Phytohabitans flavus sp. nov., *Phytohabitans rumicis* sp. nov. and *Phytohabitans houttuyniae* sp. nov., isolated from plant roots, and emended description of the genus *Phytohabitans*

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An actinomycete strain, designated K09-0627^T, was isolated from the roots of an orchid collected in Okinawa Prefecture, Japan. Two actinomycete strains K11-0047^T and K11-0057^T were isolated from the roots of *Rumex acetosa* and *Houttuynia cordata* collected in Kanagawa Prefecture, Japan. 16S rRNA gene sequence analyses indicated that the isolates belonged to the genus *Phytohabitans*, and that they were closely related to each other and to *Phytohabitans suffusus* K07-0523^T. The DNA–DNA relatedness values between the three isolates and *Phytohabitans suffusus* were below 70 %. On the basis of phylogenetic analysis, DNA–DNA relatedness values and phenotypic characteristics, the strains should be classified as novel species in the genus *Phytohabitans*, for which the names *Phytohabitans flavus* sp. nov. (type strain, K09-0627^T=JCM 17387^T=NBRC 107702^T=DSM 45551^T), *Phytohabitans rumicis* sp. nov. (type strain, K11-0047^T=JCM 17829^T=NBRC 108638^T=BCC 48146^T) and *Phytohabitans houttuyniae* sp. nov. (type strain, K11-0057^T=JCM 17830^T=NBRC 108639^T=BCC 48147^T) are proposed.

Numerous actinomycetes have been isolated from soils and have contributed to the discovery of useful bioactive compounds. It is becoming increasingly difficult to find novel bioactive compounds originating from soil-dwelling actinomycete strains, so the focus of attention has switched to search for novel actinomycetes from alternative sources. Many rare actinomycetes are now being isolated from plants (Matsumoto *et al.*, 1998; Janso & Carter, 2010). We have previously isolated actinomycete species from plants to search for novel bioactive secondary metabolites and reported two novel species, *Actinoallomurus radicum* K08-0182^T (Matsumoto *et al.*, 2012) and *Streptosporangium oxazolinicum* K07-0460^T (Inahashi *et al.*, 2011a) which produced novel antitrypanosomal alkaloids, the spoxazomycins (Inahashi *et al.*, 2011b). We have also reported the isolation of the novel actinomycete, *Phytohabitans suffusus* K07-0523^T (Inahashi *et al.*, 2010), a member of a new genus *Phytohabitans* which was isolated from the roots of an orchid

collected in Okinawa prefecture, Japan. At the time of writing, the genus *Phytohabitans* comprised only one species, *P. suffusus*. In this study we describe the taxonomy of the strains K09-0627^T, K11-0047^T and K11-0057^T. Strain K09-0627^T was isolated from the same variety of orchid as *P. suffusus* K07-0523^T; strains K11-0047^T and K11-0057^T were isolated from the roots of two different varieties of plants. All three strains were phylogenetically identified as being members of the genus *Phytohabitans*.

Strain K09-0627^T was isolated from the roots of a variety of orchid collected in Okinawa Prefecture, Japan, in May 2009. Strains K11-0047^T and K11-0057^T were isolated from the roots of *Rumex acetosa* and *Houttuynia cordata*, respectively, collected in Kanagawa Prefecture, Japan, in March 2010. All strains were isolated on water proline agar (1.0 % proline, tap water, pH 7.0) according to the method previously described by Inahashi *et al.* (2010). Strains K09-0627^T, K11-0047^T and K11-0057^T and the reference strain *Phytohabitans suffusus* K07-0523^T were cultured for 4 weeks at 27 °C on nutrient agar (Difco), ISP media 2 and 4 (Difco) and ISP media 3, 5, 6 and 7 (Nihon Pharmaceutical) to observe cultural characteristics. The colour of aerial and substrate mycelia and soluble pigments

The GenBank/EMBL/DDBJ accession numbers for the 16S rRNA gene sequences of strains K09-0627^T, K11-0047^T and K11-0057^T are AB663558, AB663559 and AB663560, respectively.

Two supplementary tables and four supplementary figures are available with the online version of this paper.

were determined using the Colour Harmony Manual (Taylor *et al.*, 1958). Morphologies were observed using a scanning electron microscope (JSM-5600; JEOL) after cultivation on ISP 4 and 7 media for 4–8 weeks at 27 °C.

The temperature, pH and NaCl tolerance ranges for growth were determined on nutrient agar or ISP medium 2. Utilization of carbohydrates as sole carbon sources was tested using ISP medium 9 (Nihon Pharmaceutical) according to the method of Pridham & Gottlieb (1948). Various media were used for assessment of physiological and biochemical characteristics: ISP medium 4 was used for starch hydrolysis; ISP medium 8 (0.5 % peptone, 0.3 % beef extract, 0.5 % KNO₃, pH 7.0) for nitrate reduction; glucose-peptone-gelatin medium (2.0 % glucose, 0.5 % peptone, 20 % gelatin, pH 7.0) for gelatin liquefaction; 10 % skimmed milk for coagulation and peptonization of milk; ISP medium 6 for H₂S production; and skimmed milk agar for casein hydrolysis (Gordon *et al.*, 1974). Tyrosinase activity was determined using ISP medium 7, and other enzyme activities were determined using the API ZYM system (bioMérieux) according to the manufacturer's instructions. Gram-staining was performed using a Gram's reagent kit (Nacalai Tesque).

Biomass for the molecular systematics and chemotaxonomic studies was obtained after cultivation in yeast extract-glucose broth (1.0 % yeast extract, 1.0 % glucose, pH 7.0) for 2 weeks at 27 °C. Isoprenoid quinones extracted from cells as described by Collins *et al.* (1977) were analysed by HPLC (1100; Agilent) and mass spectrometry (JMS-T 100LP; JEOL) using a Pegasil ODS column (Senshu) as described by Tamaoka *et al.* (1983). Isomers of diaminopimelic acid were determined by TLC using whole-cell hydrolysates (Becker *et al.*, 1965). Purified cell wall was obtained using the method of Kawamoto *et al.* (1981), and the amino acid composition of hydrolysed cell walls was determined by cellulose TLC with *n*-butanol/acetic acid/H₂O (4:1:2, by vol.). The *N*-acyl types of muramic acid were determined by the method of Uchida & Aida (1977). Phospholipids in cells were identified by two-dimensional TLC using the method of Minnikin *et al.*

(1984). The presence of mycolic acids was examined by TLC following the method of Tomiyasu (1982). Whole-cell sugar composition was analysed according to the method of Becker *et al.* (1965). Methyl esters of cellular fatty acids were prepared by direct transmethylation with methanolic hydrochloride and analysed on a GLC system (HP 6890; Hewlett Packard). Identification and quantification of the fatty acid methyl esters, as well as the numerical analysis of the fatty acid profiles, were performed according to the instructions for the Microbial Identification System (MIDI).

Chromosomal DNA was prepared following the procedure of Saito & Miura (1963) and the DNA G + C content was determined by HPLC according to Tamaoka & Komagata (1984). DNA–DNA hybridization was performed by the photobiotin-labelling method of Ezaki *et al.* (1989). The 16S rRNA gene was amplified by PCR and the sequence was analysed according to the method previously described by Inahashi *et al.* (2010). The clustalw2 software program was used for multiple alignments with selected sequences for calculating evolutionary distances (Kimura, 1980). Phylogenetic trees were constructed based on the neighbour-joining (Saitou & Nei, 1987), maximum-likelihood (Felsenstein, 1981) and maximum-parsimony (Fitch, 1972) methods by SeaView version 4.2 (Gouy *et al.*, 2010). Data were resampled with 1000 bootstrap replications (Felsenstein, 1985). The values of sequence similarities were determined using the EzTaxon server 2.1 (Chun *et al.*, 2007).

Strains K09-0627^T, K11-0047^T and K11-0057^T grew well on ISP medium 2, 3 and 4. The colony colour of strains K09-0627^T and K11-0047^T was yellow to brown and that of strain K11-0057^T was orange to brown (Table 1). Vegetative mycelia were branched but not fragmented. Strain K09-0627^T formed single spores on ISP medium 4 (Fig. 1). Strains K11-0047^T and K11-0057^T formed long chains, of more than 10 spores, on ISP medium 4 or 7, respectively (Fig. 1). Strain K09-0627^T grew at 20–35 °C (optimum, 22–34 °C) and pH 7–11 (optimum, pH 7–9), strain K11-0047^T grew at 20–34 °C (optimum, 26–28 °C) and pH 7–11 (optimum, pH 7–9) and strain K11-0057^T grew at 20–42 °C (optimum,

Fig. 1. Scanning electron micrographs of: (a) Strain K09-0627^T grown on ISP medium 4 for 6 weeks at 27 °C; (b) Strain K11-0047^T grown on ISP medium 4 for 8 weeks at 27 °C; (c) Strain K11-0057^T grown on ISP medium 7 for 4 weeks at 27 °C. Bars, 2 μm (a–b); 1 μm (c).

Table 1. Cultural characteristics of strains K09-0627^T, K11-0047^T, K11-0057^T and *Phytohabitans suffuscus* K07-0523^T

Strains: 1, K09-0627^T; 2, K11-0047^T; 3, K11-0057^T; 4, *Phytohabitans suffuscus* K07-0523^T. All data from this study. Colour designation based on Colour Harmony Manual (Taylor *et al.*, 1958).

Medium	1	2	3	4
ISP medium 2				
Growth	Good	Good	Good	Good
Colony colour	Amber (3pe) to luggage tan (4ne)	Orange rust (4pe)	Luggage tan (4ne)	Orange (4la)
Reverse	Amber (3pe)	Topaz (3ne)	Light amber (3ic)	Light amber (3ic)
Aerial mycelium	Poor, white (a)	None	None	None
ISP medium 3				
Growth	Good	Good	Good	Good
Colony colour	Bamboo (2gc) to topaz (3ne)	Brite yellow (2la) to brite gold (2nc)	Orange rust (4pe) to deep brown (4pl)	Oak brown (4pi)
Reverse	Bamboo (2gc) to mustard gold (2ne)	Colonial yellow (2ga) to gold (2lc)	Cork tan (4ie) to beaver (4li)	Light fawn (4ge)
Aerial mycelium	Poor, white (a)	None	None	None
ISP medium 4				
Growth	Good	Good	Good	Good
Colony colour	Amber (3pe)	Bamboo (2gc)	Apricot (4ia)	Russet orange (4nc)
Reverse	Light tan (3gc)	Mustard (2le)	Pastel orange (4ic)	Apricot (4ga)
Aerial mycelium	Poor, white (a)	Poor, white (a)	Poor, white (a)	Poor, white (a)
ISP medium 5				
Growth	Poor	Good	Good	Good
Colony colour	Light ivory (2ca) to light amber (3ic)	Light ivory (2ca) to mustard gold (2ne)	Brite (3ia)	Apricot (4ga)
Reverse	Light ivory (2ca) to light amber (3ic)	Light ivory (2ca) to mustard gold (2ne)	Light amber (3ic)	Apricot (4ga)
Aerial mycelium	Poor, white (a)	None	None	None
ISP medium 6				
Growth	Poor	Poor	Moderate	Poor
Colony colour	Topaz (3ne)	Bamboo (2gc)	Topaz (3ne)	Golden brown (3pg)
Reverse	Topaz (3ne)	Bamboo (2gc)	Amber (3nc)	Golden brown (3pg)
Aerial mycelium	None	None	None	None
ISP medium 7				
Growth	Good	Moderate	Moderate	Good
Colony colour	Light wheat (2ea)	Bamboo (2gc)	Flesh pink (4ca) to oak brown (4pi)	Russet orange (4nc)
Reverse	Light wheat (2ea)	Bamboo (2gc)	Bisque (4ec) to adobe brown (3lg)	Nude tan (4gc)
Aerial mycelium	None	None	Poor, white (a)	None
Nutrient agar				
Growth	Good	Moderate	Moderate	Good
Colony colour	Light wheat (2ea)	Light wheat (2ea)	Mustard brown (2pi)	Orange rust (4pe)
Reverse	Light wheat (2ea)	Light wheat (2ea)	Mustard brown (2pi)	Flesh pink (4ca)
Aerial mycelium	None	None	None	Poor, white (a)

30 °C) and pH 6–11 (optimum, pH 7–9). The three novel strains and *P. suffuscus* K07-0523^T did not produce soluble pigment. Other phenotypic characteristics are given in Table 2 and the species descriptions.

Strains K09-0627^T, K11-0047^T and K11-0057^T contained D-glutamic acid, D-glycine, D-alanine, *meso*-diaminopimelic

acid, hydroxydiaminopimelic acid and L-lysine in the cell walls. The *N*-acyl type of muramic acid was glycolyl. Mycolic acids were not detected. Phosphatidylethanolamine and some unknown phospholipids were detected (Fig. S1, available in IJSEM online). Arabinose, galactose, mannose, ribose and xylose were detected as whole-cell sugars. The major cellular fatty acids were iso-C_{16:0} and anteiso-C_{17:0}

Table 2. Differential characteristics among strains K09-0627^T, K11-0047^T, K11-0057^T and *Phytohabitans suffuscus* K07-0523^T

Strains: 1, K09-0627^T; 2, K11-0047^T; 3, K11-0057^T; 4, *Phytohabitans suffuscus* K07-0523^T. +, Positive; w, weakly positive; –, negative.

Characteristics	1	2	3	4
Number of spores	1	>10	>10	>10
Growth at 42 °C	–	–	+	–
Utilization of:				
D-Xylose	+	–	+	+
L-Rhamnose	+	–	+	+
Sucrose	–	+	+	+
Maltose	–	+	+	–
D-Sorbitol	–	+	–	–
Peptonization of milk	–	–	w	+
Coagulation of milk	–	–	–	+
Reduction of nitrate to nitrite	–	+	–	–
Liquefaction of gelatin	–	w	w	w
Enzyme activity of:				
Alkaline phosphatase	+	+	+	w
Esterase (C4)	+	+	+	–
Esterase lipase (C8)	+	+	w	–
Leucine arylamidase	–	+	+	+
Valine arylamidase	–	+	+	w
Cystine arylamidase	–	+	w	w
Trypsin	–	+	+	+
α-Chymotrypsin	–	+	w	–
Acid phosphatase	–	+	+	+
Naphthol-AS-BI-phosphohydrolase	w	+	+	w
α-Galactosidase	–	–	+	–
β-Galactosidase	–	+	+	+
β-Glucuronidase	–	–	w	–
α-Glucosidase	–	–	+	+
β-Glucosidase	–	+	+	+
N-acetyl-β-glucosaminidase	–	–	+	+
α-Fucosidase	–	w	–	–

(Table 3). The menaquinones were MK-9(H₄) (7 %), MK-9(H₆) (21 %), MK-9(H₈) (41 %), MK-10(H₄) (4 %), MK-10(H₆) (11 %) and MK-10(H₈) (15 %) for strain K09-0627^T;

MK-9(H₆) (2 %), MK-9(H₈) (3 %), MK-10(H₄) (3 %), MK-10(H₆) (22 %) and MK-10(H₈) (70 %) for strain K11-0047^T; and MK-9(H₆) (2 %), MK-9(H₈) (3 %), MK-10(H₄) (5 %), MK-10(H₆) (33 %) and MK-10(H₈) (57 %) for strain K11-0057^T (Fig. S2). The DNA G + C contents of strains K09-0627^T, K11-0047^T and K11-0057^T were 71, 72 and 73 mol%, respectively.

The 16S rRNA gene sequences of strains K09-0627^T (1466 bp), K11-0047^T (1470 bp) and K11-0057^T (1468 bp) showed highest sequence similarity with *P. suffuscus* K07-0523^T. The sequence similarities among strains K09-0627^T, K11-0047^T, K11-0057^T and *P. suffuscus* K07-0523^T were 98.0 to 98.8 % (Table S1). Phylogenetic analysis based on the 16S rRNA gene sequences indicated that strains K09-0627^T, K11-0047^T and K11-0057^T formed a cluster with *P. suffuscus* K07-0523^T (Fig. 2).

The phylogenetic, morphological and chemotaxonomic properties indicated that strains K09-0627^T, K11-0047^T and K11-0057^T belonged to the genus *Phytohabitans*. However, DNA–DNA relatedness values among strains K09-0627^T, K11-0047^T and K11-0057^T and *P. suffuscus* K07-0523^T were below the value of 70 % recommended by Wayne *et al.* (1987) for the assignment of strains to the same species (Table S2). Furthermore, these strains exhibited different characteristics, as shown in Table 2. Strain K09-0627^T formed single spores and didn't utilize sucrose; strain K11-0047^T reduced nitrate to nitrite, utilized D-sorbitol but not D-xylose or L-rhamnose; and strain K11-0057^T grew at 42 °C and possessed α-galactosidase activity. The above results support our proposal that strains K09-0627^T, K11-0047^T and K11-0057^T represent novel species in the genus *Phytohabitans* with the names of *Phytohabitans flavus* sp. nov., *Phytohabitans rumicis* sp. nov. and *Phytohabitans houttuyniae* sp. nov., respectively.

Emended description of the genus *Phytohabitans* Inahashi *et al.* 2010

In addition to the description given by Inahashi *et al.* (2010), menaquinones are MK-9(H₆), MK-9(H₈), MK-10(H₄),

Fig. 2. Neighbour-joining tree based on 16S rRNA gene sequences showing the phylogenetic positions of strains K09-0627^T, K11-0047^T, K11-0057^T and related actinomycetes. Only bootstrap values above 50 % (percentages of 1000 replications) are indicated. Solid circles and asterisks indicate that the corresponding nodes were also recovered in the maximum-likelihood tree and maximum-parsimony trees, respectively. Bar, 0.01 nt substitutions per site.

Table 3. Cellular fatty-acid compositions (%) of strains K09-0627^T, K11-0047^T, K11-0057^T and *Phytohabitans suffuscus* K07-0523^T

Strains: 1, K09-0627^T; 2, K11-0047^T; 3, K11-0057^T; 4, *Phytohabitans suffuscus* K07-0523^T. —, not detected.

	1	2	3	4
C _{12:0} 2-OH	0.4	—	—	—
iso-C _{14:0}	0.3	0.4	0.3	0.2
iso-C _{15:0}	0.4	2.3	1.2	10.2
anteiso-C _{15:0}	0.4	0.9	1.1	2.2
C _{15:0}	—	0.4	—	—
iso-C _{16:1}	12.6	1.1	2.9	0.7
iso-C _{16:0}	43.6	22.7	30.7	12.4
C _{16:0} 9- <i>cis</i>	—	—	—	1.3
C _{16:0}	0.4	0.4	0.4	1.3
C _{16:0} 9-methyl	—	1.0	—	—
C _{16:0} 10-methyl	0.5	—	0.8	2.2
anteiso-C _{17:1}	6.8	3.4	7.2	1.6
iso-C _{17:0}	1.1	3.3	3.7	19.5
anteiso-C _{17:0}	14.4	26.9	33.1	28.6
C _{17:1} 9- <i>cis</i>	—	5.8	—	2.6
C _{17:0}	—	6.0	3.3	1.5
C _{16:1} 2-OH	0.9	2.6	7.3	4.9
C _{17:0} 10-methyl	—	0.8	—	—
iso-C _{18:0}	10.8	2.6	2.4	1.2
C _{18:1} 9- <i>cis</i>	—	3.8	—	5.0
C _{18:0}	7.4	4.4	3.6	4.5
Summed feature 8*	—	5.0	—	—
C _{19:0}	—	5.8	1.8	—

*Summed features represent two or three fatty acids that cannot be separated by the Microbial Identification System. Summed feature 8 comprises C_{19:1} and/or C_{19:1} 10-*cis*.

MK-10(H₆) and/or MK-10(H₈). The DNA G + C content is 71–73 %.

Description of *Phytohabitans flavus* sp. nov.

Phytohabitans flavus (fla'vus. L. masc. adj. *flavus* yellow, referring to colour of the colonies).

Aerobic, Gram-positive and mesophilic actinomycete. Colonies are yellow to brown. Vegetative mycelia are branched and not fragmented. Exhibits good growth on nutrient agar and ISP medium 2, 3, 4 and 7. Forms single spores on ISP medium 4. The surface of the spores is smooth and spore size is 1.0 × 1.0 µm. Growth occurs at 20–35 °C (optimum, 22–34 °C) and pH 7–11 (optimum, pH 7–9). No growth is observed in the presence of 2 % NaCl. Casein is degraded. Starch is hydrolysed. Gelatin is not liquefied. Milk is not peptonized or coagulated. Nitrate is not reduced to nitrite. H₂S and melanin are not produced. D-glucose, L-arabinose, D-xylose, D-mannitol, D-fructose and L-rhamnose are utilized, but raffinose, melibiose, *myo*-inositol, sucrose, maltose, D-sorbitol and cellulose are not. Tyrosinase is not

produced. Positive result in the API ZYM system for alkaline phosphatase, esterase (C4) and esterase lipase (C8), weakly positive result for naphthol-AS-BI-phosphohydrolase, but negative result for lipase (C14), leucine arylamidase, valine arylamidase, cystine arylamidase, trypsin, α-chymotrypsin, acid phosphatase, α-galactosidase, β-galactosidase, β-glucuronidase, α-glucosidase, β-glucosidase, N-acetyl-β-glucosaminidase, α-mannosidase, and α-fucosidase. The cell wall contains D-glutamic acid, D-glycine, D-alanine, *meso*-diaminopimelic acid, hydroxydiaminopimelic acid and L-lysine. The whole-cell sugar pattern consists of arabinose, galactose, glucose, mannose, ribose and xylose. The major cellular fatty acids are iso-C_{16:0}, anteiso-C_{17:0}, iso-C_{16:1} and iso-C_{18:0}. The menaquinones are MK-9(H₄), MK-9(H₆), MK-9(H₈), MK-10(H₄), MK-10(H₆) and MK-10(H₈).

The type strain, K09-0627^T (=JCM 17387^T=NBRC 107702^T=DSM 45551^T), was isolated from the roots of an orchid collected in Okinawa Prefecture, Japan. The G + C content of the genomic DNA of the type strain is 71 mol%.

Description of *Phytohabitans rumicis* sp. nov.

Phytohabitans rumicis (ru'mi.cis. L. n. *rumex* -icis sorrel and also a scientific genus name; L. gen. n. *rumicis* of sorrel, isolated from *Rumex acetosa*).

Aerobic, Gram-positive and mesophilic actinomycete. Colonies are yellow to brown. Vegetative mycelia are branched and not fragmented. Exhibits good growth on ISP medium 2, 3, 4 and 5. Forms long chains of more than 10 spores on ISP medium 4. The surface of the spores are smooth and spore size is 0.5 × 1.3 µm. Growth occurs at 20–34 °C (optimum, 26–28 °C) and pH 7–11 (optimum, pH 7–9). No growth in the presence of 2 % NaCl. Casein is degraded. Starch is hydrolysed. Gelatin is liquefied weakly. Milk is not peptonized or coagulated. Nitrate is reduced to nitrite. H₂S and melanin are not produced. D-glucose, L-arabinose, D-mannitol, D-fructose, sucrose, maltose and D-sorbitol are utilized, but D-xylose, raffinose, melibiose, L-rhamnose, *myo*-inositol and cellulose are not. Tyrosinase is not produced. Positive result in the API ZYM system for alkaline phosphatase, esterase (C4), esterase lipase (C8), leucine arylamidase, valine arylamidase, cystine arylamidase, trypsin, α-chymotrypsin, acid phosphatase, naphthol-AS-BI-phosphohydrolase, β-galactosidase and β-glucosidase are positive, weakly positive result for α-fucosidase, but negative result for lipase (C14), α-galactosidase, β-glucuronidase, α-glucosidase, N-acetyl-β-glucosaminidase and α-mannosidase. The cell wall contains D-glutamic acid, D-glycine, D-alanine, *meso*-diaminopimelic acid, hydroxydiaminopimelic acid and L-lysine. The whole-cell sugar pattern consists of arabinose, galactose, glucose, mannose, ribose, rhamnose and xylose. The major cellular fatty acids are anteiso-C_{17:0} and iso-C_{16:0}. The menaquinones are MK-9(H₆), MK-9(H₈), MK-10(H₄), MK-10(H₆) and MK-10(H₈).

The type strain, *Phytohabitans rumicis* K11-0047^T (=JCM 17829^T=NBRC 108638^T=BCC 48146^T), was isolated from

the roots of *Rumex acetosa* collected in Kanagawa Prefecture, Japan. The G+C content of the genomic DNA of the type strain is 72 mol%.

Description of *Phytohabitans houttuyniae* sp. nov.

Phytohabitans houttuyniae (hout.tuy.ne'ae. N.L. gen. n. *houttuyniae* of *Houttuynia*, referring to the isolation of the strain from *Houttuynia cordata*).

Aerobic, Gram-positive and mesophilic actinomycete. Colonies are orange to brown. Vegetative mycelia are branched and not fragmented. Exhibits good growth on ISP medium 2, 3, 4 and 5. Forms long chains of more than 10 spores on ISP medium 4 and 7. The surface of the spores is smooth and spore size is $0.5 \times 1.0 \mu\text{m}$. Growth occurs at 20–42 °C (optimum, 30 °C) and pH 6–11 (optimum, pH 7–9). No growth in the presence of 3 % NaCl. Casein is degraded. Starch is hydrolysed. Gelatin is liquefied weakly. Milk is peptonized weakly and not coagulated. Nitrate is not reduced to nitrite. H₂S and melanin are not produced. D-glucose, L-arabinose, D-xylose, D-mannitol, D-fructose, L-rhamnose, sucrose and maltose are utilized, but raffinose, melibiose, *myo*-inositol, D-sorbitol and cellulose are not. Tyrosinase is not produced. Positive result in the API ZYM system for alkaline phosphatase, esterase (C4), leucine arylamidase, valine arylamidase, trypsin, acid phosphatase, naphthol-AS-BI-phosphohydrolase, α -galactosidase, β -galactosidase α -glucosidase, β -glucosidase and *N*-acetyl- β -glucosaminidase, weakly positive result for esterase lipase (C8), cystine arylamidase, α -chymotrypsin and β -glucuronidase, but negative result for lipase (C14), α -mannosidase and α -fucosidase. The cell wall contains D-glutamic acid, D-glycine, D-alanine, *meso*-diaminopimelic acid, hydroxydiaminopimelic acid and L-lysine. The whole-cell sugar pattern consists of arabinose, galactose, mannose, ribose, rhamnose and xylose. The major cellular fatty acids are anteiso-C_{17:0} and iso-C_{16:0}. The menaquinones are MK-9(H₆), MK-9(H₈), MK-10(H₄), MK-10(H₆) and MK-10(H₈).

The type strain, *Phytohabitans houttuyniae* K11-0057^T (=JCM 17830^T=NBRC 108639^T=BCC 48147^T), was isolated from the roots of *Houttuynia cordata* collected in Kanagawa Prefecture, Japan. The G+C content of the genomic DNA of the type strain is 73 mol%.

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