Journal of Species Research 11(4):310-320, 2022

A report on 20 unrecorded bacterial species of Korea isolated from soil in 2021

Ji Yeon Han[1], Oung Bin Lim[1], So-Yi Chea[1], Hyosun Lee[1], Ki-Eun Lee[2], In-Tae Cha[2], Won-Jae Chi[2] and Dong-Uk Kim[1,*]

[1]*Department of Biological Science, College of Biological and Environmental Sciences, Sangji University, Wonju 26339, Republic of Korea*
[2]*Microorganism Resources Division, National Institute of Biological Resources, Incheon 22689, Republic of Korea*

**Correspondent: dukim@sangji.ac.kr*

As a subset study to discover indigenous prokaryotic species in Korea, we isolated 20 bacterial strains and assigned them to the phyla *Actinobacteria*, *Bacteroidota*, *Firmicutes*, and *Proteobacteria*. From the high 16S rRNA gene sequence similarity (≥98.7%) and formation of a robust phylogenetic clades, we determined that each strain belonged to independent, predefined bacterial species. There are no official reports of these 20 species in Korea; therefore, 7 strains of the *Actinobacteria*, 2 strain of the *Bacteroidota*, 3 strains of the *Firmicutes*, and 8 strains of the *Firmicutes* are described in Korea for the first time. Gram reaction, colony and cell morphology, basic biochemical characteristics, and isolation sources are also described in the species description section.

Keywords: 16S rRNA, bacterial diversity, unreported species

DOI:10.12651/JSR.2022.11.4.310

Introduction

We isolated 20 unrecorded bacterial species from various soil samples collected in Korea and identified them as members of the phyla *Actinobacteria*, *Bacteroidota*, *Firmicutes*, and *Proteobacteria*. The present report focuses on the isolation and description of unrecorded species. At the time of writing, the phyla comprise *Actinobacteria* (including 6 classes), *Bacteroidota* (including 6 classes), *Firmicutes* (including 7 classes), and *Proteobacteria* (including 8 classes) based on the List of Prokaryotic names with Standing in Nomenclature (LPSN) (http://www.bacterio.net). The phylum *Actinobacteria*, one of the largest phyla within the domain *Bacteria*, is widely distributed in aquatic and terrestrial environments (Lawson, 2018). The phylum is comprised of Gram-stain-positive organisms with a high G+C content (Gao and Gupta, 2005); the phylum *Bacteroidota* is distributed in many different ecological niches (fresh water, ocean, soil, and gastrointestinal tract of animals) and known to degrade polymeric organic compounds (Thomas *et al*., 2011); the phylum *Firmicutes* is distributed in diverse environments and characterized as Gram-stain-positive, low G+C content and rod/coccus-shaped (Nahar, 2018); the phylum *Proteobacteria* is one of the largest phyla within the domain *Bacteria* (Seong, 2019) and members of this phylum are the most versatile.

The present report focuses on the description of 20 bacterial species belonging to the phyla Actinobacteria, Bacteroidota, Firmicutes, and Proteobacteria that have not officially been reported in Korea.

Materials and methods

A total of 20 bacterial strains assigned to the phyla *Actinobacteria*, *Bacteroidota*, *Firmicutes*, and *Proteobacteria* were isolated from various soils, including agricultural soil, forest soil, and marine soil. Samples collected from each environment were independently processed, serially diluted, spread onto diverse culture agar media [R2A, Nutrient agar (NA), Tryptic Soy Agar (TSA), Luria-Bertani (LB) agar, PTYG, and Marine agar], and incubated at 28°C for 3−7 days (Table 1). All strains were purified as single colonies and stored as 15−17% glycerol suspension at −80°C as well as lyophilized ampoules.

Colony morphology and cell size of the strains were observed by using transmission electron microscopy.

Electron micrograph of the strains are shown in Fig. 1. Gram reaction was performed according to the classic Gram procedure described by Doetsch (1981). Biochemical characteristics were tested by using API 20NE, API 32GN, and API ZYM galleries (bioMérieux) according to the manufacturer's instructions. Genomic DNA was extracted and the 16S rRNA gene was amplified by PCR with 27mf and 1492r universal bacterial primers (Weisburg *et al*., 1991). The 16S rRNA gene sequences of the related taxa were obtained from EzBioCloud server (Yoon *et al*., 2017). The 20 bacterial strains and related taxa (retrieved from the NCBI database) were aligned with SINA (v1.2.11) according to the SILVA seed alignment (http://www.arb-silva.de; Pruesse *et al*., 2012). The evolutionary distances were calculated using a two-parameter model (Kimura, 1983). Phylogenetic trees were constructed using the neighbor-joining (Saitou and Nei, 1987) in the MEGA7 program (Kumar *et al*., 2016) with bootstrap values based on 1,000 replications (Felsenstein, 1985).

Results and Discussion

The 20 strains were distributed into four phyla: *Actinobacteria*, *Bacteroidota*, *Firmicutes*, *Proteobacteria* (Table 1). Among these strains, EM1075, EM1106, EM1158 were coccus-shaped, WS2 was oval-shaped, and the other strains were rod-shaped (Fig. 1). Unrecorded bacteria were identified as 20 genera of *Arthrobacter*, *Azospirillum*, *Bacillus*, *Barrientosiimonas*, *Corynebacterium*, *Flexivirga*, *Georgenia*, *Kocuria*, *Lysinibacillus*, *Mesorhizobium*, *Novosphingobium*, *Paenibacillus*, *Pandoraea*, *Paraburkholderia*, *Patulibacter*, *Pedobacter*, *Pontibacter*, *Pseudooceanicola*, *Sandaracinobacter*, and *Sphingoaurantiacus* (Fig. 2). Here we report 20 unrecorded bacterial species in Korea belonging to 12 orders, which were isolated in Korea; 1 strain of Bogoriellales, 2 strains of Micrococcales, 2 strains of Dermatophilales, 1 strain of Mycobacteriales, 1 strain of Solirubrobacterales, 1 strain of Cytophagales, 1 strain of Sphingobacteriales, 3 strains of Bacillales, 3 strains of Burkholderiales, 3 strains of Sphingomonadales, 1 strain of Rhodospirillales, and 1 strain of Rhodobacterales.

Description of *Pandoraea sputorum* EM0341

Cells are Gram-stain-negative and rod-shaped. Cell size is 0.6−0.8 μm. Colonies are circular, smooth, entire, and white pigmented after 3 days of incubation at 28°C on R2A. Positive for gluconate, caprate, adipate, malate, citrate, and phenyl-acetate in API 20NE; but negative for reduction of nitrates to nitrite ($NO_3^- > NO_2^-$), reduction of nitrates to nitrogen, indole production, glucose acidification, arginine dihydrolase, urease, β-glucosidase (esculin hydrolysis), protease (gelatin hydrolysis), β-galactosidase (PNPG), D-glucose, L-arabinose, D-mannose, D-mannitol, *N*-acetyl-D-glucosamine, and D-maltose. Propionate, caprate, valerate, citrate, L-histidine, 3-hydroxy-butyrate, 4-hydroxy-benzoate, L-proline, acetate, L-alanine, 3-hydroxy-benzoate, L-serine are utilized; but does not utilize D-mannitol, D-glucose, salicin, D-melibiose, L-fucose, D-sorbitol, L-arabinose, 2-ketogluconate, L-rhamnose, *N*-acetyl-D-glucosamine, D-ribose, inositol, D-sucrose, D-maltose, itaconate, suberate, malonate, lactate, 5-ketogluconate, and glycogen. Enzymatic activity reaction was positive for alkaline phosphatase, esterase (C4), leucine arylamidase, acid phosphatase, naphtol-AS-BI-phosphohydrolase in API ZYM; but negative for esterase lipase (C8), lipase (C14), valine arylamidase, cystine arylamidase, trypsin, α-chymotrypsin, α-galactosidase, β-galactosidase, β-glucuronidase, α-glucosidase, β-glucosidase, *N*-acetyl-β-glucosaminidase, α-mannosidase, and α-fucosidase. Strain EM0341 (=NIBRBAC000509124) was isolated from a forest soil sample, Seoul, Korea.

Description of *Sandaracinobacter sibiricus* EM0359

Cells are Gram-stain-negative and rod-shaped. Cell size is 1.0−1.2 μm. Colonies are circular, smooth, entire, and yellow pigmented after 3 days of incubation at 28°C on R2A. Positive for D-glucose, L-arabinose, D-mannose, D-mannitol, *N*-acetyl-D-glucosamine, D-maltose, gluconate, adipate, malate, and citrate in API 20NE; but negative for nitrates to nitrite ($NO_3^- > NO_2^-$), reduction of nitrates to nitrogen, indole production, glucose acidification, arginine dihydrolase, urease, β-galactosidase (esculin hydrolysis), protease (gelatin hydrolysis), β-galactosidase (PNPG), caprate, and phenyl-acetate. Utilizes D-mannitol, D-glucose, salicin, L-fucose, D-sorbitol, L-arabinose, citrate, 3-hydroxy-butyrate, L-proline, L-rhamnose, *N*-acetyl-D-glucosamine, D-ribose, inositol, D-sucrose, D-maltose, suberate, malonate, lactate, 5-ketogluconate, and glycogen; but does not utilize D-melibiose, propionate, caprate, valerate, L-histidine, 2-ketogluconate, 4-hydroxy-benzoate, itaconate, acetate, L-alanine, 3-hydroxy-benzoate, and L-serine. Enzymatic activity reaction was positive for alkaline phosphatase, esterase (C4), esterase lipase (C8), leucine arylamidase, valine arylamidase, trypsin, α-chymotrypsin, acid phosphatase, naphtol-AS-BI-phosphohydrolase, and β-glucuronidase in API ZYM; but negative for lipase (C14), cystine arylamidase, α-galactosidase, β-galactosidase, β-glucuronidase, β-glucosidase, *N*-acetyl-β-glucosaminidase, α-mannosidase, and α-fucosidase. Strain EM0359 (=NIBRBAC000509125) was isolated from a forest soil sample, Seoul, Korea.

Description of *Paenibacillus edaphicus* EM0662

Cells are Gram-stain-negative and rod-shaped. Cell

Table 1. The taxonomic affiliations of isolated strains belonging to the phyla *Actinobacteria*, *Bacteroidota*, *Firmicutes*, and *Proteobacteria*.

Phylum	Class	Order	Family	Genus	Strain ID	NIBR ID	Most closely related species	Similarity (%)	Isolation source	Medium	Incubation conditions
Actinobacteria	Actinomycetia	Bogoriellales	Bogoriellaceae	*Georgenia*	EM1187	NIBRBAC000509132	*Georgenia muralis*	99.7	Agricultural soil	R2A	28°C, 3 d
		Micrococcales	Micrococcaceae	*Arthrobacter*	NC19	NIBRBAC000509136	*Arthrobacter celericrescens*	98.9	Agricultural soil	NA	28°C, 3 d
				Kocuria	EM1106	NIBRBAC000509129	*Kocuria flava*	99.9	Agricultural soil	R2A	28°C, 3 d
		Dermatophilales	Dermacoccaceae	*Flexivirga*	NSM-1	NIBRBAC000509137	*Flexivirga endophytica*	99.9	Agricultural soil	PTYG	28°C, 3 d
				Barrientosiimonas	EM1075	NIBRBAC000509128	*Barrientosiimonas humi*	99.2	Forest soil	R2A	28°C, 3 d
		Mycobacteriales	Corynebacteriaceae	*Corynebacterium*	RB28	NIBRBAC000509138	*Corynebacterium glutamicum*	99.9	Agricultural soil	R2A	28°C, 3 d
	Thermoleophilia	Solirubrobacterales	Patulibacteraceae	*Patulibacter*	EM1152	NIBRBAC000509130	*Patulibacter brassicae*	99.9	Agricultural soil	R2A	28°C, 3 d
Bacteroidota	Cytophagia	Cytophagales	Hymenobacteraceae	*Pontibacter*	JN2214	NIBRBAC000509135	*Pontibacter mucosus*	99.1	Agricultural soil	R2A	28°C, 7 d
	Sphingobacteriia	Sphingobacteriales	Sphingobacteriaceae	*Pedobacter*	WS11	NIBRBAC000509143	*Pedobacter caeni*	99.9	Agricultural soil	R2A	28°C, 3 d
Firmicutes	Bacilli	Bacillales	Paenibacillaceae	*Paenibacillus*	EM0662	NIBRBAC000509126	*Paenibacillus edaphicus*	98.7	Forest soil	R2A	28°C, 3 d
			Planococcaceae	*Lysinibacillus*	EM0665	NIBRBAC000509127	*Lysinibacillus odysseyi*	99.6	Agricultural soil	R2A	28°C, 3 d
			Bacillaceae	*Fredinandcohnia*	JN1309	NIBRBAC000509134	*Bacillus timonensis*	98.9	Agricultural soil	NA	28°C, 3 d
Proteobacteria	Betaproteobacteria	Burkholderiales	Burkholderiaceae	*Pandoraea*	EM0341	NIBRBAC000509124	*Pandoraea sputorum*	100.0	Forest soil	R2A	28°C, 3 d
				Mesorhizobium	FL16	NIBRBAC000509133	*Mesorhizobium composti*	99.9	Agricultural soil	LB	28°C, 3 d
				Paraburkholderia	WR2	NIBRBAC000509141	*Paraburkholderia graminis*	99.7	Agricultural soil	R2A	28°C, 3 d
	Alphaproteobacteria	Sphingomonadales	Sphingosinicellaceae	*Sandaracinobacter*	EM0359	NIBRBAC000509125	*Sandaracinobacter sibiricus*	99.9	Forest soil	R2A	28°C, 3 d
				Sphingoaurantiacus	EM1158	NIBRBAC000509131	*Sphingoaurantiacus polygranulatus*	99.3	Agricultural soil	R2A	28°C, 3 d
			Sphingomonadaceae	*Novosphingobium*	RM1	NIBRBAC000509139	*Novosphingobium soli*	99.2	Agricultural soil	R2A	28°C, 3 d
		Rhodospirillales	Azospirillaceae	*Azospirillum*	WD4	NIBRBAC000509140	*Azospirillum thiophilum*	99.2	Agricultural soil	R2A	28°C, 3 d
		Rhodobacterales	Rhodobacteraceae	*Pseudooceanicola*	WS2	NIBRBAC000509142	*Pseudooceanicola nitratireducens*	99.6	Marine soil	Marine	28°C, 3 d

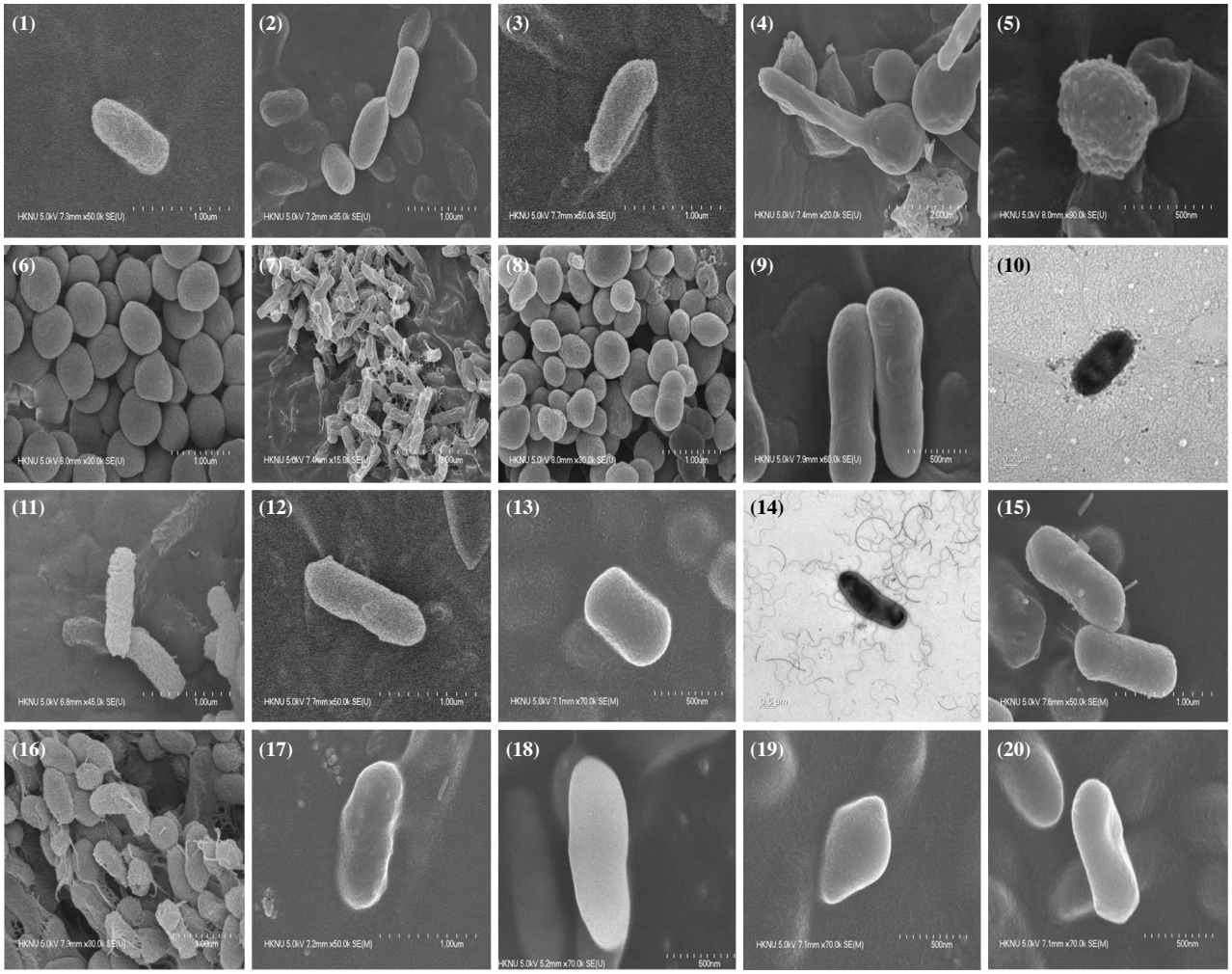

Fig. 1. Scanning electron microscopy (SEM) and transmission electron microscopy (TEM) images of cells of the unrecorded strains isolated in this study. Images 10 and 14 are TEM images, the rest are SEM images. The strains were cultured at their optimal growth conditions. (1) EM0341, (2) EM0359, (3) EM0662, (4) EM0665, (5) EM1075, (6) EM1106, (7) EM1152, (8) EM1158, (9) EM1187, (10) FL16, (11) JN1309, (12) JN2214, (13) NC19, (14) NSM-1, (15) RB28, (16) RM1, (17) WD4, (18) WR2, (19) WS2, (20) WS11.

size is 1.2−1.4 μm. Colonies are irregular, smooth, entire, and white pigmented after 3 days of incubation at 28°C on R2A. Positive for reduction of nitrates to nitrite (NO_3^- > NO_2^-), β-Glucosidase (esculin hydrolysis), β-Galactosidase (PNPG), D-glucose, L-arabinose, D-mannose, *N*-acetyl-D-glucosamine, and D-maltose in API 20NE; but negative for indole production, glucose acidification, arginine dihydrolase, urease, protease (gelatin hydrolysis), D-mannitol, gluconate, caprate, adipate, malate, citrate, and phenyl-acetate. Utilizes D-glucose, D-melibiose, L-fucose, D-sorbitol, L-arabinose, L-rhamnose, *N*-acetyl-D-glucosamine, D-ribose, D-sucrose, D-maltose, suberate, acetate, lactate, and glycogen; but does not utilize D-mannitol, salicin, propionate, caprate, valerate, citrate, L-histidine, 2-ketogluconate, 3-hydroxy-butyrate, 4-hydroxy-benzoate, L-proline, inositol, itaconate, malonate, L-alanine, 5-ketogluconate, 3-hydroxy-benzoate, and L-serine. Enzymatic activity reaction was positive for alkaline phosphatase, esterase (C4), esterase lipase (C8), acid phosphatase, naphtol-AS-BI-phosphohydrolase, β-galactosidase, α-glucosidase, and β-glucosidase in API ZYM; but negative for lipase (C14), leucine arylamidase, valine arylamidase, cystine arylamidase, trypsin, α-chymotrypsin, α-galactosidase, β-glucuronidase, *N*-acetyl-β-glucosaminidase, α-mannosidase, and α-fucosidase. Strain EM0662 (=NIBRBAC000509126) was isolated from a forest soil sample, Seoul, Korea.

Description of *Lysinibacillus odysseyi* EM0665

Cells are Gram-stain-positive and rod-shaped. Cell size is 4.6−4.8 μm. Colonies are circular, smooth, entire, and

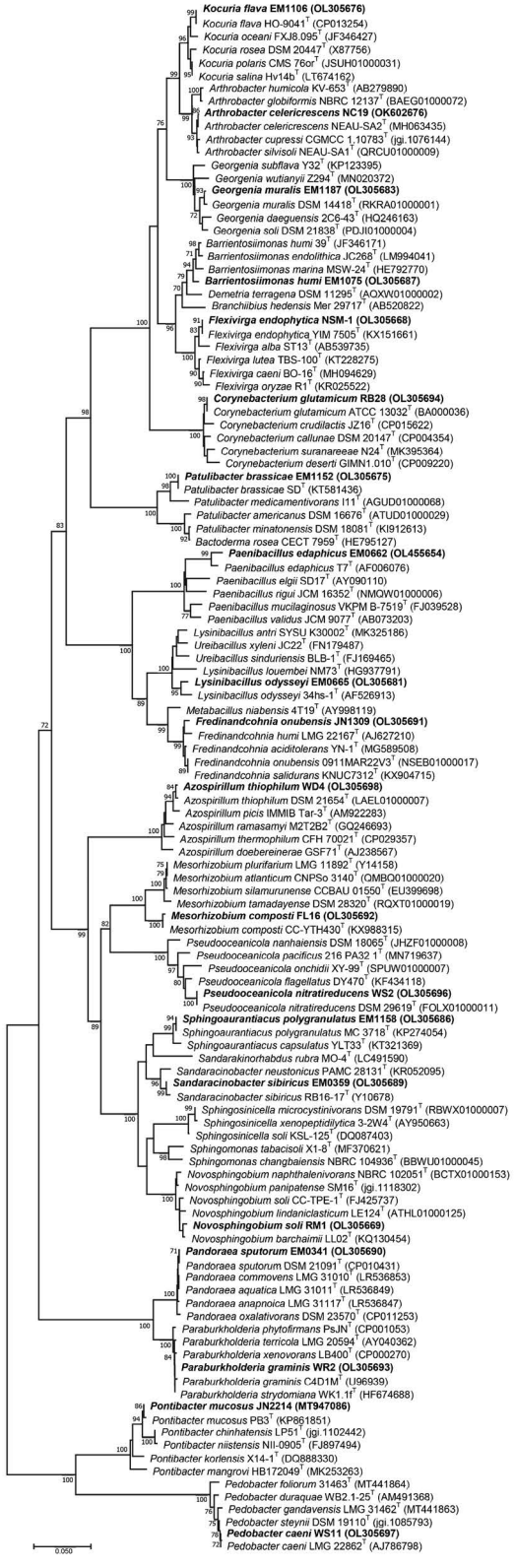

Fig. 2. A neighbor-joining phylogenetic tree based on 16S rRNA gene sequences showing the relationship between the strains isolated in this study and their relatives. Bootstrap values (>70%) are shown at the nodes. Bar: 0.050 substitutions per nucleotide position.

white pigmented after 3 days of incubation at 28°C on R2A. Positive for reduction of glucose acidification, arginine dihydrolase, and β-Glucosidase (esculin hydrolysis) in API 20NE; but negative for nitrates to nitrite ($NO_3^- > NO_2^-$), reduction of nitrates to nitrogen, indole production, urease, protease (gelatin hydrolysis), β-galactosidase (PNPG), D-glucose, L-arabinose, D-mannose, D-mannitol, *N*-acetyl-D-glucosamine, D-maltose, gluconate, caprate, adipate, malate, citrate, and phenyl-acetate. Utilizes 3-hydroxy-butyrate, acetate, and L-alanine; but does not utilize D-mannitol, D-glucose, salicin, D-melibiose, L-fucose, D-sorbitol, L-arabinose, propionate, caprate, valerate, citrate, L-histidine, 2-ketogluconate, 4-hydroxy-benzoate, L-proline, L-rhamnose, *N*-acetyl-D-glucosamine, D-ribose, inositol, D-sucrose, D-maltose, itaconate, suberate, malonate, lactate, 5-ketogluconate, glycogen, 3-hydroxy-benzoate, and L-serine. Enzymatic activity reaction was positive for alkaline phosphatase, esterase (C4), esterase Lipase (C8), naphtol-AS-BI-phosphohydrolase, and β-glucosidase in API ZYM; but negative for lipase (C14), leucine arylamidase, valine arylamidase, cystine arylamidase, trypsin, α-chymotrypsin, acid phosphatase, α-galactosidase, β-galactosidase, β-glucuronidase, α-glucosidase, *N*-acetyl-β-glucosaminidase, α-mannosidase, and α-fucosidase. Strain EM0665 (=NIBRBAC000509127) was isolated from an agricultural soil sample, Gyeongsangnam-do, Korea.

Description of *Barrientosiimonas humi* EM1075

Cells are Gram-stain-positive and coccus-shaped. Cell size is 0.55−0.57 μm. Colonies are circular, smooth, entire, and white pigmented after 3 days of incubation at 28°C on R2A. Positive for reduction of β-glucosidase (esculin hydrolysis), protease (gelatin hydrolysis), D-glucose, D-mannitol, *N*-acetyl-D-glucosamine, D-maltose, gluconate, adipate, malate, and phenyl-acetate; but negative for nitrates to nitrite ($NO_3^- > NO_2^-$), reduction of nitrates to nitrogen, indole production, glucose acidification, arginine dihydrolase, urease, β-Galactosidase (PNPG), L-arabinose, D-mannose, caprate, and citrate. Utilizes D-mannitol, D-glucose, D-melibiose, propionate, valerate, 3-hydroxy-butyrate, 4-hydroxy-benzoate, *N*-acetyl-D-glucosamine, D-sucrose, D-maltose, suberate, malonate, acetate, lactate, L-alanine, glycogen, and 3-hydroxy-benzoate; but does not utilize salicin, L-fucose, D-sorbitol, L-arabinose, caprate, citrate, L-histidine, 2-ketogluconate, L-proline, L-rhamnose, D-ribose, inositol, itaconate, 5-ketogluconate, and L-serine. Enzymatic activity reaction was positive for alkaline phosphatase, esterase (C4), esterase lipase (C8), leucine arylamidase, naphtol-AS-BI-phosphohydrolase, α-galactosidase, α-glucosidase, β-glucosidase, and α-mannosidase; but negative for lipase (C14), valine arylamidase, cystine arylamidase,

trypsin, α-chymotrypsin, acid phosphatase, β-galactosidase, β-glucuronidase, *N*-acetyl-β-glucosaminidase, and α-fucosidase. Strain EM1075 (=NIBRBAC000509128) was isolated from a forest soil sample, Seoul, Korea.

Description of *Kocuria flava* EM1106

Cells are Gram-stain-positive and coccus-shaped. Cell size is 0.5−0.7 μm. Colonies are circular, smooth, entire, and yellow pigmented after 3 days of incubation at 28°C on R2A. Positive for reduction of nitrates to nitrite (NO_3^- > NO_2^-), β-Galactosidase (PNPG), D-glucose, D-maltose, gluconate, adipate, malate, and phenyl-acetate; but negative for indole production, glucose acidification, arginine dihydrolase, urease, β-glucosidase (esculin hydrolysis), protease (gelatin hydrolysis), L-arabinose, *N*-acetyl-D-glucosamine, caprate, and citrate. Utilizes D-mannitol, D-glucose, D-melibiose, valerate, 4-hydroxy-benzoate, L-proline, D-sucrose, D-maltose, suberate, 5-ketogluconate, 3-hydroxy-benzoate, and L-serine; but does not utilize salicin, L-fucose, L-arabinose. Propionate, caprate, citrate, L-histidine, 2-ketogluconate, 3-hydroxy-butyrate, L-rhamnose, *N*-acetyl-D-glucosamine, D-ribose, itaconate, malonate, and glycogen. Enzymatic activity reaction was positive for alkaline phosphatase, esterase (C4), esterase lipase (C8), leucine arylamidase, naphtol-AS-BI-phosphohydrolase, α-galactosidase, β-galactosidase, and α-glucosidase; but negative for lipase (C14), valine arylamidase, cystine arylamidase, trypsin, α-chymotrypsin, acid phosphatase, β-glucuronidase, β-glucosidase, *N*-acetyl-β-glucosaminidase, α-mannosidase, and α-fucosidase. Strain EM1106 (=NIBRBAC000509129) was isolated from an agricultural soil sample, Gyeongsangnam-do, Korea.

Description of *Patulibacter brassicae* EM1152

Cells are Gram-stain-positive and rod-shaped. Cell size is 1.3−1.5 μm. Colonies are circular, smooth, entire, and white pigmented after 3 days of incubation at 28°C on R2A. Positive for reduction of L-arabinose; but negative for nitrates to nitrite (NO_3^- > NO_2^-), reduction of nitrates to nitrogen, indole production, glucose acidification, arginine dihydrolase, urease, β-glucosidase (esculin hydrolysis), protease (gelatin hydrolysis), β-Galactosidase (PNPG), D-glucose, D-mannose, D-mannitol, *N*-acetyl-D-glucosamine, D-maltose, gluconate, caprate, adipate, malate, citrate, and phenyl-acetate. Utilizes L-arabinose, valerate, and acetate; but does not utilize D-mannitol, D-glucose, salicin, D-melibiose, L-fucose, D-sorbitol, propionate, caprate, citrate, L-histidine, 2-ketogluconate, 3-hydroxy-butyrate, 4-hydroxy-benzoate, L-proline, L-rhamnose, *N*-acetyl-D-glucosamine, D-ribose, inositol, D-sucrose, D-maltose, itaconate, suberate, malonate, lactate, L-alanine, 5-ketogluconate, glycogen, 3-hydroxy-benzoate, and L-serine. Enzymatic activity reaction was positive for alkaline phosphatase, esterase (C4), esterase lipase (C8), leucine arylamidase, cystine arylamidase, acid phosphatase, and naphtol-AS-BI-phosphohydrolase; but negative for lipase (C14), valine arylamidase, trypsin, α-chymotrypsin, α-galactosidase, β-galactosidase, β-glucuronidase, α-glucosidase, β-glucosidase, *N*-acetyl-β-glucosaminidase, α-mannosidase, and α-fucosidase. Strain EM1152 (=NIBRBAC000509130) was isolated from an agricultural soil sample, Gyeongsangnam-do, Korea.

Description of *Sphingoaurantiacus polygranulatus* EM1158

Cells are Gram-stain-negative and coccus-shaped. Cell size is 0.5−0.7 μm. Colonies are circular, smooth, entire, and red pigmented after 3 days of incubation at 28°C on R2A. Positive for reduction of D-glucose, L-arabinose, and *N*-acetyl-D-glucosamine; but negative for nitrates to nitrite (NO_3^- > NO_2^-), reduction of nitrates to nitrogen, indole production, glucose acidification, arginine dihydrolase, urease, β-glucosidase (esculin hydrolysis), protease (gelatin hydrolysis), β-Galactosidase (PNPG), D-mannose, D-mannitol, D-maltose, gluconate, caprate, adipate, malate, citrate, and phenyl-acetate. D-Glucose, L-arabinose, 3-hydroxy-butyrate, L-proline, L-rhamnose, *N*-acetyl-D-glucosamine, and D-sucrose; but does not utilize D-mannitol, salicin, D-melibiose, L-fucose, D-sorbitol, propionate, caprate, valerate, citrate, L-histidine, 2-ketogluconate, 4-hydroxy-benzoate, D-ribose, inositol, D-maltose, itaconate, suberate, malonate, acetate, lactate, L-alanine, 5-ketogluconate, glycogen, 3-hydroxy-benzoate, and L-serine. Enzymatic activity reaction was positive for alkaline phosphatase, esterase (C4), esterase lipase (C8), leucine arylamidase, acid phosphatase, naphtol-AS-BI-phosphohydrolase, and *N*-acetyl-β-glucosaminidase; but negative for lipase (C14), valine arylamidase, cystine arylamidase, trypsin, α-chymotrypsin, α-galactosidase, β-galactosidase, β-glucuronidase, α-glucosidase, β-glucosidase, α-mannosidase, and α-fucosidase. Strain EM1158 (=NIBRBAC000509131) was isolated from an agricultural soil sample, Gyeongsangnam-do, Korea.

Description of *Georgenia muralis* EM1187

Cells are Gram-stain-positive and rod-shaped. Cell size is 1.5−1.7 μm. Colonies are circular, smooth, entire, and white pigmented after 3 days of incubation at 28°C on R2A. Positive for reduction of D-glucose, L-arabinose, D-mannose, D-mannitol, *N*-acetyl-D-glucosamine, and D-maltose; but negative for nitrates to nitrite (NO_3^- > NO_2^-), reduction of nitrates to nitrogen, indole production, glucose acidification, arginine dihydrolase, urease, β-glucosidase (esculin hydrolysis), protease (gelatin hy-

drolysis), β-Galactosidase (PNPG), gluconate, caprate, adipate, malate, citrate, and phenyl-acetate. Utilizes D-mannitol, D-glucose, salicin, L-arabinose, *N*-acetyl-D-glucosamine, D-sucrose, and D-maltose; but does not utilize D-melibiose, L-fucose, D-sorbitol, propionate, caprate, valerate, citrate, L-histidine, 2-ketogluconate, 3-hydroxy-butyrate, 4-hydroxy-benzoate, L-proline, L-rhamnose, D-ribose, inositol, itaconate, suberate, malonate, acetate, lactate, L-alanine, 5-ketogluconate, glycogen, 3-hydroxy-benzoate, and L-serine. Enzymatic activity reaction was positive for esterase (C4), esterase lipase (C8), leucine arylamidase, naphtol-AS-BI-phosphohydrolase, α-glucosidase, and *N*-acetyl-β-glucosaminidase; but negative for alkaline phosphatase, lipase (C14), valine arylamidase, cystine arylamidase, trypsin, α-chymotrypsin, acid phosphatase, α-galactosidase, β-galactosidase, β-glucuronidase, β-glucosidase, α-mannosidase, and α-fucosidase. Strain EM1187 (=NIBRBAC000509132) was isolated from an agricultural soil sample, Gyeongsangnam-do, Korea.

Description of *Mesorhizobium composti* FL16

Cells are Gram-stain-negative and rod-shaped. Cell size is 0.9−1.1 μm. Colonies are circular, smooth, entire, and yellow pigmented after 3 days of incubation at 28°C on LB. Positive for reduction of nitrates to nitrite ($NO_3^- > NO_2^-$), urease, β-glucosidase (esculin hydrolysis), D-glucose, L-arabinose, D-mannose, D-mannitol, *N*-acetyl-D-glucosamine, and D-maltose; but negative for indole production, glucose acidification, arginine dihydrolase, protease (gelatin hydrolysis), β-Galactosidase (PNPG), gluconate, caprate, adipate, malate, citrate, and phenyl-acetate. Utilizes D-mannitol, D-glucose, L-fucose, D-sorbitol, L-arabinose, propionate, valerate, L-histidine, 2-ketogluconate, 3-hydroxy-butyrate, L-proline, *N*-acetyl-D-glucosamine, D-ribose, inositol, D-sucrose, D-maltose, acetate, lactate, and L-alanine; but does not utilize salicin, D-melibiose, caprate, citrate, 4-hydroxy-benzoate, L-rhamnose, itaconate, suberate, malonate, 5-ketogluconate, glycogen, 3-hydroxy-benzoate, and L-serine. Enzymatic activity reaction was positive for alkaline phosphatase, esterase (C4), esterase lipase (C8), leucine arylamidase, acid phosphatase, naphtol-AS-BI-phosphohydrolase, α-glucosidase, and β-glucosidase; but negative for lipase (C14), valine arylamidase, cystine arylamidase, trypsin, α-chymotrypsin, α-galactosidase, β-galactosidase, β-glucuronidase, *N*-acetyl-β-glucosaminidase, α-mannosidase, and α-fucosidase. Strain FL16 (=NIBRBAC000509133) was isolated from an agricultural soil sample, Chungcheongnam-do, Korea.

Description of *Bacillus timonensis* JN1309

Cells are Gram-stain-negative and rod-shaped. Cell size is 1.1−1.3 μm. Colonies are circular, smooth, entire, and yellow pigmented after 3 days of incubation at 28°C on NA. Positive for reduction of β-glucosidase (esculin hydrolysis), β-Galactosidase (PNPG), D-glucose, L-arabinose, D-mannose, D-mannitol, *N*-acetyl-D-glucosamine, D-maltose, and gluconate; but negative for nitrates to nitrite ($NO_3^- > NO_2^-$), reduction of nitrates to nitrogen, indole production, glucose acidification, arginine dihydrolase, urease, protease (gelatin hydrolysis), caprate, adipate, malate, citrate, and phenyl-acetate. Utilizes D-mannitol, D-glucose, D-melibiose, L-arabinose, valerate, L-histidine, *N*-acetyl-D-glucosamine, D-sucrose, D-maltose, acetate, lactate, and glycogen; but does not utilize salicin, L-fucose, D-sorbitol, propionate, caprate, citrate, 2-ketogluconate, 3-hydroxy-butyrate, 4-hydroxy-benzoate, L-proline, L-rhamnose, D-ribose, inositol, itaconate, suberate, malonate, L-alanine, 5-ketogluconate, 3-hydroxy-benzoate, and L-serine. Enzymatic activity reaction was positive for esterase (C4), esterase lipase (C8), lipase (C14), naphtol-AS-BI-phosphohydrolase, β-galactosidase, α-glucosidase, β-glucosidase, and *N*-acetyl-β-glucosaminidase; but negative for alkaline phosphatase, leucine arylamidase, valine arylamidase, cystine arylamidase, trypsin, α-chymotrypsin, acid phosphatase, α-galactosidase, β-glucuronidase, α-mannosidase, and α-fucosidase. Strain JN1309 (=NIBRBAC000509134) was isolated from an agricultural soil sample, Jeju Island, Korea.

Description of *Pontibacter mucosus* JN2214

Cells are Gram-stain-negative and rod-shaped. Cell size is 1.3−1.5 μm. Colonies are circular, smooth, entire, and pink pigmented after 7 days of incubation at 28°C on R2A. Positive for reduction of urease, β-glucosidase (esculin hydrolysis), protease (gelatin hydrolysis), D-glucose, L-arabinose, D-mannose, D-mannitol, and *N*-acetyl-D-glucosamine; but negative for nitrates to nitrite ($NO_3^- > NO_2^-$), reduction of nitrates to nitrogen, indole production, glucose acidification, arginine dihydrolase, β-Galactosidase (PNPG), D-maltose, gluconate, caprate, adipate, malate, citrate, and phenyl-acetate. Utilizes D-mannitol, D-glucose, L-fucose, L-arabinose, L-rhamnose, and *N*-acetyl-D-glucosamine; but does not utilize salicin, D-melibiose, D-sorbitol, propionate, caprate, valerate, citrate, L-histidine, 2-ketogluconate, 3-hydroxy-butyrate, 4-hydroxy-benzoate, L-proline, D-ribose, inositol, D-sucrose, D-maltose, itaconate, suberate, malonate, acetate, lactate, L-alanine, 5-ketogluconate, glycogen, 3-hydroxy-benzoate, and L-serine. Enzymatic activity reaction was positive for alkaline phosphatase, esterase (C4), esterase lipase (C8), leucine arylamidase, valine arylamidase, cystine arylamidase, acid phosphatase, naphtol-AS-BI-phosphohydrolase, α-galactosidase, α-glucosidase, β-glucosidase, and *N*-acetyl-β-glucosaminidase;

but negative for lipase (C14), trypsin, α-chymotrypsin, β-galactosidase, β-glucuronidase, α-mannosidase, and α-fucosidase. Strain JN2214 (=NIBRBAC000509135) was isolated from an agricultural soil sample, Jeju Island, Korea.

Description of *Arthrobacter celericrescens* NC19

Cells are Gram-stain-positive and rod-shaped. Cell size is 0.65−0.85 μm. Colonies are circular, smooth, entire, and yellow pigmented after 3 days of incubation at 28°C on NA. Positive for reduction of β-glucosidase (esculin hydrolysis), β-Galactosidase (PNPG), D-glucose, L-arabinose, D-mannose, D-mannitol, *N*-acetyl-D-glucosamine, D-maltose, gluconate, malate, citrate, and phenyl-acetate; but negative for nitrates to nitrite ($NO_3^- > NO_2^-$), reduction of nitrates to nitrogen, indole production, glucose acidification, arginine dihydrolase, urease, protease (gelatin hydrolysis), caprate, and adipate. Utilizes D-mannitol, D-glucose, salicin, D-melibiose, D-sorbitol, L-arabinose, citrate, L-histidine, 2-ketogluconate, 4-hydroxy-benzoate, L-proline, *N*-acetyl-D-glucosamine, inositol, D-sucrose, D-maltose, lactate, L-alanine, 3-hydroxy-benzoate propionate, and L-serine; but does not utilize L-fucose, propionate, caprate, valerate, 3-hydroxy-butyrate, L-rhamnose, D-ribose, itaconate, suberate, malonate, acetate, 5-ketogluconate, and glycogen. Enzymatic activity reaction was positive for alkaline phosphatase, esterase (C4), esterase lipase (C8), leucine arylamidase, valine arylamidase, cystine arylamidase, acid phosphatase, naphtol-AS-BI-phosphohydrolase, α-galactosidase, β-galactosidase, α-glucosidase, β-glucosidase, and α-mannosidase; but negative for lipase (C14), trypsin, α-chymotrypsin, β-glucuronidase, *N*-acetyl-β-glucosaminidase, and α-fucosidase. Strain NC19 (=NIBRBAC 000509136) was isolated from an agricultural soil sample, Chungcheongnam-do, Korea.

Description of *Flexivirga endophytica* NSM-1

Cells are Gram-satin-positive and rod-shaped. Cell size is 2.5−2.7 μm. Colonies are circular, smooth, entire, and yellow pigmented after 3 days of incubation at 28°C on PTYG. Positive for reduction of urease, D-glucose, L-arabinose, D-mannose, gluconate, adipate, malate, and phenyl-acetate; but negative for nitrates to nitrite ($NO_3^- > NO_2^-$), reduction of nitrates to nitrogen, indole production, glucose acidification, arginine dihydrolase, β-glucosidase (esculin hydrolysis), protease (gelatin hydrolysis), β-Galactosidase (PNPG), D-mannitol, *N*-acetyl-D-glucosamine, D-maltose, caprate, and citrate. Utilizes D-glucose, L-fucose, L-arabinose, propionate, valerate, 2-ketogluconate, 3-hydroxy-butyrate, L-rhamnose, D-ribose, itaconate, suberate, acetate, lactate, 5-ketogluconate, and 3-hydroxy-benzoate; but does not utilize D-mannitol, salicin, D-melibiose, D-sorbitol, caprate, citrate, L-histidine, 4-hydroxy-benzoate, L-proline, *N*-acetyl-D-glucosamine, inositol, D-sucrose, D-maltose, malonate, L-alanine, glycogen, and L-serine. Enzymatic activity reaction was positive for alkaline phosphatase, esterase (C4), esterase lipase (C8), leucine arylamidase, trypsin, acid phosphatase, and naphtol-AS-BI-phosphohydrolase; but negative for lipase (C14), valine arylamidase, cystine arylamidase, α-chymotrypsin, α-galactosidase, β-galactosidase, β-glucuronidase, α-glucosidase, β-glucosidase, *N*-acetyl-β-glucosaminidase, α-mannosidase, and α-fucosidase. Strain NSM-1 (=NIBRBAC000509137) was isolated from an agricultural soil sample, Chungcheongnam-do, Korea.

Description of *Corynebacterium glutamicum* RB28

Cells are Gram-stain-positive and rod-shaped. Cell size is 1.1−1.3 μm. Colonies are circular, smooth, entire, and yellow pigmented after 3 days of incubation at 28°C on R2A. Positive for reduction of nitrates to nitrite ($NO_3^- > NO_2^-$), glucose acidification, urease, D-glucose, D-mannose, D-maltose, gluconate, and citrate; but negative for indole production, arginine dihydrolase, β-glucosidase (esculin hydrolysis), protease (gelatin hydrolysis), β-Galactosidase (PNPG), L-arabinose, D-mannitol, *N*-acetyl-D-glucosamine, caprate, adipate, malate, and phenyl-acetate. Utilizes D-glucose, propionate, citrate, 4-hydroxy-benzoate, D-ribose, inositol, D-sucrose, D-maltose, malonate, acetate, lactate, and 3-hydroxy-benzoate; but does not utilize D-mannitol, salicin, D-melibiose, L-fucose, D-sorbitol, L-arabinose, caprate, valerate, L-histidine, 2-ketogluconate, 3-hydroxy-butyrate, L-proline, L-rhamnose, *N*-acetyl-D-glucosamine, itaconate, suberate, L-alanine, 5-ketogluconate, glycogen, and L-serine. Enzymatic activity reaction was positive for esterase (C4), leucine arylamidase, acid phosphatase, and naphtol-AS-BI-phosphohydrolase; but negative for alkaline phosphatase, esterase lipase (C8), lipase (C14), valine arylamidase, cystine arylamidase, trypsin, α-chymotrypsin, α-galactosidase, β-galactosidase, β-glucuronidase, α-glucosidase, β-glucosidase, *N*-acetyl-β-glucosaminidase, α-mannosidase, and α-fucosidase. Strain RB28 (=NIBRBAC000509138) was isolated from an agricultural soil sample, Gyeongsangnam-do, Korea.

Description of *Novosphingobium soli* RM1

Cells are Gram-satin-negative and rod-shaped. Cell size is 0.8−1.0 μm. Colonies are circular, smooth, entire, and yellow pigmented after 3 days of incubation at 28°C on R2A. Positive for reduction of β-glucosidase (esculin hydrolysis), D-glucose, D-maltose, and malate; but negative for nitrates to nitrite ($NO_3^- > NO_2^-$), reduction of nitrates to nitrogen, indole production, glucose acidification, arginine dihydrolase, urease, protease (gelatin hydroly-

sis), β-Galactosidase (PNPG), L-arabinose, D-mannose, D-mannitol, *N*-acetyl-D-glucosamine, gluconate, caprate, adipate, citrate, and phenyl-acetate. Utilizes D-glucose, valerate, 3-hydroxy-butyrate, 4-hydroxy-benzoate, L-proline, L-rhamnose, D-sucrose, D-maltose, and acetate; but does not utilize D-mannitol, salicin, D-melibiose, L-fucose, D-sorbitol, L-arabinose, propionate, caprate, citrate, L-histidine, 2-ketogluconate, *N*-acetyl-D-glucosamine, D-ribose, inositol, itaconate, suberate, malonate, lactate, L-alanine, 5-ketogluconate, glycogen, 3-hydroxy-benzoate, and L-serine. Enzymatic activity reaction was positive for alkaline phosphatase, esterase (C4), esterase lipase (C8), leucine arylamidase, valine arylamidase, acid phosphatase, naphtol-AS-BI-phosphohydrolase, α-glucosidase, and β-glucosidase; but negative for lipase (C14), cystine arylamidase, trypsin, α-chymotrypsin, α-galactosidase, β-galactosidase, β-glucuronidase, *N*-acetyl-β-glucosaminidase, α-mannosidase, and α-fucosidase. Strain RM1 (=NIBRBAC000509139) was isolated from an agricultural soil sample, Chungcheongnam-do, Korea.

Description of *Azospirillum thiophilum* WD4

Cells are Gram-stain-negative and rod-shaped. Cell size is 1.4−1.6 μm. Colonies are irregular, smooth, entire, and white pigmented after 3 days of incubation at 28°C on R2A. Positive for reduction of nitrates to nitrite ($NO_3^- > NO_2^-$), urease, β-glucosidase (esculin hydrolysis), β-Galactosidase (PNPG), D-glucose, L-arabinose, D-mannitol, gluconate, caprate, malate, and phenyl-acetate; but negative for indole production, glucose acidification, arginine dihydrolase, protease (gelatin hydrolysis), D-mannose, *N*-acetyl-D-glucosamine, D-maltose, adipate, and citrate. Utilizes D-mannitol, D-glucose, D-sorbitol, L-arabinose, propionate, caprate, valerate, L-histidine, 2-ketogluconate, 3-hydroxy-butyrate, 4-hydroxy-benzoate, L-proline, D-ribose, malonate, acetate, lactate, and L-alanine; but does not utilize salicin, D-melibiose, L-fucose, citrate, L-rhamnose, *N*-acetyl-D-glucosamine, inositol, D-sucrose, D-maltose, itaconate, suberate, 5-ketogluconate, glycogen, 3-hydroxy-benzoate, and L-serine. Enzymatic activity reaction was positive for alkaline phosphatase, esterase (C4), esterase lipase (C8), leucine arylamidase, acid phosphatase, naphtol-AS-BI-phosphohydrolase, β-galactosidase, and β-glucosidase; but negative for lipase (C14), valine arylamidase, cystine arylamidase, trypsin, α-chymotrypsin, α-galactosidase, β-glucuronidase, α-glucosidase, *N*-acetyl-β-glucosaminidase, α-mannosidase, and α-fucosidase. Strain WD4 (=NIBRBAC000509140) was isolated from an agricultural soil sample, Chungcheongnam-do, Korea.

Description of *Paraburkholderia graminis* WR2

Cells are Gram-stain-negative and rod-shaped. Cell size is 1.4−1.6 μm. Colonies are circular, smooth, entire, and yellow pigmented after 3 days of incubation at 28°C on R2A. Positive for reduction of nitrates to nitrite ($NO_3^- > NO_2^-$), β-Galactosidase (PNPG), D-glucose, D-mannose, D-mannitol, *N*-acetyl-D-glucosamine, gluconate, caprate, malate, and citrate; but negative for indole production, glucose acidification, arginine dihydrolase, urease, β-glucosidase (esculin hydrolysis), protease (gelatin hydrolysis), L-arabinose, D-maltose, adipate, and phenyl-acetate. Utilizes D-mannitol, D-glucose, L-fucose, caprate, citrate, 2-ketogluconate, L-rhamnose, *N*-acetyl-D-glucosamine, D-ribose, inositol, D-sucrose, and 5-ketogluconate; but does not utilize salicin, D-melibiose, D-sorbitol, L-arabinose, propionate, valerate, L-histidine, 3-hydroxy-butyrate, 4-hydroxy-benzoate, L-proline, D-maltose, itaconate, suberate, malonate, acetate, lactate, L-alanine, glycogen, 3-hydroxy-benzoate, and L-serine. Enzymatic activity reaction was positive for alkaline phosphatase, esterase (C4), esterase lipase (C8), leucine arylamidase, valine arylamidase, acid phosphatase, naphtol-AS-BI-phosphohydrolase, α-galactosidase, β-galactosidase, and *N*-acetyl-β-glucosaminidase; but negative for lipase (C14), cystine arylamidase, trypsin, α-chymotrypsin, β-glucuronidase, α-glucosidase, β-glucosidase, α-mannosidase, and α-fucosidase. Strain WR2 (=NIBRBAC000509141) was isolated from an agricultural soil sample, Gyeongsangnam-do, Korea.

Description of *Pseudooceanicola nitratireducens* WS2

Cells are Gram-stain-negative and oval-shaped. Cell size is 0.7−0.9 μm. Colonies are circular, smooth, entire, and yellow pigmented after 3 days of incubation at 28°C on Marine agar. Positive for reduction of nitrates to nitrite ($NO_3^- > NO_2^-$), D-glucose, D-mannitol, D-maltose, gluconate, malate, citrate, and phenyl-acetate; but negative for indole production, glucose acidification, arginine dihydrolase, urease, β-glucosidase (esculin hydrolysis), protease (gelatin hydrolysis), β-Galactosidase (PNPG), L-arabinose, D-mannose, *N*-acetyl-D-glucosamine, caprate, and adipate. D-mannitol, D-glucose, citrate, D-sucrose, D-maltose, L-alanine; but does not utilize salicin, D-melibiose, L-fucose, D-sorbitol, L-arabinose, propionate, caprate, valerate, L-histidine, 2-ketogluconate, 3-hydroxy-butyrate, 4-hydroxy-benzoate, L-proline, L-rhamnose, *N*-acetyl-D-glucosamine, D-ribose, inositol, itaconate, suberate, malonate, acetate, lactate, 5-ketogluconate, glycogen, 3-hydroxy-benzoate, and L-serine. Enzymatic activity reaction was positive for alkaline phosphatase, esterase (C4), esterase lipase (C8), leucine arylamidase, acid phosphatase, and naphtol-AS-BI-phosphohydrolase; but negative for lipase (C14), valine arylamidase, cystine arylamidase, trypsin, α-chymotrypsin, α-galactosidase, β-galactosidase, β-glucuronidase, α-glucosidase, β-gluco-

sidase, *N*-acetyl-β-glucosaminidase, α-mannosidase, and α-fucosidase. Strain WS2 (=NIBRBAC000509142) was isolated from a marine soil sample, Jeju Island, Korea.

Description of *Pedobacter caeni* WS11

Cells are Gram-stain-negative and rod-shaped. Cell size is 1.0−1.2 μm. Colonies are irregular, smooth, entire, and white pigmented after 3 days of incubation at 28°C on R2A. Positive for reduction of β-glucosidase (esculin hydrolysis), β-Galactosidase (PNPG), D-glucose, L-arabinose, D-mannose, *N*-acetyl-D-glucosamine, D-maltose, and malate; but negative for nitrates to nitrite ($NO_3^- > NO_2^-$), reduction of nitrates to nitrogen, indole production, glucose acidification, arginine dihydrolase, urease, protease (gelatin hydrolysis), D-mannitol, gluconate, caprate, adipate, citrate, and phenyl-acetate. Utilizes D-glucose, salicin, D-melibiose, L-arabinose, *N*-acetyl-D-glucosamine, D-sucrose, and D-maltose; but does not utilize D-mannitol, L-fucose, D-sorbitol, propionate, caprate, valerate, citrate, L-histidine, 2-ketogluconate, 3-hydroxy-butyrate, 4-hydroxy-benzoate, L-proline, L-rhamnose, D-ribose, inositol, itaconate, suberate, malonate, acetate, lactate, L-alanine, 5-ketogluconate, glycogen, 3-hydroxy-benzoate, and L-serine. Enzymatic activity reaction was positive for alkaline phosphatase, esterase (C4), esterase lipase (C8), leucine arylamidase, valine arylamidase, trypsin, α-chymotrypsin, acid phosphatase, naphtol-AS-BI-phosphohydrolase, α-galactosidase, β-galactosidase, α-glucosidase, β-glucosidase, *N*-acetyl-β-glucosaminidase, and α-mannosidase; but negative for lipase (C14), cystine arylamidase, β-glucuronidase, and α-fucosidase. Strain WS11 (=NIBRBAC000509143) was isolated from an agricultural soil sample, Gyeongsangnam-do, Korea.

Acknowledgements

This work was supported by a grant from the National Institute of Biological Resources (NIBR), funded by the Ministry of Environment (MOE) of the Republic of Korea (NIBR202102109).

References

Alexander, M. 1999. Biodegradation and bioremediation. Gulf Professional Publishing.

Doetsch, R.N. 1981. Determinative methods of light microscopy. Manual of Methods for General Bacteriology 21-33.

Felsenstein, J. 1985. Confidence limits on phylogenies: an approach using the bootstrap. Evolution 39(4):783-791.

Gao, B. and R.S. Gupta. 2005. Conserved indels in protein sequences that are characteristic of the phylum *Actinobacteria*. Int J Syst Evol Microbiol 55(6):2401-2412.

Gianfreda, L. and M.A. Rao. 2008. Interactions between xenobiotics and microbial and enzymatic soil activity. Crit Rev Environ Sci Technol 38(4):269-310.

Higson, F.K. 1991. Degradation of xenobiotics by white rot fungi. Rev Environ Contam Toxicol 111-152.

Hong, S.H., S.M. Lee and E.Y. Lee. 2011. Bioremediation Efficiency of Oil-Contaminated Soil using Microbial Agents. MBL 39(3):301-307.

King, G.M., J.E. Kostka, T.C. Hazen and P.A. Sobecky. 2015. Microbial responses to the Deepwater Horizon oil spill: from coastal wetlands to the deep sea. Ann Rev Mar Sci 7:377-401.

Kim, D.U., C.N. Seong, K. Jahng, S.D. Lee, C.J. Cha, K. Joh, C.O. Jeon, S.B. Kim and M.K. Kim. 2018. A report on 15 unrecorded bacterial species of Korea isolated in 2016, belonging to the class *Betaproteobacteria*. JSR 7(2):97-103.

Kim, D.U., J.Y. Kim, C.J. Cha, W. Kim and M.K. Kim. 2018. A report of unrecorded bacterial species of Korea isolated in 2016, belonging to the family *Deinococcaceae* and *Planctomycetaceae*. JSR 7(1):9-12.

Kim, H.J., Y.J. Jung, H.Y. Kim and M. Hur. 2019. Isolation and characterization of 6 unrecorded *Pseudomonas* spp. from Korean soil. KJM 55(1):39-45.

Kimura, M. 1983. The neutral theory of molecular evolution. Cambridge University Press.

Kumar, S., G. Stecher and K. Tamura. 2016. MEGA7: molecular evolutionary genetics analysis version 7.0 for bigger datasets. Mol Biol Evol 33(7):1870-1874.

Lawson, P.A. 2018. The phylum *Actinobacteria*. The Bifidobacteria and Related Organisms 1-8.

McClain, C.R., C. Nunnally and M.C. Benfield. 2019. Persistent and substantial impacts of the Deepwater Horizon oil spill on deep-sea megafauna. R Soc Open Sci 6(8):191164.

Nahar, S., D.H. Lee, J.W. Bae, W.T. Im, K.Y. Jahng, K. Joh, W. Kim, S.D. Lee, H. Yi and C.J. Cha. 2018. Report on 30 unrecorded bacterial species of the phylum *Firmicutes* isolated from Korea in 2016. JSR 7(1):50-59.

Nedashkovskaya, O.I., S.B. Kim, M. Suzuki, L.S. Shevchenko, M.S. Lee, K.H. Lee, M.S. Park, G.M. Frolova, H.W. Oh, K.S. Bae, H.Y. Park and V.V. Mikhailov. 2005. *Pontibacter actiniarum* gen. nov., sp. nov., a novel member of the phylum '*Bacteroidota*', and proposal of *Reichenbachiella* gen. nov. as a replacement for the illegitimate prokaryotic generic name *Reichenbachia* Nedashkovskaya *et al*. 2003. Int J Syst Evol Microbiol 55(6):2583-2588.

Pruesse, E., J. Peplies and F.O. Glöckner. 2012. SINA: accurate high-throughput multiple sequence alignment of ribosomal RNA genes. Bioinformatics 28(14):1823-1829.

Saitou, N. and M. Nei. 1987. The neighbor-joining method: a new method for reconstructing phylogenetic trees. Mol

Biol Evol 4(4):406-425.

Seong, C.N., M.S. Kim, J.W. Kang and H.M. Park. 2019. Taxonomic hierarchy of the phylum *Proteobacteria* and Korean indigenous novel *Proteobacteria* species. JSR 8(2):197-214.

Sintayehu, D.W. 2018. Impact of climate change on biodiversity and associated key ecosystem services in Africa: a systematic review. EHS 4(9):225-239.

Smith, D., H. Hinz, J. Mulema, P. Weyl and M.J. Ryan. 2018. Biological control and the Nagoya Protocol on access and benefit sharing-a case of effective due diligence. Biocontrol Sci Technol 28(10):914-926.

Thomas, F., J.H. Hehemann, E. Rebuffet, M. Czjzek and G. Michel. 2011. Environmental and gut Bacteroidota: the food connection. Front. Microbiol 2:93.

Weisburg, W.G., S.M. Barns, D.A. Pelletier and D.J. Lane. 1991. 16S ribosomal DNA amplification for phylogenetic study. J Bacteriol 173(2):697-703.

Yoon, S.H., S.M. Ha, S. Kwon, J. Lim, Y. Kim, H. Seo and J. Chun. 2017. Introducing EzBioCloud: a taxonomically united database of 16S rRNA gene sequences and whole-genome assemblies. Int J Syst Evol Microbiol 67(5):1613.

Submitted: May 30, 2022
Revised: September 20, 2022
Accepted: September 20, 2022