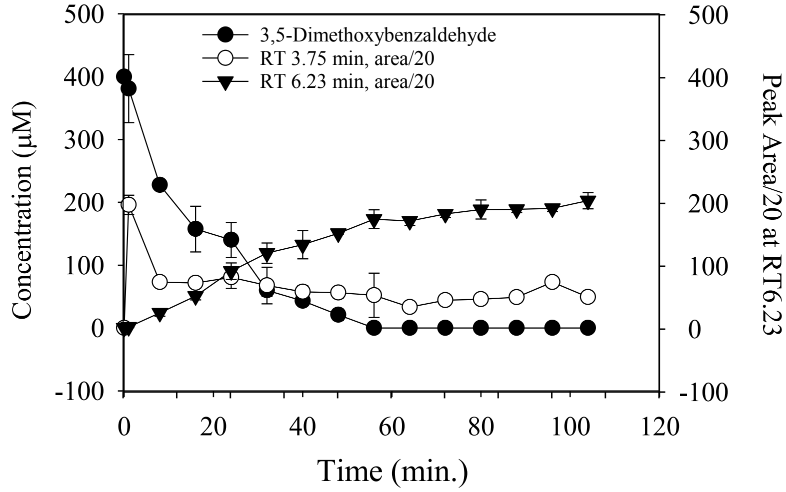

Figure S2. Dimethoxybenzaldehyde metabolism kinetics and novel metabolites produced during enzyme assays with dialyzed crude extracts prepared from 3,5-dimethoxybenzaldehyde-induced cells (grown in 1 mM 3,5-dimethoxybenzaldehyde for 4 days) of *Sphingobium* sp. strain JS1018.

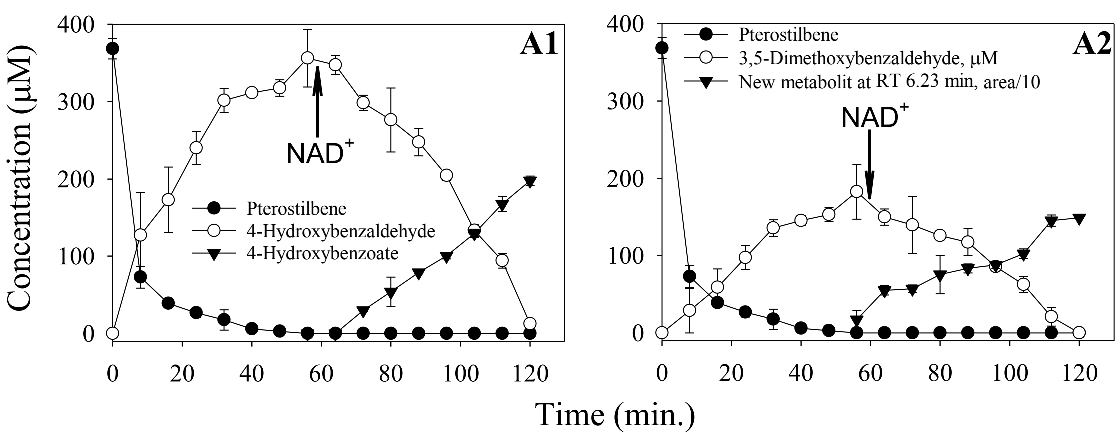

Figure S3. Degradation of pterostilbene (A1 and A2) in dialyzed crude extract of resveratrol-grown JS1018 cells. NAD^+ (3 mM) was added at 60 min in the enzyme assay.

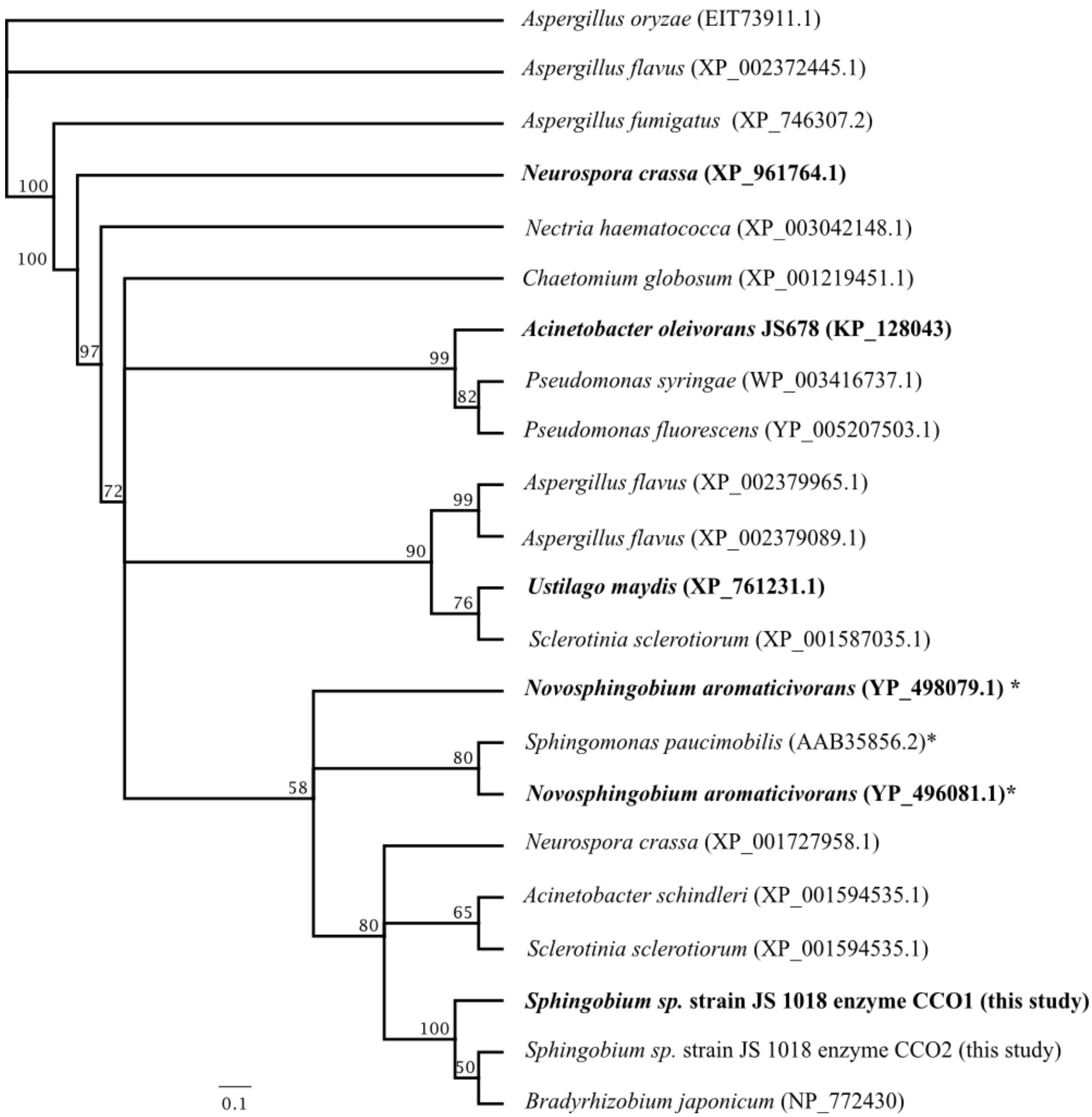

Figure S4. Phylogenetic analysis of functionally characterized carotenoid cleaving oxygenases (1-5). Enzymes that transform a stilbenoid are in bold and enzymes that were originally identified as lignostilbene oxygenases are marked with *. The tree was constructed based on neighbor joining method and bootstrap values are included in nodes.

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Sphingomonas paucimobilis        ------------------------------------------------------------
Spingobium sp. JS 1018           -----------------------------------------------------------M
Acinetobacter sp. JS678          -----------------------------------------------------------M
Arabidopsis thaliana             ------------------------------------------------------------
Synechocystis sp. PCC6803        -----------------------------------------------------------M
Novosphingobium aromaticivorans  MASLITTKAMMSHHHVLSSTRITTLYSDNSIGDQQIKTKPQVPHRLFARRIFGVTRAVIN

Sphingomonas paucimobilis        MAHFPQTPGFSGTLRP---------LRIEGDILDIEIEGEVPPQLNGTFHRVHPDAQFPP
Spingobium sp. JS 1018           TSCFPDDPIYRGFDAP---------GRVEANVFDLEVEGRVPPELDGTFFRVAPDPQWPP
Acinetobacter sp. JS678          SFTFPNTSEFTGLYEP---------CRIEADITDLVIEGDIPSAIKGTFYQVAPDPQYPP
Arabidopsis thaliana             MGAFPQTIYFTGANAP---------VGEEPDLRGLKVEGDLPAEVRGSFYRAIPDPAFPP
Synechocystis sp. PCC6803        VTSPPTSSPSQRSYSPQDWLRGYQSQPQEWDYWVEDVEGSIPPDLQGTLYRNGPGLLEIG
Novosphingobium aromaticivorans  SAAPSPLPEKEKVEGERRCHVAWTSVQQENWEGELTVQGKIPTWLNGTYLRNGPGLWNIG
                                     .                       *       ::* :*. : *:  :  *.

Sphingomonas paucimobilis        RFEDDQFFNGDGMVSLFRFH-DGKIDFRQRYAQTDKWKVERKAG----KSLFGAYRNPLT
Spingobium sp. JS 1018           MLGHDIFFNGDGMVCAFRFK-DGRVDFTSRYAQTDKFVAERQAR----KALYGAYRNPYT
Acinetobacter sp. JS678          MLGNDIFFNGDGVVTAIELG-EGRVSMKRRYVQTPRLVAQKQAH----RSLNGVYRNIYT
Arabidopsis thaliana             RFENDHTLSGDGMVSRLSFNGDGTADFIQKYVETARYKAEKAAG----KALFGKYRNPFT
Synechocystis sp. PCC6803        DRPLKHPFDGDGMVTAFKFPGDGRVHFQSKFVRTQGYVEEQKAGKMIYRGVFGSQPAGGW
Novosphingobium aromaticivorans  DHDFRHLFDGYSTLVKLQFD-GGRIFAAHRLLESDAYKAAKKHNRLCYREFSETPKSVII
                                        :.* . :  : :   *      :  .:      :       : .

Sphingomonas paucimobilis        DDASVQGMIRGT-----------ANTNVMVHAG--KLYAMKEDSPCLIMDPLTLETEGYT
Spingobium sp. JS 1018           DDPSVAGSIRST-----------ANTNVIVHHG--LLLALKEDSPPVAMRPDTLETIGNY
Acinetobacter sp. JS678          NDP-LAAKNNTT-----------ANTTVIEHNG--VLLAMKEDALPWALDLKTLETIGEW
Arabidopsis thaliana             DDPEVQGVDRTV-----------ANTTPVWHAG--RMLMAKEDGRPYRVDPRTLATIGSY
Synechocystis sp. PCC6803        LKTIFDLRLKNI-----------ANTNITYWGD--RLLALWEGGQPHRLEPSNLATIGLD
Novosphingobium aromaticivorans  NKNPFSGIGEIVRLFSGESLTDNANTGVIKLGDGRVMCLTETQKGSILVDHETLETIGKF
                                  .  .    .             ***      .   :           :   .* * *

Sphingomonas paucimobilis        NFDGKLQS-QTFCAHPKIDPVT----GNLCAFAYGAKGLMTLDMAYIEISPTGKLLKEIP
Spingobium sp. JS 1018           RFGDKMMS-ETFTAHPKVDPVS----GELIAFGYSAKGVATSDLAYYVIDRHGEVVHEAW
Acinetobacter sp. JS678          DFNGQINS-ATFTAHPKIEPKT----GNLLCFAYEAKGDGTPDIAYYEISATGELLKEIW
Arabidopsis thaliana             DFGGALKS-ETMTAHVRIDAGT----GELFFYGYEADGQASTKVAYCIVGPDGELKREQW
Synechocystis sp. PCC6803        DLGGILAEGQPLSAHPRIDPASTFDGGQPCYVTFSIKSSLSSTLTLLELDPQGKLLRQKT
Novosphingobium aromaticivorans  EYDDVLSDHMIQSAHPIVTETE----MWTLIPDLVKPGYRVVRMEAGSNKREVVGRVRCR
                                   .. : .     **  :                   .     :             .

Sphingomonas paucimobilis        FQNPYYCMMHDFGVTEDYAVFAVMPLLSS----WDRLEQRLPFFGFDTTLPCYLGILPRN
Spingobium sp. JS 1018           FTAPRAASIHDFAVTENYVVFPVGSHEIE----TERLKAGKPAFVWRPDVEQIYGVLPRR
Acinetobacter sp. JS678          FQAPYAAMIHDFAVTENYVIFPIIPLTVD----IERMKKGGQHFQWQPDLEQLFGILPRS
Arabidopsis thaliana             FDAPYCAMMHDFTISENYALFPIYPTTAD----LDRLKAGGEHWHHQPELDSWLGVMPRY
Synechocystis sp. PCC6803        ETFPGFAFIHDFAITPHYAIFLQNNVTLNGLPYLFGLRGAGECVQFHPDKPAQIILVPRD
Novosphingobium aromaticivorans  SGSWGPGWVHSFAVTENYVVIPEMPLRYSVKNLLRAEPTPLYKFEWCPQDGAFIHVMSKL
                                         :*.* :: .*.::       .                  .       ::.:

Sphingomonas paucimobilis        GDARDLRWFKTGN-CFVGHVMNAFNDGT--------------KVHIDMPVSRNNSFPFF-
Spingobium sp. JS 1018           GNAEDMRWFTVPTNGFQGHTINAWDDGH--------------KVYVDMPMLNDNAFWFYP
Acinetobacter sp. JS678          GQAEDIQWFYGPKNGFQGHTLNSFEKNG--------------KIYVDMPVASGNVFYFFP
Arabidopsis thaliana             GDVSEIKWFKGPKGCHSYHMMNAWEDADG-------------MLHFDACLNNTNAFAFIR
Synechocystis sp. PCC6803        G---GEIKRIPVQAGFVFHHANAFEENG--------------KIILDSICYNSLPQVDTD
Novosphingobium aromaticivorans  TG--EVVASVEVPAYVTFHFINAYEEDKNGDGKATVIIADCCEHNADTRILDMLRLDTLR
                                                   *  *:::.                    *

Sphingomonas paucimobilis        DVHGAPFDPVAGQGFLTRWTVDMASNGDSFEKTERLFDRPDEFPRIDERYATRAYRHGWM
Spingobium sp. JS 1018           DENGHAPHPSTLKQTMTRWIFDLSSNS-VTPQMDIIPAPMGEFPHIDERYATRPYRHAFL
Acinetobacter sp. JS678          PAEAPVHSEQITSALMRWEFDLQATDHHVKPQPITNKQYPCEFPRCDERFNGLEYSYGFL
Arabidopsis thaliana             EPSGIHMGPQDIKGALTRWTVDPRADG--GDVVETVIGPPGDFPVIPAKLQGRPYKTGWM
Synechocystis sp. PCC6803        GDFRSTNFDNLDPGQLWRFTIDPAAAT---VEKQLMVSRCCEFPVVHPQQVGRPYRYVYM
Novosphingobium aromaticivorans  SSHGHDVLPDARIGRFRIPLDGSKYGKLETAVEAEKHGRAMDMCSINPLYLGQKYRYVYA
                                                :                         ::           *   :

Sphingomonas paucimobilis        LILDTEKPYEAPGG-----AFYALTNTLGHIDLATGKSSSWWAGPRCAIQEPCFIPRSPD
Spingobium sp. JS 1018           AVIDPTAPYDFQRCGPP--SVNAFLNGLAHVDMTTGASRRWLPGPTSTVQEPVFAPRSPE
Acinetobacter sp. JS678          LAFDPDLAFDHENLG-E--YPFQFFNQLARVNVQTGITETWYPGDKYCFQEPIFIPRSND
Arabidopsis thaliana             LSMNPELQGPPLFAGPVGVSFNLLLRLDGMDTPAPQVTGALALPPMAGFNEPVHVP--AA
Synechocystis sp. PCC6803        GAAHHSTG-------------NAPLQAILKVDLESGTETLRSFAPHGFAGEPIFVPRPGG
Novosphingobium aromaticivorans  CGAQRPCN---------------FPNALSKVDIVEKKVKNWHEHG-MIPSEPFFVPRPGA
                                    .                     .                        ** . *

Sphingomonas paucimobilis        APEGDGYVIALVDDHVANY---SDLAIFDAQHVDQGPIARAKLPVRIRQGLHGNWADASR
Spingobium sp. JS 1018           SPEGDGYVIALVNRLDEMR---SDLVVLDAQHIDEGPVATIRLPLRLRNGLHGNWVPSSA
Acinetobacter sp. JS678          ASEGDGWVASIMNDLLEEK---SELVILDTQNWEKGPIARVKIPFRLRMSLHGNWSPQEK
Arabidopsis thaliana             DPAKDGWLVFLVDQQVGDNQFVHEAWVVDAGNIGAGAVAKVHIPTRLRPQVHGWWVPQAQ
Synechocystis sp. PCC6803        VAEDDGWLLCLIYKADLHR---SELVILDAQDITAPAIATLKLKHHIPYPLHGSWAQT--
Novosphingobium aromaticivorans  THEDDGVVISIVSEENGGS------FAILLDGSSFEEIARAKFPYGLPYGLHGCWIPKD-
                                     ** :  ::               .         :*  ::   :   :** *

Sphingomonas paucimobilis        LAVAA----
Spingobium sp. JS 1018           MRSPLPA--
Acinetobacter sp. JS678          ---------
Arabidopsis thaliana             LDALEGSAA
Synechocystis sp. PCC6803        ---------
Novosphingobium aromaticivorans  ---------
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Figure S5. Conserved histidines (red rectangles) and glutamic acids (blue rectangles) of CCO1 and previously characterized carotenoid oxygenases usinf T-cofeee server. The accession numbers of the sequences from top to the bottom used are Q53353, KY888940, Q8VY26, P74334*, KX523172 and Q2G4H8*. *enzymes with established crystal structures.

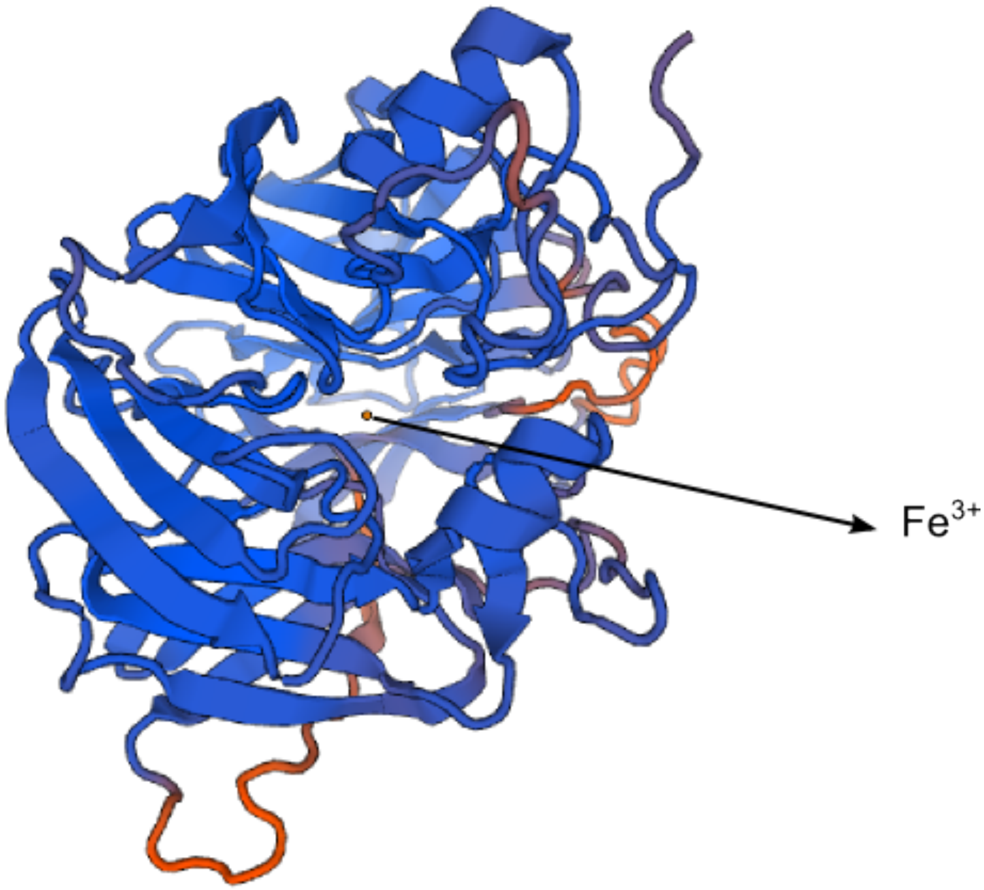

Figure S6. Model using SWISS-MODEL (6-8).

Table S1 Stilbenoid degrading bacteria isolated from peanut plants in Dawson, GA.

Isolates	Most closely related sequence (Accession number)	Max Identifica-tion (%)	Grow on Res/Ptero (Base pairs)	Potential PGPB species** (see ref.)
Rhizosphere soil				
JS678	*Acinetobacter calcoaceticus* B9 (JQ579640)	99.9	Res/Ptero (1411)	H(9, 10)
JS679	*Pseudomonas fluorescens* NBRC 13922 (AB680523)	99.7	Res/Ptero (1409)	H/N(11)
JS680	*Pseudomonas fluorescens* strain IBFC2012-45 (KC246049)	99.9	Res (1408)	H/N(11)
JS681	*Pseudomonas sp.* MGR37 (JQ627866)	99.8	Res (1393)	-
JS682	*Pseudomonas* sp. d6(2010) (HQ166101)	99.8	Res/Ptero (1410)	N
JS683	*Burkholderia cenocepacia* SR2-07 (KF891406)	99.8	Res/Ptero (1402)	H/N(12)
JS1012 Soil 1_D2	*Pseudomonas oryzihabitans* (JX067903)	99.8	Res (1407)	H(13)
JS1013 Soil 2_C3	*Agrobacterium tumefaciens* (KC107786)	100	Res/Ptero (1352)	H/N(14)
JS1014 Soil 3_F5	*Pseudomonas putida* strain SP2 (GQ200822)	100	Res/Ptero (1402)	H/N(15)
JS1015 Soil 4_B9	*Pseudomonas frederiksbergensis* strain M60 (KC934887)	99.8	Res/Ptero (1394)	-
JS1016 Soil 5_2ndC3	*Pseudomonas putida* strain P-1017-1 (HQ324912)	99.6	Res/Ptero (1392)	H/N(15)
JS1017 Soil 6_A1Ptero	*Pseudomonas putida* strain NB2011 (JF261631)	99.4	Res/Ptero (1401)	H/N(15)
JS1018 Soil 7_C2Ptero	*Sphingobium yanoikuyae* strain BF-18 (EU307932)	100	Res/Ptero (1361)	-
JS1019 Soil 8_D2Ptero	*Sphingobium yanoikuyae* strain St16 (JN700070)	99.5	Res/Ptero (1360)	-
JS1020 Soil 9_F3Ptero	*Sinorhizobium morelense* strain LMG 9954 (AM181735)	99.9	Res/Ptero (1359)	N(16)
JS1021 Soil 10_H3Ptero	*Pseudorhodoferax aquiterrae* NAFc-7 (NR_108842)	99.0	Res/Pteto (1406)	-
JS1022 Soil 11_B4Ptero	*Pseudomonas* sp. SJH-007 (KC335141)	100	Res/Ptero (1410)	-
Peanut seeds				
JS1023 Seed 12_A1	*Xanthomonas translucens* strain P25 (AY994101)	99.7	Res (1419)	N(17)
JS1024 Seed 13_E3	*Xanthomonas translucens* strain P7 (AY994100)	99.6	Res (1417)	N(17)
JS1025 Seed 14_F3	*Xanthomonas* sp. Sbr1009a (KC311265)	99.8	Res/Ptero (1405)	N(17)

JS1026 Seed 15_A1	*Pandoraea* sp. JB1 (DQ167022)	99.8	Res/Ptero (1399)	N(18)
JS1027 Seed 16_B2	*Pandoraea* sp. CCUG 39680 (AY268171)	99.5	Res/Ptero (1407)	N(18)
JS1028 Seed 17_C1	*Pandoraea* sp. B-6 (JN128829)	99.5	Res/Ptero (1400)	N(18)
JS1029 Seed 19_B2Ptero	*Xanthomonas* sp. Era34 (JQ977166)	99.8	Res/Ptero (1401)	N(17)
JS1030 Seed 20_D2Ptero	*Xanthomonas translucens* NBRC 13559 (AB680445)	99.8	Res/Ptero (1418)	N(17)
Peanut shells				
JS1031 Shell 21_D1	Uncultured *Herbaspirillum* sp. clone A4H6M9 (GQ206314)	99.8	Res/Ptero (1401)	-
JS1032 Shell 22_E1	*Pandoraea* sp. LY (AF532595)	99.8	Res/Ptero (1406)	N(18)
JS1033 Shell 23_F1	*Burkholderia* sp. A45 (KF788025)	99.5	Res/Ptero (1401)	N(12)
JS1034 Shell 24_H1	*Pandoraea* sp. AU1775 (AY043377)	99.9	Res/Ptero (1401)	N(18)
JS1035 Shell 25_C4	*Burkholderia* sp. IBP-VNS150 (JQ518349)	99.6	Res/Ptero (1398)	H/N(12)
JS1045 Shell 26_F4Ptero	*Pectobacterium cypripedii* strain B1 (JF430157)	99.0	Res/Ptero (1409)	N(19)

* Strains were isolated from resveratrol enrichments except for the ones with “ptero” in the designation, which were enriched with pterostilbene”.

** PGPB represents Plant Growth-Promoting Bacteria (including rhizobia) that could enhance plant growth through producing plant hormones (‘H’) and/or improving plant nutrition (‘N’).

Table S2 DNA sequences of two putative carotenoid cleavage oxygenase (*cco*) genes identified from the genome of *Sphingobium yanoikuyae* strain JS1018.

>*cco*1-JS1018 (KX523172)
atgacatcgtgctttcctgacgatccgatctatcgcggatttgatgcaccaggtcgagtt
gaggcgaatgttttcgatctcgaggtcgaaggccgggttcctccggagcttgatggaaca
ttctttcgcgtcgctcctgacccccaatggccaccgatgctggggcatgacattttcttc
aacggcgatgggatggtttgtgccttccgcttcaaggacggacgtgtcgattttacgtcc
agatatgcacagacggacaagtttgtggcggaacggcaggcacgcaaggcgctgtacggc
gcatatcgcaatccatacacggatgacccgagcgtggccggctctattcgcagtaccgcc
aataccaacgtaatcgttcatcatggattgctgctggccctcaaggaagacagcccgcct
gtggccatgcggcccgatacgctcgagacaatcggaaactatcgattcggcgacaagatg
atgagtgagactttcacggcgcatccgaaggtcgatccggtcagtggcgaattgatcgca
ttcggatatagcgcaaaaggcgtcgcaaccagcgatctcgcctattacgtaatcgaccgc
catggggaagtggtacacgaggcttggttcaccgcgcctcgcgccgcttcaattcatgat
ttcgcggtgaccgaaaattatgtggtatttcctgtcggctcgcatgagattgagactgag
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gtgctcccgcggcgcggtaatgcggaggatatgcgctggtttacggttcccaccaacggg
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atgacgacaggtgcaagccgccgttggcttcccggaccgacctccacagtccaggagcct
gtcttcgctccacgctcacccgaatcgcccgaaggtgatggctacgtgattgcgcttgtc
aaccggcttgatgaaatgcgtagcgacctcgttgttcttgatgcccagcatatcgacgaa
ggtccggtcgcgaccatccgtctcccgttgcgactgcgcaatggactgcatggtaattgg
gttccttcaagtgccatgaggtcgccattgccggcttga

>*cco*2-JS1018 (KX523173)
atggcaacttcgttacggcacccggtgattgatcatgcgcccgcgtggcggaccgataat
ccgcacctaaacggagcatgggcgccatggacggaagaaacgtcagccttcgatgtaccc
gtcgaaggcaccattcctgaagatcttgctggcgcccttttccggatttcagcaaatccc
cgctttgagcctatcgatctggaaacctaccattggttcgatggagacggcatggtgggt
gggatttacattcgtgacggcaaggtcagctaccgtcaaaaatgggtggagactgcgtcg
atggccgtggaattggcggcgcggcaggccttgtatcctggcctagtgaatggctcgaaa
ggccggcctttgccggctggcgcgccgccgatgaagaacgttgccaacattaccgccggt
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ctgactctcgccacgcgcggtagcttcgattttcatggtcgcgtcaatcagacctgtgcg
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catcgctggaccatcgatttgtcgacaggccgcgtccatgaggaaagacttagcgatctt
gctggcgattttcccaaaatcaacgatgccttgacgacacggcatcatcgtttcggctat
tggacggcaaccaccaagtctggttcggaagcaatgaccttcgggctggtaaagcatgac
ctcgagcgaggcagcatcgatctgatcgagagtccggacgccagccttacccagccaacg
gaagtcgtcttcgttgcccggcgtggcgcagtcgaagaggatgacggttatctcctgtcg
ctgtggtggaaccgcgaaacgcgattgagcgaattgcttgtgcacagcgcgaaggaacca
agccacaatccgctggcgcgagtgcgccttcccgcccgccttccttacggcccccacggg
aactgggctgatgccgaaagtctggatcaggcggccgctgcttatgcgacgggaaattga

Materials and Methods – Extra LCMS Methods for Sample Analysis

A few of selected samples were also analyzed by a mass spectrometry Thermo Orbitrap XLT (Thermo Sci.). The column was a Supelco Ascentis Express C8, 300 μm × 15cm, using 2.7 μm particles. The LC system was a Nano ACQUITY UPLC System (Waters Corp.). Solvent A was 5% acetonitrile in water, and solvent B was 95% acetonitrile in water. Both solvents contained 0.1% (v/v) formic acid. The flow rate was 5 μL min^{-1}. The gradient began at 100% A and was held for 5 min, then ramped to 100% B at 45 min. It was held there until 55 min and then reset to 100% A until the end of the run at 60 mins. The Orbitrap was scanned in positive ESI mode from 200-2000 Da, at a mass resolution of 30000.

REFERENCES

1. Brefort T, Scherzinger D, Limon MC, Estrada AF, Trautmann D, Mengel C, Avalos J, Al-Babili S. 2011. Cleavage of resveratrol in fungi: characterization of the enzyme Rco1 from *Ustilago maydis*. Fungal Genet Biol 48:132-143.
2. Kamoda S, Saburi Y. 1993. Cloning, expression, and sequence analysis of a lignostilbene-alpha,beta-dioxygenase gene from *Pseudomonas paucimobilis* TMY1009. Biosci Biotechnol Biochem 57:926-930.
3. Kamoda S, Saburi Y. 1993. Structural and enzymatical comparison of lignostilbene-alpha,beta-dioxygenase isozymes, I, II, and III, from *Pseudomonas paucimobilis* TMY1009. Biosci Biotechnol Biochem 57:931-934.
4. Marasco EK, Schmidt-Dannert C. 2008. Identification of bacterial carotenoid cleavage dioxygenase homologues that cleave the interphenyl alpha,beta double bond of stilbene derivatives via a monooxygenase reaction. Chembiochem 9:1450-1461.
5. Masai E, Katayama Y, Nishikawa S, Fukuda M. 1999. Characterization of *Sphingomonas paucimobilis* SYK-6 genes involved in degradation of lignin-related compounds. J Ind Microbiol Biotechnol 23:364-373.
6. Biasini M, Bienert S, Waterhouse A, Arnold K, Studer G, Schmidt T, Kiefer F, Gallo Cassarino T, Bertoni M, Bordoli L, Schwede T. 2014. SWISS-MODEL: modelling protein tertiary and quaternary structure using evolutionary information. Nucleic Acids Res 42:W252-258.
7. Arnold K, Bordoli L, Kopp J, Schwede T. 2006. The SWISS-MODEL workspace: a web-based environment for protein structure homology modelling. Bioinformatics 22:195-201.
8. Benkert P, Biasini M, Schwede T. 2011. Toward the estimation of the absolute quality of individual protein structure models. Bioinformatics 27:343-350.
9. Kang SM, Joo GJ, Hamayun M, Na CI, Shin DH, Kim HY, Hong JK, Lee IJ. 2009. Gibberellin production and phosphate solubilization by newly isolated strain of *Acinetobacter calcoaceticus* and its effect on plant growth. Biotechnol Lett 31:277-281.
10. Yamaga F, Washio K, Morikawa M. 2010. Sustainable biodegradation of phenol by *Acinetobacter calcoaceticus* P23 isolated from the rhizosphere of duckweed *Lemna aoukikusa*. Environ Sci Technol 44:6470-6474.
11. Kochar M, Upadhyay A, Srivastava S. 2011. Indole-3-acetic acid biosynthesis in the biocontrol strain *Pseudomonas fluorescens* Psd and plant growth regulation by hormone overexpression. Res Microbiol 162:426-435.
12. Onofre-Lemus J, Hernandez-Lucas I, Girard L, Caballero-Mellado J. 2009. ACC (1-aminocyclopropane-1-carboxylate) deaminase activity, a widespread trait in *Burkholderia* species, and its growth-promoting effect on tomato plants. Appl Environ Microbiol 75:6581-6590.
13. Belimov AA, Safronova VI, Sergeyeva TA, Egorova TN, Matveyeva VA, Tsyganov VE, Borisov AY, Tikhonovich IA, Kluge C, Preisfeld A, Dietz KJ, Stepanok VV. 2001. Characterization of plant growth promoting rhizobacteria isolated from polluted soils and containing 1-aminocyclopropane-1-carboxylate deaminase. Can J Microbiol 47:642-652.
14. Hao X, Xie P, Johnstone L, Miller SJ, Rensing C, Wei G. 2012. Genome sequence and mutational analysis of plant-growth-promoting bacterium *Agrobacterium tumefaciens* CCNWGS0286 isolated from a zinc-lead mine tailing. Appl Environ Microbiol 78:5384-5394.

15. Roca A, Pizarro-Tobias P, Udaondo Z, Fernandez M, Matilla MA, Molina-Henares MA, Molina L, Segura A, Duque E, Ramos JL. 2013. Analysis of the plant growth-promoting properties encoded by the genome of the rhizobacterium *Pseudomonas putida* BIRD-1. Environ Microbiol 15:780-794.
16. Larrainzar E, Gil-Quintana E, Seminario A, Arrese-Igor C, Gonzalez EM. 2014. Nodule carbohydrate catabolism is enhanced in the *Medicago truncatula* A17-*Sinorhizobium medicae* WSM419 symbiosis. Front Microbiol 5:447.
17. Lucy M, Reed E, Glick BR. 2004. Applications of free living plant growth-promoting rhizobacteria. Antonie Van Leeuwenhoek 86:1-25.
18. Anandham R, Gandhi PI, Madhaiyan M, Sa T. 2008. Potential plant growth promoting traits and bioacidulation of rock phosphate by thiosulfate oxidizing bacteria isolated from crop plants. J Basic Microbiol 48:439-447.
19. Adams AS, Currie CR, Cardoza Y, Klepzig KD, Raffa KF. 2009. Effects of symbiotic bacteria and tree chemistry on the growth and reproduction of bark beetle fungal symbionts. Can J For Res 39:1133-1147.