Open access • Posted Content • DOI:10.20944/PREPRINTS201608.0005.V1

Specificity in Legume-Rhizobia Symbioses — Source link

Mitchell Andrews, Morag E Andrews

Institutions: Lincoln University (New Zealand)

Published on: 01 Aug 2016

Topics: Mesorhizobium, Bradyrhizobium, Rhizobia, Phaseoleae and Galega

 doi:10.20944/preprints201608.0005.v1

Review

Specificity in Legume-Rhizobia Symbioses

Mitchell Andrews * and Morag E Andrews

Faculty of Agriculture and Life Sciences, Lincoln University, PO Box 84, Lincoln 7647, New Zealand; moragandrews@gmail.com

* Correspondence: mitchell.andrews@lincoln.ac.nz; Tel.: +64-3-423-0692

Abstract: The Leguminosae (legume family) is divided into three sub-families, the Caesalpiniodeae, Mimosoideae and Papilionoideae. Here, the literature on legume-rhizobia symbioses was reviewed, and genotypically characterised rhizobia related to the taxonomy of the legumes they were isolated from. Only data from field soils were considered. The objective of the work was to assess to what extent legume specificity for rhizobial symbiont is related to legume taxonomy. *Bradyrhizobium* spp. were the exclusive rhizobial symbionts of species in the Caesalpinioideae but data are limited. Where tested, species within the two Mimosoideae tribes, Ingeae and Mimoseae were nodulated by different rhizobial genera. Generally, Papilionoideae species with indeterminate nodules were promiscuous in relation to rhizobial symbionts but high specificity for rhizobial partners appears to hold at tribe level for the Fabeae (*Rhizobium* spp.), genus level for *Medicago* (*Ensifer* spp.), *Cytisus* (*Bradyrhizobium* spp.) and *Lupinus* (*Bradyrhizobium* spp.), and species level for *Galega* spp. (*Neorhizobium galegeae*), *Hedysarum coronarium* (*Rhizobium sullae*), *Cicer arietinum* (*Mesorhizobium* spp.) and New Zealand native *Sophora* spp. (*Mesorhizobium* spp.). High legume specificity for rhizobial symbionts was linked to specific rhizobial symbiosis genes. For Papilionoideae species with determinate nodules, the Dalbergieae were primarily nodulated by *Bradyrhizobium* but were promiscuous with respect to *Bradyrhizobium* spp. while those in the Desmodieae, Phaseoleae, Psoraleae and Loteae were promiscuous across different rhizobial genera. Possible advantages and disadvantages of high specificity or promiscuity are discussed.

Keywords: Leguminosae; N_2 fixation; nodulation

---

1. Introduction

The Leguminosae (= Fabaceae, the legume family) is comprised of ca 19,300 species within 750 genera which occur as herbs, shrubs, vines or trees in mainly terrestrial habitats and are components of most of the world's vegetation types [Lewis et al. 2005; Sprent 2009; LPWG 2013]. Currently, the legume family is divided into three sub-families, the Caesalpiniodeae, Mimosoideae and Papilionoideae [LPWG 2013, Cardoso et al. 2013]. Members of the Caesalpinioideae are grouped in four tribes, the Caesalpinieae, Cassieae, Cercideae and Detarieae comprising ca 170 genera and 2,250 species. The Mimosoideae are grouped in two tribes, the Ingeae and Mimoseae with ca 80 genera and 3,270 species while the Papilionoideae consists of 28 tribes with ca 480 genera and 13,800 species.

Most legume species can fix atmospheric nitrogen (N_2) via symbiotic bacteria (general term 'rhizobia') in root nodules and this can give them an advantage under low soil nitrogen (N) conditions if other factors are favourable for growth [Raven 2010; Andrews et al. 2013]. Also, N_2 fixation by legumes can be a major input of N into natural and agricultural ecosystems [Andrews et al. 2007, 2011; Jackson et al. 2008; Vitousek et al. 2013]. Generally, legume nodules can be classified as indeterminate or determinate in growth [Sprent 2009]. Indeterminate nodules maintain meristematic tissue while determinate nodules have a transient meristem. Nodule type is dependent on host plant, and legume species which can produce both determinate and indeterminate nodules are rare [Fernández-Lopez et al. 1998; Liu et al. 2014]. All genera examined

 doi:10.20944/preprints201608.0005.v1

in the Caesalpinioideae and Mimosoideae had indeterminate nodules (Sprent, 2009). Within the Papilionoideae, most tribes had indeterminate nodules but the Desmodieae, Phaseoleae, Psoraleae and some members of the Loteae show 'desmodoid' determinate nodules and the Dalbergieae 'aeschynomenoid' determinate nodules [Sprent 2009]. Most indeterminate nodules have a single persistent apical meristem, however, a few genera such as *Lupinus* (tribe Genisteae, Papilionoideae) and *Listia* (tribe Crotalaria, Papilionoideae), have nodules with two or more lateral meristems which in some cases completely surround the subtending root [Yates et al. 2007; Sprent 2009]. Rhizobia 'infected' tissue within desmodoid nodules always contains uninfected cells while aeschynomenoid nodules have uniform infected tissue and are always associated with lateral or adventitious roots (Sprent 2009).

Over the past twenty-five years, DNA based methods have become increasingly used to characterize rhizobia. In particular, phylogenetic analyses of sequences of the 16S ribosomal RNA (rRNA) gene, a range of 'housekeeping' genes and genes involved in symbiosis have been developed as a 'standard approach' [Martens et al. 2007; Liu et al. 2014; Peix et al. 2015]. The main symbiosis genes studied are the '*nif*' genes which encode the subunits of nitrogenase, the rhizobial enzyme that fixes N_2, and the '*nod*' genes which encode Nod factors that induce various symbiotic responses on legume roots. The *nod* genes are activated by plant root exudates mainly flavonoids [Masson-Boivin et al. 2009]. The 16S rRNA gene sequence on its own can delineate rhizobia at the genus level [Lindstrom et al. 2015]. The *nif* and *nod* genes are often carried on plasmids or symbiotic islands and these genes can be transferred (lateral transfer) between different bacterial species within a genus and more rarely across genera [Vinuesa et al. 2005b; Cummings et al. 2009; Remigi et al. 2016]. Bacterial species from a range of genera in the alphaproteobacteria (most commonly *Bradyrhizobium*, *Ensifer* (= *Sinorhizobium*), *Mesorhizobium*, and *Rhizobium*) and two genera in the betaproteobacteria (*Burkholderia* (= *Paraburkholderia*) and *Cupriavidus*) can form functional (N_2 fixing) nodules on specific legumes (Tables 1-4). *Pseudomonas* in the gammaproteobacteria was reported to nodulate *Robinia pseudoacacia* [Shiraishi et al. 2010] and *Acacia confusa* [Huang et al. 2012] but this has not been confirmed.

Legume species differ in their specificity for rhizobial symbionts. *Galega officinalis* (tribe Galegeae) and *Hedysarum coronarium* (tribe Hedysareae) have been highlighted as being highly specific with respect to their rhizobial symbionts [Lindström 1989; Squartini et al. 2002; Franche et al. 2009; Liu et al. 2012]. Both these species are in the inverted repeat lacking clade (IRLC). The IRLC is marked by the loss of one copy of the inverted region of the plastid genome (Wojciechowski et al. 2004; Schwarz et al. 2015]. Almost all genera in the IRLS are temperate and all have indeterminate nodules. The IRLC contains several important temperate grain (e.g. *Pisum sativum* and *Vicia faba*) and forage (e.g. *Trifolium* spp. and *Medicago* spp.) legumes. There is evidence that at least some of these crop legumes have a high degree of rhizobial specificity. For example, an analysis of core and symbiotic genes of rhizobia nodulating *Vicia faba* and *Vicia sativa* from different continents showed that they belong to a phylogenetically compact group indicating that these species are restrictive hosts [Álvarez-Martinez et al. 2009]. In contrast, *Macroptilium purpureum* and the grain legumes *Phaseolus vulgaris* and *Vigna unguiculata* in the tribe Phaseoleae are nodulated by rhizobia from different genera across the alpha- and beta-proteobacteria [Martínez-Romero 2003; Elliot et al. 2007; Guimarães et al. 2012; Table 4]. The Phaseoleae are of tropical/subtropical origin and have determinate (desmodoid) nodules [Sprent 2009].

Here, the literature on legume-rhizobial symbioses was reviewed, and genotypically-characterised rhizobia related to the taxonomy of the legumes they were isolated from. Only data from field soils were considered. The objective of the work was to assess to what extent legume specificity for rhizobial symbiont is related to legume taxonomy.

2. Framework and assumptions of study

The general classification of the Leguminosae follows Lewis *et al*. 2005 [Lewis et al. 2005] with updates [LPWG 2013; Cardoso et al. 2013]. The sub-families Caesalpiniodeae, Mimosoideae and Papilionoideae are considered separately. The Papilionoideae is split into those that show

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 1 August 2016 doi:10.20944/preprints201608.0005.v1

indeterminate nodules and those that show determinate nodules. Those that show indeterminate nodules are further split into the IRLC, and all other clades.

Nodulating bacteria were classified to genus level, on the basis of sequences of the 16S rRNA gene (almost all cases), and/ or the 16S-23S DNA intergenic spacer region, and/ or common house-keeping genes, and/ or DNA-DNA hybridisations and these results are presented in tables. Cases where legume specificity for rhizobial symbiont appeared to occur at genus level are considered further in the text. Rhizobial genus and species names validated in the International Journal of Systematic and Evolutionary Microbiology were used with one exception; *Burkholderia* was retained as opposed to using *Paraburkholderia* [Oren & Garrity 2015; Dobritsa & Samadpour 2016] as a case to reinstate *Burkholderia* is being prepared by workers in the field. The term symbiovar (sv.) is used when describing rhizobial strains within the same species which differ with respect to the legume species they effectively nodulate [Rogel et al. 2011].

A comprehensive collation of published legume-rhizobia symbioses was carried out. Articles were collected by searching the ISI Web of Science using each legume genus partnered with each of rhizobia, *Bradyrhizobium, Burkholderia, Cupriavidus, Ensifer, Mesorhizobium, Rhizobium* and *Sinorhizobium* as key words. Further searches were carried out on the literature quoted in the selected papers and those listed as quoting the selected papers in ISI Web of Science. Only data for plants sampled under field conditions, or for plants grown in soils taken from the field, or supplied field soil extracts, were used. Bacteria isolated from legume nodules were accepted as rhizobia if they were shown to produce functional (N_2 fixing) nodules on inoculation of their original legume host or a species within the original host legume genus under axenic conditions. The range of measurements and visual assessments used as evidence of the occurrence of N_2 fixation were accepted. These were acetylene reduction activity, red/pink nodules (evidence of haemoglobin and hence nodules assumed to be active), increased total plant or shoot dry matter or N content, visually greener (increased chlorophyll) and increased plant vigour. However, it is acknowledged that in some cases, greater growth, vigour and/ or greenness could have been caused by plant hormone production by the bacterium [Andrews *et al*. 2003]. All data obtained for all species are presented with three exceptions. Representative data are presented for *Glycine max*, *Phaseolus vulgaris* and *Vigna unguiculata* due to the large number of publications on these three species.

3. Caesalpinioideae-Rhizobia Symbioses

Of the three legume sub-families, the Caesalpinioideae contains the smallest proportion of nodulated genera with nodulation confirmed for *Campsiandra, Chidlowia, Dimorphandra, Erythrophleum, Melanoxylon, Moldenhauwera* and *Tachigali* in the tribe Caesalpinieae and *Chamaecrista* in the tribe Cassieae [Sprent 2009]. Only two studies have genotypically characterised rhizobia of Caesalpinioideae species. Firstly, five rhizobial isolates from *Dimorphandra wilsonii* and one from *Dimorphandra jorga* sampled in the Cerrado biome in Brazil were *Bradyrhizobium* [Fonseca et al. 2012]. Secondly, 166 rhizobial isolates from *Erythrophleum fordii* sampled at four sites in the Guangdong and Guangsii Provinces of the southern sub-tropical region of China were also all *Bradyrhizobium* [Yao et al. 2014]. In both studies, core and symbiosis gene sequences indicated that there were diverse and novel strains amongst the isolates.

Data are available for bacterial isolates from nodules of other Caesalpinioideae species but their ability to produce N_2 fixing nodules on their legume host under axenic conditions was not tested. Specifically, three isolates from *Tachigali versicolor* sampled on Barro Colorado Island, Panama which were not tested on their original host plant but shown to nodulate *Macroptilium atropurpureum* were *Bradyrhizobium* [Parker 2000]. Similarly, strain STM934, stated to be confirmed as *Bradyrhizobium* was isolated from nodules of *Erythrophleum guineensis* growing in natural forests of the Ziama reservation in S.E. Guinea and shown to produce functional nodules on *Macroptilium atropurpureum* [Diabate et al. 2005]. In this case, a re-inoculation experiment was carried out on the original host but the substrate was non-sterile forest soil. *Bradyrhizobium* was isolated from and shown to nodulate *Chamaecrista* sampled in Kakadu National Park, Northern Territory, Australia but N_2 fixation was not reported [Lafay & Burdon 2007]. Also, there are several reports that

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 1 August 2016 doi:10.20944/preprints201608.0005.v1

Bradyrhizobium inoculum can increase nodulation of *Chamaecrista* spp. under field conditions in Australia and China [Michalk and Zhi-Kai 1994; Keller 2014; www.tropicalforagesinfo]. Thus, overall, the available evidence indicates that *Bradyrhizobium* spp. are the dominant, possibly exclusive, rhizobial symbionts of legumes in the Caesalpinioideae but the degree of specificity between legumes in the Caesalpinioideae and their rhizobial symbionts cannot be assessed without further work.

4. Mimosoideae-Rhizobia Symbioses

Rhizobia have been characterized from 15 species across seven genera in the tribe Ingeae and ca 90 species from 13 genera in the tribe Mimoseae within the sub-family Mimosoideae (Table 1). *Bradyrhizobium, Ensifer, Mesorhizobium* and *Rhizobium* were each reported to nodulate species in the Ingeae and the Mimoseae. Also, *Ochrobactrum* was reported to nodulate *Acacia mangium* (Ingeae), *Allorhizobium* and *Devosia* were reported to nodulate *Neptunia natans* (Mimoseae), and there are many reports that *Cupriavidus* and *Burkholderia* nodulate *Mimosa* spp. and related species (Mimoseae) (Table 1). In addition, with the exception of *Acacia auriculiformis* (Ingeae) and *Mimosa diplotricha* (Mimoseae), all species which were examined in three or more separate studies, *Acacia mangium*, *Acacia saligna, Calliandra grandiflora* and *Senegalia senegal* (Ingeae), *Leucaena leucocephala, Mimosa pudica, Parapiptadenia rigida, Prosopis alba* and *Vachellia tortilis* (Mimoseae), were nodulated by at least three different rhizobial genera. Thus, a range of rhizobial genera, including both alpha- and beta-proteobacteria, can nodulate legume species across the two Mimosoideae tribes and, generally, where tested over different studies, species within the Ingeae and Mimoseae tribes were promiscuous with respect to their rhizobial symbionts.

Despite their ability to form symbioses with different rhizobial genera, Mimosa spp. appear to be predominantly nodulated by *Burkholderia* in Brazil, *Ensifer/Rhizobium* in Mexico and *Cupriavidus* in Uruguay [Bontemps et al. 2010, 2016, dos Reis et al. 2010, Platero et al. 2016]. This is likely to be at least in part related to the relative occurrence of the potential symbionts in the different soils due, for example, to differences in soil pH [Bontemps et al 2016, Platero et al 2006]. However, it has been reported that in competition studies between a *Burkholderia* strain, a *Cupriavidus* strain and three *Rhizobium* strains which were all potential rhizobial symbionts of three *Mimosa* spp., the *Burkholderia* strain outcompeted the other strains to the point of exclusion in flooded soils [Elliott et al. 2009]. This advantage of the *Burkholderia* strain could not be explained by differences in initial inoculum levels, growth rate, growth inhibition of the other rhizobia or nodulation rate but the advantage decreased if 0.5 mM nitrate was added to the system. These data show that the competitive ability of different potential rhizobial strains can be greatly dependent on environmental conditions.

5. Papilionoideae-Rhizobia Symbioses

5.1. The IRLC

Data are available for 110 species from 29 genera within six tribes in the IRLC with *Ensifer, Mesorhizobium,* and *Rhizobium* commonly, and *Bradyrhizobium, Neorhizobium* and *Phyllobacterium* rarely, reported to nodulate species within this clade (Table 2). There are no reports of *Burkholderia* or *Cupriavidus* symbionts within the IRLC. Previously, *Galega officinalis, Galega orientalis* and *Hedysarum coronarium* were reported to only form effective nodules with their respective symbionts *Neorhizobium galegeae* sv. officinalis, *Neorhizobium galegeae* sv. orientalis and *Rhizobium sullae* [Lindström 1989; Squartini et al. 2002; Franche et al. 2009; Liu et al. 2012]. Several mechanisms maintain these highly specific legume-rhizobia symbioses [Suominen et al. 2003; Franche et al 2009; Gharzouli et al. 2013]. For example, in the *Galega orientalis – Neorhizobium galegeae* sv. orientalis interaction, the first recognition between the flavonoid inducer secreted from the roots of *Galega orientalis* and the NodD protein of *N. galegeae* sv. orientalis is specific for these organisms [Suominen et al 2003].

The data in Table 2, indicate three other specific relationships between IRLC legumes and rhizobia. Firstly, eight separate studies on *Cicer arietinum* carried out over different countries and

 doi:10.20944/preprints201608.0005.v1

continents, reported *Mesorhizobium* as the only symbiont (Table 2). *Mesorhizobium ciceri* and *M. mediterraneum* were common but not exclusive *Mesorhizobium* symbionts of *Cicer arietinum* in most studies outside China with *M. muleiense* the main symbiont in Northwest China [Zhang et al 2016]. In the three studies where tested, *Mesorhizobium* symbionts other than *M. ciceri*, *M. mediterraneum* and *M. muleiense* showed *nifH* and *nodC* gene sequences similar to these three common symbionts indicating that *Cicer arietinum* strongly selects rhizobia with specific symbiotic genes [Rivas et al 2006; Zhang et al 2012, 2016].

Secondly, for the tribe Fabeae, seventeen studies across five *Lathyrus* species, *Lens culinaris, Pisum sativum* and eleven *Vicia* spp. reported *Rhizobium* as the only symbiont. Across these studies, *Rhizobium leguminosarum* and where tested, *R. leguminosarum* sv. viciae was the most common symbiont. Also, in a study of 154 isolates of 18 *Vicia* species grown in 16 Chinese provinces, only 17 representative *Rhizobium leguminosarum* sv. viciae isolates, from a wide range of potential rhizobia, produced fully developed, effective ('color red') nodules [Lei et al. 2008]. Thus, a highly specific relationship has developed between species in the Fabeae and *R. leguminosarum* sv. viciae but it is not an exclusive relationship as *R. fabeae* [Tian et al 2008], *R. multihospitium* [Han et al 2008b], *R. pisi* [Santillana et al 2008], *R. laguerreae* [Said et al 2014] and *R. anhuiense* [Zhang et al 2015] have been reported to effectively nodulate Fabeae species. However, the *nifH* and *nodC* gene sequences of all these rhizobia show high similarity indicating specificity towards the Fabeae species [Zhang et al. 2015].

Thirdly, within the tribe Trifolieae, 12 out of 13 separate studies across 11 *Medicago* spp. reported *Ensifer* as symbiont although in some cases not exclusively. In particular, highly specific relationships have developed between *Medicago* spp. and the closely related (core and symbiosis genes) *E. meliloti* and *E. medicae* with symbiovars of these rhizobial species associated with particular *Medicago* spp. (Villegas et al. 2006; Gubry Rangin et al. 2013).

In relation to other members of the IRLC, *Ensifer, Mesorhizobium* and *Rhizobium* were shown to nodulate species within *Astragalus, Colutea, Glycyrrhiza, Oxytropis* and *Sphaerophyceae* (Galegeae), *Caragana* (Hedysareae), *Tephrosa* (Millettieae) and *Trifolium* (Trifolieae). Also, *Astragalus adsurgense, Astragalus complanatus, Colutea arborescens, Oxytropis glabera* and *Sphaerophysia sabula* (Galegeae), *Caragana intermedia* (Hedysareae), *Tephrosia purpurea* (Millettieae) and *Trifolium fragiferum* and *Trifolium repens* (Trifolieae) were all nodulated by three different rhizobial genera. Thus, for the IRLC, high specificity in relation to rhizobial partners appears to hold at tribe level for the Fabeae, genus level for *Medicago* and species level for *Galega officinalis, Galega orientalis, Hedysarum coronarium* and *Cicer arietinum* but it is not a characteristic of all members of the clade.

5.2. Clades with indeterminate nodules, excluding the IRLC

Data are available for approximately 100 species from 50 genera across 11 Papilionoideae tribes with indeterminate nodules which do not show the IRLC mutation (Table 3). *Azorhizobium, Bradyrhizobium, Burkholderia, Ensifer, Herbaspirillum, Mesorhizobium, Methylobacterium, Microvirga, Neorhizobium, Ochrobactrum, Pararhizobium, Phyllobacterium* and *Rhizobium* were all reported to nodulate species within this group. *Amorpha fructicosa* and *Dalea purpurea* (Amorpheae), *Retama sphaerocarpa* and *Spartium junceum* (Genisteae), *Coronilla varia* (Loteae), *Gliricidia sepium* and *Robinia pseudoacacia* (Robineae) and *Sesbania sericea* and *Sesbania virgata* (Sesbanieae) were nodulated by two rhizobial genera. *Aspalathus linearis* and *Crotalaria pallida* (Crotalarieae), *Sesbania cannabina, Sesbania punicea, Sesbania rostrata* and *Sesbania sesban* (Sesbanieae), *Sophora alopecuroides* and *Sophora flavescens* (Sophoreae) and *Ammopiptanthus nanus* and *Ammopiptanthus mongolicus* (Thermopsideae) were all nodulated by at least three different rhizobial genera. Thus, generally, where tested, Papilionoideae species with indeterminate nodules excluding the IRLC were promiscuous in relation to rhizobial symbiont. However, within the Genisteae, *Bradyrhizobium* was the only symbiont reported for nine *Cytisus* spp. across ten separate studies and three *Genista* spp. across three separate studies (Table 3). Also, 10 *Lupinus* spp. (Genisteae) across 11 separate studies were predominantly nodulated by *Bradyrhizobium*. These results indicate that *Bradyrhizobium* may be the main symbionts of Genisteae species but further work is required to confirm this. The relationship

 doi:10.20944/preprints201608.0005.v1

between *Cytisus* spp. and *Lupinus* spp. and their *Bradyrhizobium* symbionts is highly specific and dependent on geographical origin of the legumes. For example, most *Bradyrhizobium* isolates from *Lupinus* spp. in Europe form a distinct lineage, 'clade 11', on the basis of their *nodC* gene sequences [Stepkowski et al. 2007, 2011]. Similarly, different *Bradyrhizobium* spp. associated with *Cytisus villosus* in Morocco all showed similar *nodC* and *nifH* sequences which were closely related to those of *Bradyrhizobium japonicum* sv. genistearum [Chahboune et al. 2011].

On more limited data (one study), *Bradyrhizobium* was found to be the exclusive symbiont of four *Indigofera* spp. [Doignon-Bourcier et al. 1999] although in a separate study *Burkholderia* was reported to be the symbiont of *Indigofera angustifolia* [Lemaire et al. 2015]. Also, in one study, in the Cape Floristic Region (CFR) of South Africa, *Burkholderia* was reported to be the exclusive symbiont of ten *Cyclopia* spp., *Podalyria calyptera* and *Virgilia oroboides*, all species in the Podalyrieae plus three *Hypocalyptus* spp. (Hypocalypteae) [Beukes et al. 2013]. *Burkholderia* was confirmed to nodulate *Podolyria calyptrata* and *Virgilia oroboides* in the CFR [Lemaire et al. 2015]. The majority of *Burkholderia* isolates had unique *nifH* and *nodA* gene sequences and the specificity of these symbioses needs testing.

Previously, *Sesbania sesban* was reported to be highly promiscuous with respect to rhizobial symbionts [Cummings et al. 2009] and the data here indicate that this could be a genus level trait (Table 3). However, the reports that *Sophora alopecuroides* and *Sophora flavescens* sampled in China are nodulated by a wide range of rhizobial genera with a wide range of symbiosis gene sequences [Zhao et al. 2010; Jiao et al. 2015a] contrasts with the finding that New Zealand (NZ) native *Sophora* spp. were exclusively nodulated by *Mesorhizobium* spp. with almost identical unique *nodA* and *nodC* gene sequences [Tan et al. 2015; De Meyer et al. 2015, 2016]. Also, none of twenty rhizobial isolates from common weed and crop legumes in NZ produced functional nodules on the NZ native *Sophora microphylla* [Liu 2014]. This emphasises that species within the same genus can vary greatly with respect to their specificity for rhizobial symbionts.

5.3. Clades with Determinate Nodules

The Dalbergieae are almost exclusively of tropical/ sub-tropical distribution and show aeschynomenoid determinate nodule structure (Sprent 2009). Rhizobia have been characterised for 24 species from seven genera in the Dalbergieae, *Adesmia, Aeschynomene, Arachis, Centrolobium, Dalbergia, Pterocarpus* and *Zornia* (Table 4). *Bradyrhizobium* was found to nodulate all species except *Adesmia bicolor* (*Rhizobium*) and *Dalbergia odorifera* (*Burkholderia*), with *Rhizobium* also reported for *Arachis hypogaea*. For *Arachis hypogaea*, twelve separate studies reported *Bradyrhizobium* as a rhizobial symbiont with two of these also reporting *Rhizobium.* Thus, on the data available, *Arachis hypogaea* and the Dalbergieae, in general, appear to be primarily nodulated by *Bradyrhizobium*. However, across studies, both core and symbiosis gene sequences indicate that *Arachis hypogaea*, *Arachis duranensis* and *Aeschynomene* spp. are nodulated by a diverse range of *Bradyrhizobium* spp. and are promiscuous with respect to *Bradyrhizobium* spp.

The closely related tribes Desmodieae, Phaseoleae and Psoraleae are also mainly of tropical/ sub-tropical distribution and, with rare exceptions, species within these tribes showed desmodoid nodule structure (Sprent 2009; Liu et al. 2014). Rhizobia have been characterized for 25 species from three genera, *Desmodium, Kummerowia* and *Laspedeza,* in the Desmodieae (Table 4). Species from all three genera, *Desmodium microphyllum, Desmodium racemosum, Desmodium sequax, Kummerowia striata, Lespedeza bicolor* and *Lespedeza daurica* were nodulated by rhizobia from three separate genera. Similarly, for 28 species across 14 genera within the Phaseoleae, there was no strong evidence for high specificity for rhizobial symbiont (Table 4). *Phaseolus vulgaris* and *Vigna unguiculata* have been highlighted as being promiscuous with respect to their rhizobial symbionts under field conditions. Data in Table 4 show that both species can be nodulated by different rhizobial genera in the alphaproteobacteria as well as *Burkholderia* in the betaproteobacteria. Across three studies, *Phaseolus lunatus* was reported to be nodulated by *Bradyrhizobium* and *Rhizobium* while on one study each, both *Vigna sangularis* and *Vigna subterranean* were reported to be nodulated by three separate rhizobial genera. Data are limited for other genera/ species within the Phaseoleae with the exception of *Glycine max* which is the main grain/ oil seed legume grown worldwide. *Glycine max* was nodulated by *Bradyrhizobium, Ensifer* and *Rhizobium*. Data are limited for Psoraleae but in the one case where two separate studies were carried out on the one species (*Psoralea pinnata*) it was nodulated by *Burkholderia* and *Mesorhizobium* [Kanu & Dakora 2012; Lemaire et al. 2015]. Thus, where tested, species within the Desmodieae, Phaseoleae and Psoraleae were promiscuous with respect to their rhizobial symbionts.

Species in the Loteae which show desmodoid nodule structure are of temperate distribution [Sprent 2009]. Data are available for 16 *Lotus* spp. within the Loteae across 13 separate studies.. For all species examined in two or more studies at least two rhizobia genera were reported as symbionts. In the case of *Lotus corniculatus*, *Geobacillus*, *Paenibacillus* and *Rhodococcus* were for the first time reported as rhizobial symbionts (Ampomah and Huss-Danell 2011). These bacterial species had similar symbiosis gene sequences to *Mesorhizobium* isolated from the same plants and it was concluded that lateral gene transfer of these genes had occurred from the *Mesorhizobium*. However, this work needs to be independently verified. Overall, the available data indicate that legume species with desmodoid determinate nodule structure are promiscuous with respect to their rhizobia symbionts.

6. Legume Specificity for Rhizobial Symbionts

High specificity or promiscuity of legumes with respect to rhizobial symbionts are both likely to have advantages and disadvantages to the legume [Ehinger et al. 2014]. For example, promiscuity could allow a legume to participate in a wider range of beneficial interactions and hence possibly occupy more environments. However, high specificity is likely to result in increased 'fitness', e.g. increased N_2 fixation, within a narrower range of conditions [Ehinger et al 2014]. In an agricultural situation, the degree of crop legume specificity for rhizobial symbiont is an important factor in determining the level of success of applied rhizobial inoculant [Andrews et al. 2009].

The objective of the work was to assess to what extent legume specificity for rhizobial symbiont is related to legume taxonomy. The legume sub-families, Caesalpiniodeae, Mimosoideae and Papilionoideae were considered separately with species in the Papilionoideae split in relation to whether they show indeterminate or determinate nodules. *Bradyrhizobium* spp. were the exclusive rhizobial symbionts of species in the Caesalpinioideae but rhizobia were authenticated for only three legume species over two studies and the degree of specificity between legumes in the Caesalpinioideae and their rhizobial symbionts cannot be assessed without further work.

In relation to the Mimosoideae, generally, where examined in three or more studies, species within both the Ingeae and Mimoseae tribes were promiscuous with respect to their rhizobial symbionts and there is no strong evidence for high specificity for rhizobial symbionts for any species in this sub-family. For Papilionoideae species with determinate nodules, the Dalbergieae were primarily nodulated by *Bradyrhizobium* but were promiscuous with respect to *Bradyrhizobium* spp. while those in the Desmodieae, Phaseoleae, Psoraleae and Loteae were promiscuous across different rhizobial genera. Papilionoideae species with indeterminate nodules were split into the IRLC, and all other clades. A range of species within both groups nodulated with different rhizobia genera but there was also strong evidence that some species within both groups showed high specificity for rhizobial symbiont. High specificity for rhizobial symbiont appears to hold at tribe level for the Fabeae (*Rhizobium* spp.), genus level for *Medicago (Ensifer* spp.*)*, *Cytisus* (*Bradyrhizobium* spp.) and *Lupinus* (*Bradyrhizobium* spp.), and species level for *Galega* spp. (*Neorhizobium galegeae*), *Hedysarum coronarium* (*Rhizobium sullae*), *Cicer arietinum* (*Mesorhizobium* spp.) and NZ native *Sophora* spp. (*Mesorhizobium* spp.). In all cases, this high specificity involved rhizobial species within the alphaproteobacteria and was associated with specific symbiosis genes of the rhizobial symbiont (Sections 5.1, 5.2). The legume species which show high specificity in rhizobial symbionts have common features in that they are all within the Papilionoideae, have indeterminate nodules and are of temperate distribution.

 doi:10.20944/preprints201608.0005.v1

References

1. Alam, F.; Bhuiyan, M.A.H.; Alam, S.S.; Waghmode, T.R.; Kim, P.J. Effect of Rhizobium sp. BARIRGm901 inoculation on nodulation, nitrogen fization and yield of soybean (Glycine max) genotypes in gray terrace soil. *Biosci. Biotechnol. Biochem*. **2015**, 1660-1668.
2. Alvarez-Martínez, E.R.; Valverde, Á.; Ramírez-Bahena, M.H.; García-Fraile, P.; Tejedor, C.; Mateos, P.F.; Santillana, N.; Zúñiga, D.; Peix, A.; Velázquez, E. The analysis of core and symbiotic genes of rhizobia nodulating *Vicia* from different continents reveals their common phylogenetic origin and suggests the distribution of *Rhizobium leguminosarium* strains together with *Vicia* seeds. *Arch. Microbiol*. **2009**, *191*, 659-668.
3. Amarger, N.; Macheret, V.; Laguerre, G. *Rhizobium gallicum* sp. nov. and *Rhizobium giardinii* sp. nov., from *Phaseolus vulgaris* nodules. *Int. J. Syst. Bacteriol.* **1997**, *47*, 996-1006.
4. Ampomah, O.Y.; Huss-Danell, K. Genetic diversity of root nodule bacteria nodulating *Lotus corniculatus* and *Anthyllis vulneraria* in Sweden. *Syst. Appl. Microbiol.* **2011**, *34*, 267-275.
5. Ampomah, O.Y.; Huss-Danell, K. Nodulation of *Thermopsis lupinoides* by a *Mesorhizobium huakuii* strain with a unique *nodA* gene in Kamtchatka, Russia. *Appl. Environ. Microbiol.* **2011**, *77*, 5513-5516.
6. Ampomah, O.Y.; Huss-Danell, K. Genetic diversity of rhizobia nodulating native *Vicia* spp. in Sweden. *Syst. Appl. Microbiol.* **2016**, *39*, 203-210.
7. Andam, C.P.; Mondo, S.J.; Parker, M.A. Monophyly of *nodA* and *nifH* genes across Texan and Costa Rican populations of *Cupriavidus* nodule symbionts. *Appl. Env. Microbiol.* **2007**, *73*, 4686-4690.
8. Andrews, M.; James, E.K.; Cummings, S.P.; Zavalin, A.A.; Vinogradova, L.V.; McKenzie, B.A. Use of nitrogen fixing bacteria inoculants as a substitute for nitrogen fertiliser for dryland graminaceous crops: progress made, mechanisms of action and future potential. *Symbiosis*, **2003**, *35*, 209-229.
9. Andrews, M.; James, E.K.; Sprent, J.I.; Boddey, R.M.; Gross, E.; dos Reis Jr, F.B. Nitrogen fixation in legumes and actinorhizal plants in natural ecosystems: values obtained using ^{15}N natural abundance. *Plant Ecol. Divers.* **2011**, *4*, 131-140.
10. Andrews, M.; Lea, P.L.; Raven, J.A.; Azevedo, R.A. Nitrogen use efficiency. 3. Nitrogen fixation: genes and costs. *Ann. Appl. Biol*. **2009**, *155*, 1-13.
11. Andrews, M.; Raven, J.A.; Lea, P.J. Do plants need nitrate? The mechanisms by which nitrogen form affects plants. *Ann. Appl. Biol.* **2013**, *163*, 174-199.
12. Andrews, M.; Scholefield, D.; Abberton, M.T.; McKenzie, B.A.; Hodge, S.; Raven, J.A. Use of white clover as an alternative to nitrogen fertilizer for dairy pastures in nitrate vulnerable zones in the UK: productivity, environmental impact and economic considerations. *Ann. Appl. Biol.* **2007**, *151*, 11-23.
13. Aoki, S.; Kondo, T.; Prévost, D.; Nakata, S.; Kajita, T.; Itó, M. Genotypic and phenotypic diversity of rhizobia isolated from *Lathyrus japonicus* indigenous to Japan. *Syst. Appl. Microbiol.* **2010**, *33*, 383-397.
14. Aouani, M.E.; Mhamdi, R.; Jebara, M.; Amarger, N. Characterization of rhizobia nodulating chickpea in Tunisia. *Agronomie* **2001**, *21*, 577-581.
15. Appunu, C.; Sasirekha, N.; Prabavathy, V.R.; Nair, S. A significant proportion of indigenous rhizobia from India associated with soybean (*Glycine max* L.) distinctly belong to *Bradyrhizobium* and *Ensifer* genera. *Biol. Fertil. Soils* **2009**, *46*, 57-63.
16. Araujo, J.; Díaz-Alcántara, C-A.; Velázquez, E.; Urbano, B.; González-Andrés, F. *Bradyrhizobium yuanmingense* related strains form nitrogen-fixing symbiosis with *Cajanus cajan* L. in Dominican Republic and are efficient biofertilizers to replace N fertilization. *Sci. Hort.* **2015,** *192*, 421-428.
17. Ardley, J.K.; Parker, M.A.; De Meyer, S.E.; Trengove, R.D.; O'Hara, G.W.; Reeve, W.G.; Yates, R.J.; Dilworth, M.J.; Willems, A.; Howieson, J.G. *Microvirga lupini* sp. nov., *Microvirga lotononidis* sp. nov. and *Microvirga zambiensis* sp. nov. are alphaproteobacterial root-nodule bacteria that specifically nodulate and fix nitrogen with geographically and taxonomically separate legume hosts. *Int. J. Syst. Evol. Microbiol.* **2012**, *62*, 2579-2588.
18. Armas-Carpote, N.; Pérez-Yépez, J.; Martínez-Hidalgo, P.; Garzón-Machado, V.; del Arco-Aguilar, M.; Velázquez, E.; Léon-Barrios, M. Core and symbiotic genes reveal nine *Mesorhizobium* genospecies and three symbiotic lineages among the rhizobia nodulating *Cicer canariense* in its natural habitat (La Palma, Canary Islands). *Syst. Appl. Microbiol.* **2014**, *37*, 140-148.

19. Ba, S.; Willems, A.; de Lajudie, P.; Roche, P.; Jeder, H.; Quatrini, P.; Neyra, M.; Ferro, M.; Promé J-C.; Gillis, M.; Boivin-Masson, C.; Lorquin, J. Symbiotic and taxonomic diversity of rhizobia isolated from *Acacia tortilis* sp. subsp. *Raddiana* in Africa. *Syst. Appl. Microbiol.* **2002**, *25*, 130-145.
20. Badri, Y.; Zribi, K.; Badri, M.; Huguet, T.; van Berkum, P.; Aouani, M.E. Comparison of rhizobia that nodulate *Medicago laciniata* and *Medicago truncatula* present in a single Tunisian arid soil. *Canadian J. Microbiol*. **2007**, *53*, 277-283.
21. Baimiev, Al.Kh.; Baimiev, An.Kh.; Gubaidullin, I.I.; Kulikova, O.L.; Chemeris, A.V. Bacteria closely related to *Phyllobacterium trifolii* according to their 16S rRNA gene are discovered in the nodules of Hungarian sainfoin. *Genetika*, **2007**, *43*, 587-590.
22. Bala, A.; Giller, K.E. Symbiotic specificity of tropical tree rhizobia for host legumes. *New Phytol.* **2001**, *149*, 495-507.
23. Baraúna, A.C.; da Silva, K.; Pereira, G.M.D.; Kaminski, P.E.; Perin, L.; Zilli, J.E. Diversity and nitrogen fixation efficiency of rhizobia isolated from nodules of *Centrolobium paraense*. *Pesquisa. Agropecu. Bras.* **2014**, *49*, 296-305.
24. Barcellos, F.G.; Menna, P.; Batista, J.S.da S.; Hungria, M. Evidence of horizontal transfer of symbiotic genes from a *Bradyrhizobium japonicum* inoculant strain to indigenous diazotrophs *Sinorhizobium* (*Ensifer*) *fredii* and *Bradyrhizobium elkanii* in a Brazilian savannah soil. *Appl. Environ. Microbiol.* **2007**, *73*, 2635-2643.
25. Barrett, C.F.; Parker, M.A. Prevalence of *Burkholderia* sp. nodule symbionts on four mimosoid legumes from Barro Colorado Island, Panama. *Syst. Appl. Microbiol.* **2005**, *28*, 57-65.
26. Barrett, C.F.; Parker, M.A. Coexistence of *Burkholderia, Cupriavidus,* and *Rhizobium* sp. nodule bacteria on two *Mimosa* spp. in Costa Rica. *Appl. Environ. Microbiol.* **2006**, *72*, 1198-1206.
27. Bejarano, A.; Ramírez-Bahena, M-H.; Velázquez, E.; Peix, A. *Vigna unguiculata* is nodulated in Spain by endosymbionts of Genisteae legumes and by a new symbiovar (vignae) of the genus *Bradyrhizobium*. *Syst. Appl. Microbiol.* **2014**, *37*, 533-540.
28. Ben Romdhane, S.; Trabelsi, M.; Aouani, M.E.; de Lajudie, P.; Mhamdi, R. The diversity of rhizobia nodulating chickpea (*Cicer arietinum*) under water deficiency as a source of more efficient inoculants. *Soil Biol. Biochem.* **2009**, 41**,** 2568-2572.
29. Benata, H.; Mohammed, O.; Noureddine, B.; Abdelbasset, B.; Abdelmoumen, H.; Muresu, R.; Squartini, A.; El Idrissi, M.M. Diversity of bacteria that nodulate *Prosopis juliflora* in the eastern area of Morocco. *Syst. Appl. Microbiol.* **2008**, *31*, 378-386.
30. Beukes, C.W.; Stępkowski, T.; Venter, S.N.; Cłapa T.; Phalane, F.L.; le Roux, M.M.; Steenkamp, E.T. Crotalaria and Genisteae of the South African Great Escarpment are nodulated by novel *Bradyrhizobium* species with unique and diverse symbiotic loci. *Mol. Phylogenet. Evol*. **2016**, 206-218.
31. Beukes, C.W.; Venter, S.N.; Law, I.J.; Phalane, F.L.; Steenkamp, E.T. South African papilionoid legumes are nodulated by diverse *Burkholderia* with unique nodulation and nitrogen-fixation loci. *PLoS ONE* **2013**, *8* (7), e68406.
32. Beyhaut, E.; Tlusty, B.; van Berkum, P.; Graham, P.H. *Rhizobium giardinii* is the microsymbiont of Illinois bundleflower (*Desmanthus illinoensis* (Michx.) Mcmillan) in Midwestern prairies. *Can. J. Microbiol.* **2006**, *52*, 903-907.
33. Bianco, L.; Angelini, J.; Fabra, A.; Malpassi, R. Diversity and symbiotic effectiveness of indigenous rhizobia-nodulating *Adesmia bicolor* in soils of Central Argentina. *Curr. Microbiol.* **2013**, *66*, 174-184.
34. Blanco, A.R.; Csukasi, F.; Abreu, C.; Sicardi, M. Characterization of rhizobia from *Sesbania* species native to seasonally wetland areas in Uruguay. *Biol. Fertil. Soils* **2008**, *44*, 925-932.
35. Bontemps, C.; Elliott, G.N.; Simon, M.F.; dos Reis Jr, F.B.; Gross, E.; Lawton, R.C.; Neto, N.E.; Loureiro, M.deF.; de Faria, S.M.; Sprent, J.I.; James, E.K.; Young, P.W. *Burkholderia* species are ancient symbionts of legumes. *Mol. Ecol*. **2010**, *19*, 44-52.
36. Bontemps, C.; Rogel, M.A.; Wiechmann, A.; Mussabekova, A.; Moody, S.; Simon, M.F.; Moulin, L.; Elliott, G.N.; Lacercat-Didier, L.; Dasilva, C.; Grether, R.; Camargo-Ricalde, S.L.; Chen, W.; Sprent, J.I.; Martínez-Romero, E.; Young, J.P.W.; James, E.K. Endemic *Mimosa* species from Mexico prefer alphaproteobacterial rhizobial symbionts. *New Phytol*. **2016**, *209*, 319-333.
37. Bourebaba, Y.; Durán, D.; Boulila, F.; Ahnia, H.; Boulila, A.; Temprano, F.; Palacios, J.M.; Imperial, J.; Ruiz-Argüeso, T.; Rey, L. Diversity of *Bradyrhizobium* strains nodulating *Lupinus micranthus* on both sides of the Western Mediterranean: Algeria and Spain. *Syst. Appl. Microbiol*. **39**, 266-274.

38. Bournaud, C.; de Faria, S.M.; dos Santos, J.M.F.; Tisseyre, P.; Silva, M.; Chaintreuil, C.; Gross, E.; James, E.K.; Prin, Y.; Moulin, L. *Burkholderia* species are the most common and preferred nodulating symbionts of the Piptadenia group (Tribe Mimoseae). *PLoS ONE* **2013**, *8 (5)*, e63478.
39. Bromfield, E.S.P.; Tambong, J.T.; Cloutier, S.; Prévost, D.; Laguerre, G.; van Berkum, P.; Tran Thi, T.V.; Assabgui, R.; Barran, L.R. *Ensifer, Phyllobacterium* and *Rhizobium* species occupy nodules of *Medicago sativa* (alfalfa) and *Melilotus alba* (sweet clover) grown at a Canadian site without a history of cultivation. *Microbiol*. **2010**, *156*, 505-520.
40. Cao, Y.; Wang, E-T.; Zhao, L.; Chen, W-M.; Wei, G-H. Diversity and distribution of rhizobia nodulated with *Phaseolus vulgaris* in two ecoregions of China. *Soil Biol. Biochem.* **2014**, *78*, 128-137.
41. Cardinale, M.; Lanza, A.; Bonnì, M.L.; Marsala, S.; Puglia, A.M.; Quatrini, P. Diversity of rhizobia nodulating wild shrubs of Sicily and some neighbouring islands. *Arch. Microbiol.* **2008**, *190*, 461-470.
42. Cardoso, D.; Pennington, R.T.; de Queiroz, L.P.; Boatwright, J.S.; Van Wyk, B.-E.; Wojciechowski, M.F.; Lavin, M. Reconstructing the deep-branching relationships of the papilionoid legumes. *S. Afr. J. Bot.* **2013**, *89*, 58-75.
43. Chahboune, R.; Barrijal, S.; Moreno, S.; Bedmar, E.J. Characterization of *Bradyrhizobium* species isolated from root nodules of *Cytisus villosus* grown in Morocco. *Syst. Appl. Microbiol*. **2011**, *34*, 440-445.
44. Chang, Y.L.; Wang, J.Y.; Wang, E.T.; Liu, H.C.; Sui, X.H.; Chen, W.X. *Bradyrhizobium lablabi* sp. nov., isolated from effective nodules of *Lablab purpureus* and *Arachis hypogaea*. *Int. J. Syst. Evol. Microbiol.* **2011**, *61*, 2496-2502.
45. Chen, J.; Hu, M.; Ma, H.; Wang, Y.; Wang, E.T.; Zhou, Z.; Gu, J. Genetic diversity and distribution of bradyrhizobia nodulating peanut in acid-neutral soils in Guangdong Province. *Syst. Appl. Microbiol*. **2016**, http://dx.doi.org/doi:10.1016/j.syapm.2016.06.002.
46. Chen, J.Y.; Gu, J.; Wang, E.T.; Ma, X.X.; Kang, S.T.; Huang, L.Z.; Cao, X.P.; Li, L.B.; Wu, Y.L. Wild peanut *Arachis duranensis* are nodulated by diverse and novel *Bradyrhizobium* species in acid soils. *Syst. Appl. Microbiol*. **2014**, *37*, 525-532.
47. Chen, W.; Sun, L.; Lu, J.; Bi, L.; Wang, E.; Wei, G. Diverse nodule bacteria were associated with *Astragalus* species in arid region of northwestern China. *J. Basic Microbiol.* **2015**, *55*, 121-128.
48. Chen, W.; Wang, E.; Wang, S.; Li, Y.; Chen, X.; Li, Y. Characteristics of *Rhizobium tianshanense* sp. nov., a moderately and slowly growing root nodule bacterium isolated from an arid saline environment in Xinjiang, People's Republic of China. *Int. J. Syst. Bacteriol.* **1995**, *45*, 153-159.
49. Chen, W-M.; de Faria, S.M.; Straliotto, R.; Pitard, R.M.; Simões-Araùjo, J.L.; Chou, J-H.; Chou, Y-J.; Barrios, E.; Prescott, A.R.; Elliott, G.N.; Sprent, J.I.; Young, J.P.W.; James, E.K. Proof that *Burkholderia* strains form effective symbioses with legumes: a study of novel *Mimosa*-nodulating strains from South America. *Appl. Environ. Microbiol.* **2005a**, *71*, 7461-7471.
50. Chen, W-M.; James, E.K.; Chou, J-H.; Sheu, S-Y.; Yang, S-Z.; Sprent, J.I. β-Rhizobia from *Mimosa pigra*, a newly discovered invasive plant in Taiwan. *New Phytol*. **2005b**, *168*, 661-675.
51. Chen, W-M.; Lee, T-M. Genetic and phenotypic diversity of rhizobial isolates from sugarcane–*Sesbania cannabina*-rotation fields. *Biol. Fertil. Soils*. **2001**, *34*, 14-20.
52. Chen, W-M.; Lee, T-M.; Lan, C-C.; Cheng, C-P. Characterization of halotolerant rhizobia isolated from root nodules of *Canavalia rosea* from seaside areas. *FEMS Microbiol. Ecol.* **2000**, *34*, 9-16.
53. Chen, W-M.; Moulin, L.; Bontemps, C.; Vandamme, P.; Béna, G.; Boivin-Masson, C. Legume symbiotic nitrogen fixation by β-Proteobacteria is widespread in nature. *J. Bacteriol*. **2003**, *185*, 7266-7272.
54. Chen, W-X.; Tan, Z-Y.; Gao, J-L.; Li, Y.; Wang, E-T. *Rhizobium hainanense* sp. nov., isolated from tropical legumes. *Int. J. Syst. Bacteriol*. **1997**, *47*, 870-873.
55. Cobo-Díaz, J.F.; Martínez-Hidalgo, P.; Fernández-González, A.J.; Martínez-Molina, E.; Toro, N.; Velázquez, E.; Fernández-López, M. The endemic *Genista versicolor* from Sierra Nevada National Park in Spain is nodulated by putative new *Bradyrhizobium* species and a novel symbiovar (sierranevadense). *Syst. Appl. Microbiol.* **2014**, *37*, 177-185.
56. Cordero, I.; Ruiz-Díez, B.; de la Peña, T.C.; Balaguer, L.; Lucas, M.M.; Rincón, A.; Pueyo, J.J. Rhizobial diversity, symbiotic effectiveness and structure of nodules of *Vachellia macracantha*. *Soil Biol. Biochem.* **2016**, *96*, 39-54.
57. Cummings, S.P.; Gyaneshwar, P.; Vinuesa, P.; Farruggia, F.T.; Andrews, M.; Humphry, D.; Elliott, G.N.; Nelson, A.; Orr, C.; Pettitt, D.; Shah, G.R.; Santos, S.R.; Krishnan, H.B.; Odee, D.; Moreira, F.M.S.; Sprent,

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 1 August 2016 doi:10.20944/preprints201608.0005.v1

J.I.; Young, J.P.W.; James, E.K. Nodulation of *Sesbania* species by *Rhizobium* (*Agrobacterium*) strain IRBG74 and other rhizobia. *Environ. Microbiol.* **2009**, *11*, 2510-2525.

58. Dall'Agnol, R.F.; Plotegher, F.; Souza, R.C.; Mendes, I.C.; dos Reis Junior, F.B.; Béna, G.; Moulin, L.; Hungria, M. *Paraburkholderia nodosa* is the main N_2-fixing species trapped by promiscuous common bean (*Phaseolus vulgaris* L.) in the Brazilian 'Cerradão'. *FEMS Microbiol. Ecol.* **2016**, *92*, doi: 10.1093/femsec/fiw108
59. da Silva, K.; De Meyer, S.E.; Rouws, L.F.M.; Farias, E.N.C.; dos Santos, M.A.O.; O'Hara, G.; Ardley, J.K.; Willems, A.; Pitard, R.M.; Zilli, J.E. *Bradyrhizobium ingae* sp. nov., isolated from effective nodules of *Inga laurina* grown in Cerrado soil. *Int. J. Syst. Evol. Microbiol.* **2014**, *64*, 3395-3401.
60. Degefu, T.; Wolde-meskel, E.; Frostegård, Å. Multilocus sequence analyses reveal several unnamed *Mesorhizobium* genospecies nodulating *Acacia* species and *Sesbania sesban* trees in Southern regions of Ethiopia. *Syst. Appl. Microbiol.* **2011**, *34*, 216-226.
61. Degefu, T.; Wolde-meskel, E.; Frostegård, Å. Phylogenetic multilocus sequence analysis identifies seven novel *Ensifer* genospecies isolated from a less-well-explored biogeographical region in East Africa. *Int. J. Syst. Evol. Microbiol.* **2012**, *62*, 2286-2295.
62. de Lajudie, P.; Laurent-Fulele, E.; Willems, A.; Torck, U.; Coopman, R.; Collins, M.D.; Kersters, K.; Dreyfus, B.; Gillis, M. *Allorhizobium undicola* gen. nov., sp. nov., nitrogen-fixing bacteria that efficiently nodulate *Neptunia natans* in Senegal. *Int. J. Syst. Bacteriol*. **1998**, *48*, 1277-1290.
63. Delamuta, J.R.M.; Ribeiro, R.A.; Ormeño-Orrillo, E.; Parma, M.M.; Melo, I.S.; Martínez-Romero, E.; Hungria, M. *Bradyrhizobium tropiciagri* sp. nov. and *Bradyrhizobium embrapense* sp. nov., nitrogen-fixing symbionts of tropical forage legumes. *Int. J. Syst. Evol. Microbiol.* **2015**, *65*, 4424-4433.
64. De Meyer, S.E.; Cnockaert, M.; Ardley, J.K.; Trengove, R.D.; Garau, G.; Howieson, J.G.; Vandamme, P. *Burkholderia rhynchosiae* sp. nov., isolated from *Rhynchosia ferulifolia* root nodules. *Int. J. Syst. Evol. Microbiol.* **2013**, *63*, 3944-3949.
65. De Meyer, S.E.; Tan, H.W.; Andrews, M.; Heenan, P.B.; Willems, A. *Mesorhizobium calcicola* sp. nov., *Msorhizobium waitakense* sp. nov., *Mesorhizobium sophorae* sp. nov., *Mesorhizobium newzealandense* sp. nov. and *Mesorhizobium kowhaii* sp. nov. isolated from *Sophora* root nodules in New Zealand. *Int. J. Syst. Evol. Microbiol.* **2016**, *66*, 786-795.
66. De Meyer, S.E.; Tan, H.W.; Heenan, P.B.; Andrews, M.; Willems, A. *Mesorhizobium waimense* sp. nov. isolated from *Sophora longicarinata* root nodules and *Mesorhizobium cantuariense* sp. nov. isolated from *Sophora microphylla* root nodules in New Zealand. *Int. J. Syst. Evol. Microbiol.* **2015**, *65*, 3419-3426.
67. Deng, Z.S.; Zhao, L.F.; Kong, Z.Y.; Yang, W.Q.; Lindström, K.; Wang, E.T.; Wei, G.H. Diversity of endophytic bacteria within nodules of the *Sphaerophysa salsula* in different regions of Loess Plateau in China. *FEMS Microbiol. Ecol.* **2011**, *76*, 463-475.
68. Diabate, M.; Munive, A.; de Faria, S.M.; Ba, A.; Dreyfus, B.; Galiana, A. Occurrence of nodulation in unexplored leguminous trees native to the West African tropical rainforest and inoculation response of native species useful in reforestation. *New Phytol*. **2005**, *166*, 231-239.
69. Diaz, L.C.; González, P.; Rubio, E.; Melchiorre, M. Diversity and stress tolerance in rhizobia from Parque Chaqueño region of Argentina nodulating *Prosopis alba*. *Biol. Fertil. Soils* **2013**, *49*, 1153-1165.
70. Djedidi, S.; Yokoyama, T.; Tomooka, N.; Ohkama-Ohtsu, N.; Risal, C.P.; Abdelly, C.; Sekimoto, H. Phenotypic and genetic characterization of rhizobia associated with alfalfa in the Hokkaido and Ishigaki regions of Japan. *Syst. Appl. Microbiol*. **2011**, *34*, 453-461.
71. Dobritsa, A.P.; Samadpour, M. Transfer of eleven *Burkholderia* species to the genus *Paraburkholderia* and proposal of *Caballeronia* gen. nov., a new genus to accommodate twelve species of *Burkholderia* and *Paraburkholderia*. *Int. J. Syst. Evol. Microbiol.* **2016**, http://dx.doi.org/10.1099/ijsem.0.001065
72. Doignon-Bourcier, F.; Sy, A.; Willems, A.; Torck, U.; Dreyfus, B.; Gillis, M.; de Lajudie, P. Diversity of bradyrhizobia from 27 tropical *Leguminosae* species native of Senegal. *System. Appl. Microbiol*. **1999**, *22*, 647-661.
73. Donate-Correa, J.; Léon-Barrios, M.; Hernández, M.; Pérez-Galdona, R.; del Arco-Aguilar, M. Different *Mesorhizobium* species sharing the same symbiotic genes nodulate the shrub legume *Anagyris latifolia*. *Syst. Appl. Microbiol.* **2007**, *30*, 615-623.
74. Dos Reis Jr.F.B.; Simon, M.F.; Gross, E.; Boddey, R.M.; Elliott, G.N.; Nero, N.E.; Loureiro, M.deF.; de Queiroz, L.P.; Scotti, M.R.; Chen, W-M.; Norén, A.; Rubio, M.C.; de Faria, S.M.; Bontemps, C.; Goi, S.R.;

Young, J.P.W.; Sprent, J.I.; James, E.K. Nodulation and nitrogen fixation by *Mimosa* spp. in the Cerrado and Caatinga biomes of Brazil. *New Phytol.* **2010**, *186*, 934-946.
75. Dreyfus, B.; Garcia, J.L.; Gillis, M. Characterisation of *Azorhizobium caulinodans* gen. nov., sp. nov., a stem nodulating nitrogen-fixing bacterium isolated from *Sesbania rostrata*. *Int. J. Syst. Bacteriol.* **1988**, *38*, 89-98.
76. Durán, D.; Rey, L.; Mayo, J.; Zúñiga-Dávila, D.; Imperial, J.; Ruiz-Argüeso, T.; Martínez-Romero, E.; Ormeño-Orrillo, E. *Bradyrhizobium paxllaeri* sp. nov. and *Bradyrhizobium icense* sp. nov., nitrogen-fixing rhizobial symbionts of Lima bean (*Phaseolus lunatus* L.) in Peru. *Int. J. Syst. Evol. Microbiol.* **2014**, *64*, 2072-2078.
77. Durán, D.; Rey, L.; Sánchez-Cañizares, C.; Navarro, A.; Imperial, J.; Ruiz-Argueso, T. Genetic diversity of indigenous rhizobial symbionts of the *Lupinus mariae-josephae* endemism form alkaline-limed soils within its area of distribution in Eastern Spain. *Syst. Appl. Microbiol*. **2013**, *36*, 128-136.
78. Ehinger, M.; Mohr, T.J.; Starcevich, J.B.; Sachs, J.L.; Porter, S.S.; Simms, E.L. Specialisation-generalisation trade off in a *Bradyrhizobium* symbiosis with wild legume hosts. *BMC Ecol.* **2014,** *14*, 8.
79. El-Akhal, M.R.; Rincón, A.; Arenal, F.; Lucas, M.M.; El Mourabit, N.; Barrijal, S.; Pueyo, J.J. Genetic diversity and symbiotic efficiency of rhizobial isolates obtained from nodules of *Arachis hypogaea* in northwestern Morocco. *Soil Biol. Biochem.* **2008**, *40*, 2911-2914.
80. El Batanony, N.H.; Castellano-Hinojosa, A.; Correa-Galeote, D.; Bedmar, E.J. The diversity of rhizobia nodulating the *Medicago*, *Melilotus* and *Trigonella* inoculation group in Egypt is marked by the dominance of two genetic types. *Symbiosis* **2015**, *67*, 3-10.
81. Elliott, G.N.; Chou, J-H.; Chen, W-M.; Bloemberg, G.V.; Bontemps, C.; Martínez-Romero, E.; Velázquez, E.; Young, J.P.W.; Sprent, J.I.; James, E.K. *Burkholderia* spp. are the most competitive symbionts of *Mimosa*, particularly under N-limited conditions. *Environ. Microbiol.* **2009**, *11*, 762-778.
82. Estrella, M.J.; Muñoz, S.; Soto, M.J.; Ruiz, O.; Sanjuán, J. Genetic diversity and host range of rhizobia nodulating *Lotus tenuis* in typical soils of the Salado River basin (Argentina). *Appl. Environ. Microbiol.* **2009**, *75*, 1088-1098.
83. Fall, D.; Diouf, D.; Ourarhi, M.; Faye, A.; Abdelmounen, H.; Neyra, M.; Sylla, S.N.; Missbah el Idrissi, M. Phenotypic and genotypic characteristics of *Acacia Senegal* (L.) Willd. root-nodulating bacteria isolated from soils in the dryland part of Senegal. *Lett. Appl. Microbiol.* **2008**, *47*, 85-97.
84. Farida, B.; Géraldine, D.; Abdelghani, B.; Djellali, B.; Said, B.; Gisèle, L. *Retama* species growing in different ecological-climatic areas of northeastern Algeria have a narrow range of rhizobia that form a novel phylogenetic clade within the *Bradyrhizobium* genus. *Syst. Appl. Microbiol.* **2009**, *32*, 245-255.
85. Fernández-López, M.; Goormachtig, S.; Gao, M.; D'Haeze, W., van Montagu, M.; Holsters, M. Ethylene-mediated phenotypic plasticity in root nodule development on *Sesbania rostrata*. *Proc. Natl. Acad. Sci. USA.* **1998**, *95*, 12724-12728.
86. Fonseca, M.B.; Peix, A.; de Faria, S.M.; Mateos, P.F.; Rivera, L.P.; Simões-Araujo, J.L.; França, M.G.C.; Isaias, R.M.dosS.; Cruz, C.; Velázquez, E.; Scotti, M.R.; Sprent, J.I.; James, E.K. Nodulation in *Dimorphandra wilsonii* Rizz. (Caesalpinioideae), a threatened species native to the Brazilian Cerrado. *PLoS ONE* **2012**, *7* (11), e49520
87. Fornasero, L.V.; del Papa, M.F.; López, J.L.; Albicoro, F.J.; Zabala, J.M.; Toniutti, M.A.; Pensiero, J.F.; Lagares, A. Phenotypic, molecular and symbiotic characterization of the rhizobial symbionts of *Desmanthus paspalaceus* (Lindm.) Burkart that grow in the province of Santa Fe, Argentina. *PLoS ONE* **2014**, *9* (8), e104636
88. Franche, C.; Lindström, K.; Elmerich, C. Nitrogen-fixing bacteria associated with leguminous and non-leguminous plants. *Plant Soil.* **2009**, *321*, 35-59.
89. Fterich, A.; Mahdhi, M.; Caviedes, M.A.; Pajuelo, E.; Rivas, R.; Rodriguez-Llorente, I.D.; Mars, M. Characterization of root-nodulating bacteria associated to *Prosopis farcta* growing in the arid regions of Tunisia. *Arch. Microbiol*. **2011**, *193*, 385-397.
90. Fuentes, J.B.; Abe, M.; Uchiumi, T.; Suzuki, A.; Higashi, S. Symbiotic root nodule bacteria isolated from yam bean (*Pachyrhizus erosus*). *J. Gen. Appl. Microbiol.* **2002**, *48*, 181-191.
91. Garau, G.; Yates, R.J.; Deiana, P.; Howieson, J.G. Novel strains of nodulating *Burkholderia* have a role in nitrogen fixation with papilionoid herbaceous legumes adapted to acid, infertile soils. *Soil Biol. Biochem.* **2009**, *41*, 125-134.

92. Gehlot, H.S.; Panwar, D.; Tak, N.; Tak, A.; Sankhla, I.S.; Poonar, N.; Parihar, R.; Shekhawat, N.S.; Kumar, M.; Tiwari, R.; Ardley, J.; James, E.K.; Sprent, J.I. Nodulation of legumes from the Thar desert of India and molecular characterization of their rhizobia. *Plant Soil* **2012**, *357*, 227-243.
93. Gehlot, H.S.; Tak, N.; Kaushik, M.; Mitra, S.; Chen, W-M.; Poweleit, N.; Panwar, D.; Poonar, N.; Parihar, R.; Tak, A.; Sankhla, I.S.; Ojha, A.; Rao, S.R.; Simon, M.F.; dos Reis Junior, F.B.; Perigolo, N.; Tripathi, A.K.; Sprent, J.I.; Young, J.P.W.; James, E.K.; Gyaneshwar, P. An invasive *Mimosa* in India does not adopt the symbionts of its native relatives. *Ann. Bot.* **2013**, *112*, 179-196.
94. Gerding, M.; O'Hara, G.W.; Bräu, L.; Nandasena, K.; Howieson, J.G. Diverse *Mesorhizobium* spp. with unique *nodA* nodulating the South African legume species of the genus *Lessertia*. *Plant Soil* **2012**, *358*, 385-401.
95. Gharzouli, R.; Carpéne, M-A.; Couderc, F.; Benguedouar, A.; Poinsot, V. Relevance of fucose-rich extracellular polysaccharides produced by *Rhizobium sullae* strains nodulating *Hedysarum coronarium* L. legumes. *Appl. Environ. Microbiol*. **2013**, *79*, 1764-1776.
96. Granada, C.E.; Beneduzi, A.; Lisboa, B.B.; Turchetto-Zolet, A.C.; Vargas, L.K.; Passaglia, L.M.P. Multilocus sequence analysis reveals taxonomic differences among *Bradyrhizobium* sp. symbionts of *Lupinus albescens* plants growing in arenized and non-arenized areas. *Syst. Appl. Microbiol.* **2015**, *38*, 323-329.
97. Grönemeyer, J.L.; Kulkarni, A.; berkelmann, D.; Hurek, T.; Reinhold-Hurek, B. *Rhizobia* indigenous to the Okavango region in Sub-Saharan Africa: diversity, adaptations, and host specificity. *Appl. Environ. Microbiol.* **2014**, *80*, 7244-7257.
98. Gu, J.; Wang, E.T.; Chen, W.X. Genetic diversity of rhizobia associated with *Desmodium* species grown in China. *Lett. Appl. Microbiol*. **2007**, *44*, 286-292.
99. Guan, S.H.; Chen, W.F.; Wang, E.T.; Lu, Y.L.; Yan, X.R.; Zhang, X.X.; Chen, W.X. *Mesorhizobium caraganae* sp. nov., a novel rhizobial species nodulated with *Caragana* spp. in China. *Int. J. Syst. Evol. Microbiol.* **2008**, *58*, 2646-2653.
100. Gubry-Rangin, C.; Béna, G.; Cleyet-Merel, J-C.; Brunel, B. Definition and evolution of a new symbiovar, sv. rigiduloides, among *Ensifer meliloti* efficiently nodulating *Medicago* species. *Syst. Appl. Microbiol*. **2013**, *36*, 490-496.
101. Guerrouj, K.; Ruíz-Díez, B.; Chahboune, R.; Ramírez-Bahena, M-H.; Abdelmoumen, H.; Quiñones, M.A.; El Idrissi, M.M.; Velázquez, E.; Fernández-Pascual, M.; Bedmar, E.J.; Peix, A. Definition of a novel symbiovar (sv. retamae) within *Bradyrhizobium retamae* sp. nov., nodulating *Retama sphaerocarpa* and *Retama monosperma*. *Syst. Appl. Microbiol.* **2013**, *36*, 218-223.
102. Gueye, F.; Moulin, L.; Sylla, S.; Ndoye, I.; Béna, G. Genetic diversity and distribution of *Bradyrhizobium* and *Azorhizobium* strains associated with the herb legume *Zornia glochidiata* sampled from across Senegal. *Syst. Appl. Microbiol*. **2009**, *32*, 387-399.
103. Guimarães, A.A.; Jaramillo, P.M.D.; Nóbrega, R.S.A.; Florentino, L.A.; Silva, K.B.; Moreira, F.M.deS. Genetic and symbiotic diversity of nitrogen-fixing bacteria isolated from agricultural soils in the Western Amazon by using cowpea as the trap plant. *Appl. Environ. Microbiol*. **2012**, *78*, 6726-6733.
104. Han, L.L.; Wang, E.T.; Lu, Y.L.; Zhang, Y.F.; Sui, X.H.; Chen, W.F.; Chen, W.X. *Bradyrhizobium* spp. and *Sinorhizobium fredii* are predominant in root nodules of *Vigna angularis*, a native legume crop in the subtropical region of China. *J. Microbiol*. **2009**, *47*, 287-296.
105. Han, T.X.; Han, L.L.; Wu, L.J.; Chen, W.F.; Sui, X.H.; Gu, J.G.; Wang, E.T.; Chen, W.X. *Mesorhizobium gobiense* sp. nov. and *Mesorhizobium tarimense* sp. nov., isolated from wild legumes growing in desert soils of Xinjiang, China. *Int. J. Syst. Evol. Microbiol*. **2008a**, *58*, 2610-2618.
106. Han, T.X.; Wang, E.T.; Wu, L.J.; Chen, W.F.; Gu, J.G.; Gu, C.T.; Tian, C.F.; Chen, W.X. *Rhizobium multihospitium* sp. nov., isolated from multiple legume species native of Xinjiang, China. *Int. J. Syst. Evol. Microbiol*. **2008b**, *58*, 1693-1699.
107. Hassen, A.I.; Bopape, F.L.; Habig, J.; Lamprecht, S.C. Nodulation of rooibos (*Aspalathus linearis* Burm. f.), an indigenous South African legume, by members of both the α-Proteobacteria and β-Proteobacteria. *Biol. Fertil. Soils* **2012**, *48*, 295-303.
108. Helene, L.C.F.; Delamuta, J.R.M.; Ribeiro, R.A.; Ormeño-Orrillo, E.; Rogel, M.A.; Martínez-Romero, E.; Hungria, M. *Bradyrhizobium viridifuturi* sp. nov., encompassing nitrogen-fixing symbionts of legumes used for green manure and environmental services. *Int. J. Syst. Evol. Microbiol.* **2015**, *65*, 4441-4448.

109. Horn, K.; Parker, I.M.; Malek, W.; Rodríguez-Echeverria, S.; Matthew, A.P. Disparate origins of *Bradyrhizobium* symbionts for invasive populations of *Cytisus scoparius* (Leguminosae) in North America. *FEMS Microbiol. Ecol.* **2014**, *89*, 89-98.
110. Howieson, J.G.; De Meyer, S.E.; Vivas-Marfisi, A.; Ratnayake, S.; Ardley, J.K.; Yates, R.J. Novel *Burkholderia* bacteria isolated from *Lebeckia ambigua* – A perennial suffrutescent legume of the fynbos. *Soil Biol. Biochem.* **2013**, *60*, 55-64.
111. Huang, B.; Lv, C.; Zhao, Y.; Huang, R. A novel strain D5 isolated from *Acacia confusa*. *PLoS ONE* **2012**, *7* (11), e49236.
112. Iglesias, O.; Rivas, R.; García-Fraile, P.; Abril, A.; Mateos, P.F.; Martinez-Molina, E.; Velázquez, E. Genetic characterization of fast-growing rhizobia able to nodulate *Prosopis alba* in North Spain. *FEMS Microbiol. Lett.* **2007**, *277*, 210-216.
113. Jackson, L.E.; Burger, M.; Cavagnaro, T.R. Roots, nitrogen transformations, and ecosystem services. *Ann. Rev. Plant Biol.* **2008**, *59*, 341-363.
114. Jaiswal, S.K.; Anand, A.; Dhar, B.; Vaishampayan, A. Genotypic characterization of phage-typed indigenous soybean Bradyrhizobia and their host range symbiotic effectiveness. *Microb. Ecol.* **2012**, *63*, 116-126.
115. Jarabo-Lorenzo, A.; Pérez-Galdona, R.; Donate-Correa, J.; Rivas, R.; Velázquez, E.; Hernández, M.; Temprano, F.; Martínez-Molina, E.; Ruiz-Argüeso, T.; Léon-Barrios, M. Genetic diversity of Bradyrhizobial populations from diverse geographic origins that nodulate *Lupinus* spp. and *Ornithopus* spp. *System. Appl. Microbiol.* **2003**, *26*, 611-623.
116. Jarabo-Lorenzo, A.; Velázquez, E.; Pérez-Galdona, R.; Vega-Hernández, M.C.; Martínez-Molina, E.; Mateos, P.F.; Vinuesa, P.; Martínez-Romero, E.; Léon-Barrios, M. Restriction fragment length polymorphism analysis of 16S rDNA and low molecular weight RNA profiling of rhizobial isolates from shrubby legumes endemic to the Canary Islands. *System. Appl*. Microbiol. **2000**, *23*, 418-425.
117. Jarvis, B.D.W.; van Berkum, P.; Chen, W.X.; Nour, S.M.; Fernandez, M.P.; Cleyet-Marel, J.C.; Gillis, M. Transfer of *Rhizobium loti, Rhizobium huakuii, Rhizobium ciceri, Rhizobium mediterraneum*, and *Rhizobium tianshanense* to *Mesorhizobium* gen. nov. *Int. J. Syst. Bacteriol.* **1997**, *47*, 895-898.
118. Jiao, Y.S.; Liu, Y.H.; Yan, H.; Wang, E.T.; Tian, C.F.; Chen, W.X.; Guo, B.L.; Chen, W.F. Rhizobial diversity and nodulation characteristics of the extremely promiscuous legume *Sophora flavescens*. *Mol. Plant Microbe Interact.* **2015a**, *28*, 1338-1352.
119. Jiao, Y.S.; Yan, H.; Ji, Z.J.; Liu, Y.H.; Sui, X.H.; Zhang, X.X.; Wang, E.T.; Chen, W.X.; Chen, W.F. *Phyllobacterium sophorae* sp. nov., a symbiotic bacterium isolated from root nodules of *Sophora flavescens. Int. J. Syst. Evol. Microbiol*. **2015b**, *65*, 399-406.
120. Kalita, M.; Malek, W.; Kaznowski, A. Analysis of genetic relationship of *Sarothamnus scoparius* microsymbionts and *Bradyrhizobium* sp. by hybridization in microdilution wells. *J. Biosci. Bioeng*. **2004**, *97*, 158-161.
121. Kan, F.L.; Chen, Z.Y.; Wang, E.T.; Tian, C.F.; Sui, X.H.; Chen, W.X. Characterization of symbiotic and endophytic bacteria isolated from root nodules of herbaceous legumes grown in Qinghai-Tibet plateau and in other zones of China. *Arch. Microbiol*. **2007**, *188*, 103-115.
122. Kanu, S.A.; Dakora, F.D. Symbiotic nitrogen contribution and biodiversity of root-nodule bacteria nodulating *Psoralea* species in the Cape Fynbos, South Africa. *Soil Biol. Biochem.* **2012**, *54*, 68-76.
123. Keller, K.R. Mutualistic rhizobia reduce plant diversity and alter community composition. *Oecologia*, **2014**, *176*, 1101-1109.
124. Kesari, V.; Ramesh, A.M.; Rangan, L. *Rhizobium pongamiae* sp. nov. from root nodules of *Pongamia pinnata*. *Biomed Res. Int.* **2013**, *2013*, 165198.
125. Khbaya, B.; Neyra, M.; Normand, P.; Zerhari, K.; Filali-Maltouf, A. Genetic diversity and phylogeny of rhizobia that nodulate *Acacia* spp. in Morocco assessed by analysis of rRNA genes. *Appl. Environ. Microbiol.* **1998**, *64*, 4912-4917.
126. Lafay, B.; Burdon, J.J. Molecular diversity of legume root-nodule bacteria in Kakadu National Park, Northern Territory, Australia. *PLoS ONE* **2007**, *3*, e277.
127. Leblanc, H.A.; McGraw, R.L.; Nygren, P.; Le Roux, C. Neotropical legume tree *Inga edulis* forms N_2-fixing symbiosis with fast-growing *Bradyrhizobium* strains. *Plant Soil* **2005**, *275*, 123-133.
128. Lei, X.; Wang, E.T.; Chen, W.F.; Sui, X.H.; Chen, W.X. Diverse bacteria isolated from root nodules of wild *Vicia* species grown in temperate region of China. *Arch. Microbiol*. **2008**, *190*, 657-671.

129. Lemaire, B.; Dlodlo, O.; Chimphango, S.; Stirton, C.; Schrire, B.; Boatwright, J.S.; Honnay, O.; Smets, E.; Sprent, J.; James, E.K.; Muasya, A.M. Symbiotic diversity, specificity and distribution of rhizobia in native legumes of the Core Cape Subregion (South Africa). *FEMS Microbiol. Ecol.* **2015**, *91*, 1-17.
130. Lemaire, B.; Van Cauwenberghe J.; Verstraete, B.; Chimphango, S.; Stirton, C.; Honnay, O.; Smets, E.; Sprent, J.; James, E.K.; Muasya, A.M. Characterization of the papilionoid-*Burkholderia* interaction in the Fynbos biome: The diversity and distribution of beta-rhizobia nodulating *Podalyria calyptrata* (Fabaceae, Podalyrieae). *Syst. Appl. Microbiol.* **2016**, *39*, 41-48.
131. Léon-Barrios, M.; Lorite, M.J.; Donate-Correa, J.; Sanjuán, J. *Ensifer meliloti* bv. lancerottense establishes nitrogen-fixing symbiosis with *Lotus* endemic to the Canary Islands and shows distinctive symbiotic genotypes and host range. *Syst. Appl. Microbiol*. **2009**, *32*, 413-420.
132. Le Roux, C.; Muller, F.; Bouvet, J-M.; Dreyfus, B.; Béna, G.; Galiana, A.; Bâ, A.M. Genetic diversity patterns and functional traits of *Bradyrhizobium* strains associated with *Pterocarpus officinalis* Jacq. in Caribbean islands and Amazonian forest (French Guiana). *Microb. Ecol*. **2014**, *68*, 329-338.
133. Le Roux, C.; Tentchev, D.; Prin, Y.; Goh, D.; Japarudin, Y.; Perrineau, M-M.; Duponnois, R.; Domergue, O.; de Lajudie, P.; Galiana, A. Bradyrhizobia nodulating the *Acacia mangium* × *A. auriculiformis* interspecific hybrid are specific and differ from those associated with both parental species. *Appl. Environ. Microbiol.* **2009**, *75*, 7752-7759.
134. Lewis, G., A.; Schrire, B.B.; Mackinder, B., C.; Lock, M., D. Legumes of the World.; Kew: Royal Botanic Gardens. 2005.
135. Li, Y.; Li, X.; Liu, Y.; Wang, E.T.; Ren, C.; Liu, W.; Xu, H.; Wu, H.; Jiang, N.; Li, Y.; Zhang, X.; Xie, Z. Genetic diversity and community structure of rhizobia nodulating *Sesbania cannabina* in saline-alkaline soils. *Syst. Appl. Microbiol.* **2016**, *39*, 195-202.
136. Li, L.; Sinkko, H.; Montonen, L.; Wei, G.; Lindström, K.; Räsänen, L.A. Biogeography of symbiotic and other endophytic bacteria isolated from medicinal *Glycyrrhiza* species in China. *FEMS Microbiol. Ecol.* **2012**, *79*, 46-68.
137. Li, Q.Q.; Wang, E.T.; Chang, Y.L.; Zhang, Y.Z.; Zhang, Y.M.; Sui, X.H.; Chen, W.F.; Chen, W.X. *Ensifer sojae* sp. nov., isolated from root nodules of *Glycine max* grown in saline-alkaline soils. *Int. J. Syst. Evol. Microbiol.* **2011**, *61*, 1981-1988.
138. Li, Y.H.; Wang, R.; Zhang, X.X.; Young, J.P.W.; Wang, E.T.; Sui, X.H.; Chen, W.X. *Bradyrhizobium guangdongense* sp. nov. and *Bradyrhizobium guangxiense* sp. nov., isolated from effective nodules of peanut. *Int. J. Syst. Evol. Microbiol.* **2015**, *65*, 4655-4661.
139. Lin, D.X.; Man, C.X.; Wang, E.T.; Chen, W.X. Diverse rhizobia that nodulate two species of *Kummerowia* in China. *Arch. Microbiol*. **2007**, *188*, 495-507.
140. Lindström, K. *Rhizobium galegae*, a new species of legume root nodule bacteria. *Int. J. Syst. Bacteriol.* **1989**, *39*, 365-367.
141. Lindström, K.; Aserse, A.A.; Mousavi, S.A. Evolution and taxonomy of nitrogen-fixing organisms with emphasis on rhizobia. In *Biological Nitrogen Fixation*, 1st ed., de Bruijn, F.J., Ed.; Wiley & Sons, Inc.: Hoboken, New Jersey, 2015; pp. 21-37.
142. Liu, X.Y.; Wang, E.T.; Li, Y.; Chen, W.X. Diverse bacteria isolated from root nodules of *Trifolium*, *Crotalaria* and *Mimosa* grown in the subtropical regions of China. *Arch. Microbiol*. **2007**, *188*, 1-14.
143. Liu, X.Y.; Wei, S.; Wang, F.; James, E.K.; Guo, X.Y.; Zagar, C.; Xia, L.G.; Dong, X.; Wang, Y.P. *Burkholderia* and *Cupriavidus* spp. are the preferred symbionts of *Mimosa* spp. in Southern China. *FEMS Microbiol. Ecol.* **2012**, *80*, 417-426.
144. Liu, X.Y.; Wu, W.; Wang, E.T.; Zhang, B.; Macdermott, J.; Chen, W.X. Phylogenetic relationships and diversity of β-rhizobia associated with *Mimosa* species grown in Sishuangbanna, China. *Int. J. Syst. Evol. Microbiol.* **2011**, *61*, 334-342.
145. Liu, W.Y.Y. Characterisation of rhizobia and studies on N_2 fixation of common weed legumes in New Zealand. PhD thesis, Lincoln University, New Zealand, 2014.
146. Liu, W.Y.Y.; Ridgway, H.J.; James, T.K.; James, E.K.; Chen, W-M.; Sprent, J.I.; Young, J.P.W.; Andrews, M. *Burkholderia* sp. induces functional nodules on the South African invasive legume *Dipogon lignosus* (Phaseoleae) in New Zealand soils. *Microb. Ecol.* **2014**, *68*, 542-555.
147. Liu, W.Y.Y.; Ridgway, H.J.; James, T.K.; Premaratne, M.; Andrews, M. Characterisation of rhizobia nodulating *Galega officinalis* (goat's rue) and *Hedysarum coronarium* (sulla). *NZ Plant Protection* **2012**, *65*, 192-196.

148. Lloret, L.; Ormeño-Orillo, E.; Rincón, R.; Martinez-Romero, J.; Rogel-Hernández, M.A.; Martinez-Romero, E. *Ensifer mexicanus* sp. nov. a new species nodulating *Acacia angustissima* (Mill.) Kuntze in Mexico. *Syst. Appl. Microbiol*. **2007**, *30*, 280-290.
149. López-López, A.; Negrete-Yankelevich, S.; Rogel, M.A.; Ormeño-Orrillo, E.; Martínez, J.; Martínez-Romero, E. Native bradyrhizobia from Los Tuxtlas in Mexico are symbionts of *Phaseolus lunatus* (Lima bean). *Syst. Appl. Microbiol*. **2013**, *36*, 33-38.
150. López-López, A.; Rogel-Hernández, M.A.; Barois, I.; Ortis Ceballos, A.I.; Martínez, J.; Ormeño-Orrillo, E.; Martínez-Romero, E. *Rhizobium grahamii* sp. nov., from nodules of *Dalea leporina, Leucaena leucocephala* and *Clitoria ternatea*, and *Rhizobium mesoamericanum* sp. nov., from nodules of *Phaseolus vulgaris*, siratro, cowpea and *Mimosa pudica*. *Int. J. Syst. Evol. Microbiol*. **2012**, *62*, 2264-2271.
151. Lorite, M.J.; Donate-Correa, J.; del Arco-Aguilar, M.; Galdona, R.P.; Sanjuán, J.; Léon-Barrios, M. *Lotus* endemic to the Canary Islands are nodulated by diverse and novel rhizobial species and symbiotypes. *Syst. Appl. Microbiol.* **2010a**, *33*, 282-290.
152. Lorite, M.J.; Muñoz, S.; Olivares, J.; Soto, M.J.; Sanjuán, J. Characterization of strains unlike *Mesorhizobium loti* that nodulate *Lotus* spp. in saline soils of Granada, Spain. *Appl. Environ. Microbiol*. **2010b**, *76*, 4019-4026.
153. Lorite, M.J.; Videira e Castro, I.; Muñoz, S.; Sanjuán, J. Phylogenetic relationship of *Lotus uliginosus* symbionts with bradyrhizobia nodulating genistoid legumes. *FEMS Microbiol. Ecol*. **2012**, *79*, 454-464.
154. Lortet, G.; Méar, N.; Lorquin, J.; Dreyfus, B.; de Lajudie, P.; Rosenberg, C.; Boivin, C. Nod factor thin-layer chromatography profiling as a tool to characterize symbiotic specificity of rhizobial strains: application to *Sinorhizobium saheli, S. teranga,* and *Rhizobium* sp. strains isolated from *Acacia* and *Sesbania. Mol. Plant-Microbe Interact.* **1996**, *9*, 736-747.
155. LPWG. Legume phylogeny and classification in the 21st century: Progress, prospects and lessons for other species-rich clades. *TAXON* **2013**, *62*, 217-248.
156. Lu, Y.L.; Chen, W.F.; Wang, E.T.; Guan, S.H.; Yan, X.R.; Chen, W.X. Genetic diversity and biogeography of rhizobia associated with *Caragana* species in three ecological regions of China. *Syst. Appl. Microbiol.* **2009**, *32*, 351-361.
157. Lu, J.K.; Dou, Y.J.; Zhu, Y.J.; Wang, S.K.; Sui, X.H.; Kang, L.H. *Bradyrhizobium ganzhouense* sp. nov., an effective symbiotic bacterium isolated from *Acacia melanoxylon* R. Br. nodules. *Int. J. Syst. Evol. Microbiol.* **2014**, *64*, 1900-1905.
158. Lu, J.K.; He, X.H.; Huang, L.B.; Kang, L.H.; Xu, D.P. Two *Burkholderia* strains from nodules of *Dalbergia odorifera* T. Chen in Hainan Island, southern China. *New Forests* **2012**, *43*, 397-409.
159. Maâtallah, J.; Berraho, E.B.; Muñoz, S.; Sanjuan, J.; Lluch, C. Phenotypic and molecular characterization of chickpea rhizobia isolated from different areas of Morocco. *J. Appl. Microbiol*. **2002**, *93*, 531-540.
160. Manassila, M.; Nuntagij, A.; Kotepong, S.; Boonkerd, N.; Teaumroong, N. Characterization and monitoring of selected rhizobial strains isolated from tree legumes in Thailand. *Afr. J. Biotechnol*. **2007**, *6*, 1393-1402.
161. Marcos-García, M.; Menéndez, E.; Cruz-González, X.; Velázquez, E.; Mateos, P.F.; Rivas, R. The high diversity of *Lotus corniculatus* endosymbionts in soils of northwest Spain. *Symbiosis* **2015**, *67*, 11-20.
162. Marsudi, N.D.S.; Glenn, A.R.; Dilworth, M.J. Identification and characterization of fast- and slow-growing root nodule bacteria from South-Western Australian soils able to nodulate *Acacia saligna. Soil Biol. Biochem.* **1999**, *31*, 1229-1238.
163. Martens, M.; Delaere, M.; Coopman, R.; De Vos, P.; Gillis, M.; Willems, A. Multilocus sequence analysis of *Ensifer* and related taxa. *Int. J. Syst. Evol. Microbiol. **2007***, 57, *489-503.*
164. Martínez-Romero, E. Diversity of *Rhizobium-Phaseolus vulgaris* symbiosis: overview and perspectives. *Plant Soil* **2003**, *252*, 11-23.
165. Martínez-Romero, E.; Segovia, L.; Mercante, F.M.; Franco, A.A.; Graham, P.; Pardo, M.A. *Rhizobium tropici*, a novel species nodulating *Phaseolus vulgaris* L. beans and *Leucaena* sp. trees. *Int. J. System. Bacteriol*. **1991**, *41*, 417-426.
166. Masson-Boivin, C.; Giraud, E.; Perret, X.; Batut, J. Establishing nitrogen-fixing symbiosis with legumes: how many rhizobium recipes? *Trends Microbiol*. **2009**, *17*, 10.
167. Matsubara, M.; Zúñiga-Dávila, D. Phenotypic and molecular differences among rhizobia that nodulate *Phaseolus lunatus* in the Supe valley in Peru. *Ann. Microbiol*. **2015**, *65*, 1803-1808.

168. Merabet, C.; Martens, M.; Mahdi, M.; Zakhia, F.; Sy, A.; Le Roux, C.; Domergue, O.; Coopman, R.; Bekki, A.; Mars, M.; Willems, A.; de Lajudie, P. Multilocus sequence analysis of root nodule isolates from *Lotus arabicus* (Senegal), *Lotus creticus, Argyrolobium uniflorum* and *Medicago sativa* (Tunisia) and description of *Ensifer numidicus* sp. nov. and *Ensifer garamanticus* sp. nov. *Int. J. Syst. Evol. Microbiol.* **2010**, *60*, 664-674.
169. Mhamdi, R.; Laguerre, G.; Aouani, M.E.; Mars, M.; Amarger, N. Different species and symbiotic genotypes of field rhizobia can nodulate *Phaseolus vulgaris* in Tunisian soils. *FEMS Microbiol. Ecol.* **2002,** *41*, 77-84**.**
170. Michalk, D.L.; Zhi-Kai, H. Grassland improvement in subtropical Guangdong Province, China. 1. Evaluation of pasture legumes. *Tropical Grasslands*, **1994**, *28*, 129-138.
171. Miché, L.; Moulin, L.; Chaintreuil, C.; Contreras-Jimenez, J.L.; Munive-Hernández, J-A.; Villegas-Hernandez, M.delC.; Crozier, F.; Béna, G. Diversity analyses of *Aeschynomene* symbionts in Tropical Africa and Central America reveal that *nod*-independent stem nodulation is not restricted to photosynthetic bradyrhizobia. *Symbiosis* **2010**, *12*, 2152-2164.
172. Mierzwa, B.; Wdowiak-Wróbel, S.; Malek, W. Phenotypic, genomic and phylogenetic characteristics of rhizobia isolated from root nodules of *Robinia pseudoacacia* (black locust) growing in Poland and Japan. *Arch. Microbiol.* **2009**, *191*, 697-710.
173. Mnasri, B.; Saïdi, S.; Chihaoui, S-A.; Mhamdi, R. *Sinorhizobium americanum* symbiovar mediterranense is a predominant symbiont that nodulates and fixes nitrogen with common bean (*Phaseolus vulgaris* L.) in a Northern Tunisian field. *Syst. Appl. Microbiol.* **2012**, *35*, 263-269.
174. Mnasri, B.; Badri, Y.; Saïdi, S.; de Lajudie, P.; Mhamdi, R. Symbiotic diversity of *Ensifer meliloti* strains recovered from various legume species in Tunisia. *Syst. Appl. Microbiol.* **2009**, *32*, 583-592.
175. Mnasri, B.; Mrabet, M.; Laguerre, G.; Aouani, M.E.; Mhamdi, R. Salt-tolerant rhizobia isolated from a Tunisian oasis that are highly effective for symbiotic N_2-fixation with *Phaseolus vulgaris* constitute a novel biovar (bv. *mediterranense*) of *Sinorhizobium meliloti*. *Arch. Microbiol*. **2007**, *187*, 79-85.
176. Montecchia, M.S.; Kerber, N.L.; Pucheu, N.L.; Perticari, A.; García, A.F. Analysis of genomic diversity among photosynthetic stem-nodulating rhizobial strains from Northeast Argentina. **2002**, *25*, 423-433.
177. Moreira, F.M.deS.; Cruz, L.; de Faria, S.M.; Marsh, T.; Martínez-Romero, E.; Pedrosa, F.deO.; Pitard, R.M.; Young, J.P.W. *Azorhizobium doebereinerae* sp. nov. microsymbiont of *Sesbania virgata* (Caz.) Pers. *Syst. Appl. Microbiol.* **2006**, *29*, 197-206.
178. Mostasso, L.; Mostasso, F.L.; Dias, B.G.; Vargas, M.A.T.; Hungria, M. Selection of bean (*Phaseolus vulgaris* L.) rhizobial strains for the Brazilian Cerrados. *Field Crops Res.* **2002**, *73*, 121-132.
179. Muñoz, V.; Ibañez, F.; Tonelli, M.L.; Valetti, L.; Anzuay, M.S.; Fabra, A. Phenotypic and phylogenetic characterization of native peanut *Bradyrhizobium* isolates obtained from Córdoba, Argentina. *Syst. Appl. Microbiol.* **2011**, *34*, 446-452.
180. Mutch, L.A.; Young, J.P.W. Diversity and specificity of *Rhizobium leguminosarum* biovar *viciae* on wild and cultivated legumes. *Mol. Ecol.* **2004**, *13*, 2435-2444.
181. Nandasena, K.G.; O'Hara, G.W.; Tiwari, R.P.; Willems, A.; Howieson, J.G. *Mesorhizobium australicum* sp. nov. and *Mesorhizobium opportunistum* sp. nov., isolated from *Biserrula pelecinus* L. in Australia. *Int. J. Syst. Evol. Microbiol.* **2009**, *59*, 2140-2147.
182. Nandasena, K.G.; O'Hara, G.W.; Tiwari, R.P.; Yates, R.J.; Howieson, J.G. Phylogenetic relationships of three bacterial strains isolated from the pasture legume *Biserrula pelecinus* L. *Int. J. Syst. Evol. Microbiol.* **2001**, *51*, 1983-1986.
183. Ngom, A.; Nakagawa, Y.; Sawada, H.; Tsukahara, J.; Wakabayashi, S.; Uchiumi, T.; Nuntagij, A.; Kotepong, S.; Suzuki, A.; Higashi, S.; Abe, M. A novel symbiotic nitrogen-fixing member of the *Ochrobactrum* clade isolated from root nodules of *Acacia mangium. J. Gen. Appl. Microbiol.* **2004**, *50*, 17-27.
184. Nick, G.; de Lajudie, P.; Eardly, B.D.; Suomalainen, S.; Paulin, L.; Zhang, X.; Gillis, M.; Lindström, K. *Sinorhizobium arboris* sp. nov. and *Sinorhizobium kostiense* sp. nov., isolated from leguminous trees in Sudan and Kenya. *Int. J. Syst. Bacterial.* **1999**, 49, 1359-1368.
185. Noisangiam, R.; Teamtisong, K.; Tittabutr, P.; Boonkerd, N.; Toshiki, U.; Minamisawa, K.; Teaumroong, N. Genetic diversity, symbiotic evolution, and proposed infection process of *Bradyrhizobium* strains isolated from root nodules of *Aeschynomene americana* L. in Thailand. *Appl. Environ. Microbiol.* **2012**, *78*, 6236-6250.
186. Nour, S.M.; Fernandez, M.P.; Normand, P.; Cleyet-Marel, J-C. *Rhizobium ciceri* sp. nov., consisting of strains that nodulate chickpeas (*Cicer arietinum* L.). *Int. J. Syst. Bacteriol*. **1994**, *44*, 511-522.

187. Odee, D.W.; Haukka, K.; McInroy, S.G.; Sprent, J.I.; Sutherland, J.M.; Young, J.P.W. Genetic and symbiotic characterization of rhizobia isolated from tree and herbaceous legumes grown in soils from ecologically diverse sites in Kenya. *Soil Biol. Biochem*. **2002**, *34*, 801-811.
188. Ogasawara, M.; Suzuki, T.; Mutoh, I., Annapurna, K.; Arora, N.K.; Nishimura, Y.; Maheshwari, D.K. *Sinorhizobium indiaense* sp. nov. and *Sinorhizobium abri* sp. nov. isolated from tropical legumes, *Sesbania rostrata* and *Abrus precatorius*, respectively. *Symbiosis* **2003**, *34*, 53-68.
189. Onyango, B.; Anyango, B.; Nyunja, R.; Koech, P.K.; Skilton, R.A.; Stomeo, F. Morphological, genetic and symbiotic characterization of root nodule bacteria isolated from Bambara groundnuts (*Vigna subterranea* L. Verdc) from soils of Lake Victoria basin, western Kenya. *J. Appl. Biol. Biotechnol.* **2015**, *3*, 1-10.
190. Oren, A.; Garrity, G.M. List of new names and new combinations previously effectively, but not validly, published. *Int. J. Syst. Evol. Microbiol.* **2015**, *65*, 2017-2025.
191. Ourarhi, M.; Abdelmoumen, H.; Guerrouj, K.; Benata, H.; Muresu, R.; Squartini, A.; El Idrissi, M.M. *Colutea arborescens* is nodulated by diverse rhizobia in Eastern Morocco. *Arch. Microbiol.* **2011**, *193*, 115-124.
192. Parker, M.A. Divergent *Bradyrhizobium* symbionts on *Tachigali versicolor* from Barro Colorado Island, Panama. *System. Appl. Microbiol*. **2000**, *23*, 585-590.
193. Parker, M.A.; Doyle, J.L.; Doyle, J.J. Comparative phylogeography of *Amphicarpaea* legumes and their root-nodule symbionts in Japan and North America. *J. Biogeogr*. **2004**, *31*, 425-434.
194. Parker, M.A.; Wurtz, A.K.; Paynter, Q. Nodule symbiosis of invasive *Mimosa pigra* in Australia and in ancestral habitats: a comparative analysis. *Biol. Invasions* **2007**, *9*, 127-138.
195. Peng, G.X.; Tan, Z.Y.; Wang, E.T.; Reinhold-Hurek, B.; Chen, W.F.; Chen, W.X. Identification of isolates from soybean nodules in Xinjiang Region as *Sinorhizobium xinjiangense* and genetic differentiation of *S. xinjiangense* from *Sinorhizobium fredii*. *Int. J. Syst. Evol. Microbiol.* **2002**, *52*, 457-462.
196. Platero, R.; James, E.K.; Rios, C.; Iriarte, A.; Sandes, L.; Zabaleta, M.; Battistoni, F.; Fabiano, E. Novel *Cupriavidus* strains isolated from root nodules of native Uruguayan *Mimosa* species. *Appl. Environ. Microbiol.* **2016**, doi:10.1128/AEM.04142-15
197. Quatrini, P. Scaglione, G.; Cardinale, M.; Caradonna, F. Puglia, A.M. *Bradyrhizobium* sp. nodulating the Mediterranean shrub Spanish broom (*Spartium junceum* L.) *J. Appl. Microbiol*. **2002**, *92*, 13-21.
198. Radeva, G.; Jurgens, G.; Niemi, M.; Nick, G.; Suominen, L.; Lindström, K. Description of two biovars in the *Rhizobium galegae* species: biovar orientalis and biovar officinalis. *System. Appl. Microbiol.* **2001**, *24*, 192-205.
199. Ramírez-Bahena, M.H.; Peix, A.; Rivas, R.; Camacho, M.; Rodríguez-Navarro, D.N.; Mateos, P.F.; Martínez-Molina, E.; Willems, A.; Velázquez, E. *Bradyrhizobium pachyrhizi* sp. nov. and *Bradyrhizobium jicamae* sp. nov., isolated from effective nodules of *Pachyrhizus erosus*. *Int. J. Syst. Evol. Microbiol.* **2009**, *59*, 1929-1934.
200. Räsänen, L.A.; Sprent, J.I.; Lindström, K. Symbiotic properties of sinorhizobia isolated from *Acacia* and *Prosopis* nodules in Sudan and Senegal. *Plant Soil* **2001**, *235*, 193-210.
201. Rashid, M.H.; Schäfer, H.; Gonzalez, J.; Wink, M. Genetic diversity of rhizobia nodulating lentil (*Lens culinaris*) in Bangladesh. *Syst. Appl. Microbiol.* **2012**, *35*, 98-109.
202. Rasolomampianina, R.; Bailly, X.; Fetiarison, R.; Rabevohitra, R.; Béna, G.; Ramaroson, L.; Raherimandimby, M.; Moulin, L.; de Lajudie, P.; Dreyfus, B.; Avarre, J.-C. Nitrogen-fixing nodules from rose wood legume trees (*Dalbergia* spp.) endemic to Madagascar host seven different genera belonging to α- and β-Proteobacteria. *Mol. Ecol.* **2005**, *14*, 4135-4146.
203. Raven, J.A. Why are mycorrhizal fungi and symbiotic nitrogen-fixing bacteria not genetically integrated into plants? *Ann. Appl. Biol.* **2010**, *157*, 381-391.
204. Rejili, M.; Mahdhi, M.; Fterich, A.; Dhaoui, S.; Guefrachi, I.; Abdeddayem, R.; Mars, M. Symbiotic nitrogen fixation of wild legumes in Tunisia: Soil fertility dynamics, field nodulation and nodules effectiveness. *Agric. Ecosyst. Environ.* **2012**, *157*, 60-69.
205. Remigi, P.; Zhu, J.; Young, J.P.W.; Masson-Boivin, C. Symbiosis within symbiosis: evolving nitrogen-fixing legume symbionts. *Trends Microbiol.* **2016**, *24*, 63-75.
206. Riah, N.; Béna, G.; Djekoun, A.; Heulin, K.; de Lajudie, P.; Laguerre, G. Genotypic and symbiotic diversity of *Rhizobium* populations associated with cultivated lentil and pea in sub-humid and semi-arid regions of Eastern Algeria. *Syst. Appl. Microbiol.* **2014**, *37*, 368-375.

 doi:10.20944/preprints201608.0005.v1

207. Ribeiro, P.R.deA.; dos Santos, J.V.; da Costa, E.M.; Lebbe, L.; Assis, E.S.; Louzada, M.O.; Guimarães, A.A.; Willems, A.; Moreira, F.M.deS. Symbiotic efficiency and genetic diversity of soybean bradyrhizobia in Brazilian soils. *Agric. Ecosyst. Environ.* **2015**, *212*, 85-93.
208. Ribeiro, R.A.; Ormeño-Orrillo, E.; Dall'Agnol, R.F.; Graham, P.H.; Martinez-Romero, E.; Hungria, M. Novel *Rhizobium* lineages isolated from root nodules of the common bean (*Phaseolus vulgaris* L.) in Andean and Mesoamerican areas. *Res. Microbiol.* **2013**, *164*, 740-748.
209. Rincón-Rosales, R.; Lloret, L.; Ponce, E.; Martínez-Romero, E. Rhizobia with different symbiotic efficiencies nodulate *Acaciella angustissima* in Mexico, including *Sinorhizobium chiapanecum* sp. nov. which has common symbiotic genes with *Sinorhizobium mexicanum*. *FEMS Microbiol. Ecol.* **2009**, *67*, 103-117.
210. Rincón-Rosales, R.; Villalobos-Escobedo, J.M.; Rogel, M.A.; Martinez, J.; Ormeño-Orrillo, E.; Martínez-Romero, E. *Rhizobium calliandrae* sp. nov., *Rhizobium mayense* sp. nov. and *Rhizobium jaguaris* sp. nov., rhizobial species nodulating the medicinal legume *Calliandra grandiflora*. *Int. J. Syst. Evol. Microbiol.* **2013**, *63*, 3423-3429.
211. Risal, C.P.; Djedidi, S.; Dhakal, D.; Ohkama-Ohtsu, N.; Sekimoto, H.; Yokoyama, T. Phylogenetic diversity and symbiotic functioning in mungbean (*Vigna radiata* L. Wilczek) bradyrhizobia from contrast agro-ecological regions of Nepal. *Syst. Appl. Microbiol.* **2012**, *35*, 45-53.
212. Rivas, R.; Laranjo, M.; Mateos, P.F.; Oliveira, S.; Martinez-Molina, E.; Velázquez, E. Strains of *Mesorhizobium amorphae* and *Mesorhizobium tianshanense*, carrying symbiotic genes of common chickpea endosymbiotic species, constitute a novel biovar (ciceri) capable of nodulating *Cicer arietinum*. *Lett. Appl. Microbiol.* **2007**, *44*, 412-418.
213. Rivas, R.; Velázquez, E.; Willems, A.; Vizcaíno, N.; Subba-Rao, N.S.; Mateos, P.F.; Gillis, M.; Dazzo, F.B.; Martínez-Molina, E. A new species of *Devosia* that forms a unique nitrogen-fixing root-nodule symbiosis with the aquatic legume *Neptunia natans* (L.f.) Druce. *Appl. Environ. Microbiol.* **2002**, *68*, 5217-5222.
214. Rodríguez-Echeverría, S.; Moreno, S.; Bedmar, E.J. Genetic diversity of root nodulating bacteria associated with *Retama sphaerocarpa* in sites with different soil and environmental conditions. *Syst. Appl. Microbiol.* **2014**, *37*, 305-310.
215. Rodríguez-Echeverría, S.; Pérez-Fernández, M.A.; Vlaar, S.; Finnan, T. Analysis of the legume-rhizobia symbiosis in shrubs from central western Spain. *J. Appl. Microbiol.* **2003**, *95*, 1367-1374.
216. Rodríguez-Navarro, D.N.; Camacho, M.; Leidi, E.O.; Rivas, R.; Velázquez, E. Phenotypic and genotypic characterization of rhizobia from diverse geographical origin that nodulate *Pachyrhizus* species. *System. Appl. Microbiol*. **2004**, *27*, 737-745.
217. Rogel, M.A.; Ormeño-Orrillo, E.; Martinez-Romero, E. Symbiovars in rhizobia reflect bacterial adaptation to legumes. *Syst. Appl. Microbiol.* **2011**, *34*, 96-104.
218. Rome, S.; Fernandez, M.P.; Brunel, B.; Normand, P.; Cleyet-Marel, J-C. *Sinorhizobium medicae* sp. nov., isolated from annual *Medicago* spp. *Int. J. Syst. Bacteriol*. **1996**, *46*, 972-980.
219. Ruiz-Díez, B.; Fajardo, S.; Puertas-Mejía, M.A.; de Felipe, M.delR.; Fernández-Pascual, M. Stress tolerance, genetic analysis and symbiotic properties of root-nodulating bacteria isolated from Mediterranean leguminous shrubs in Central Spain. *Arch. Microbiol.* **2009**, *191*, 35-46.
220. Ryan-Salter, T.P.; Black, A.D.; Andrews, M.; Moot, D.J. Identification and effectiveness of rhizobial strains that nodulate *Lupinus polyphyllus*. *Proc. NZ Grassland Assoc.* **2014**, *76*, 61-66.
221. Saïdi, S.; Chebil, S.; Gtari, M.; Mhamdi, R. Characterization of root-nodule bacteria isolated from *Vicia faba* and selection of plant growth promoting isolates. *World J. Microbiol. Biotechnol.* **2013**, *29*, 1099-1106.
222. Saidi, S.; Ramírez-Bahena, M.H.; Santillana, N.; Zúñiga, D.; Álvarez-Martínez, E.R.; Peix, A.: Mhamdi, R.; Velázquez, E. *Rhizobium laguerreae* sp. nov. nodulates *Vicia faba* on several continents. *Int. J. Syst. Evol. Microbiol.* **2014**, *64*, 242-247.
223. Sánchez-Cañizares, C.; Rey, L.; Durán, D.; Temprano, F.; Sánchez-Jiménez, P.; Navarro, A.; Polajnar, M.; Imperial, J.; Ruiz-Argüeso, T. Endosymbiotic bacteria nodulating a new endemic lupine *Lupinus mariae-josephi* from alkaline soils in Eastern Spain represent a new lineage within the *Bradyrhizobium* genus. *Syst. Appl. Microbiol.* **2011**, *34*, 207-215.
224. Sankhla, I.S.; Tak, N.; Meghwal, R.R.; Choudhary, S.; Tak, A.; Rathi, S.; Sprent, J.I.; James, E.K.; Gehlot, H.S. Molecular characterization of nitrogen fixing microsymbionts from root nodules of *Vachellia* (*Acacia*) *jacquemontii*, a native legume from the Thar Desert of India. *Plant Soil* **2016**, doi 10.1007/s11104-016-2838-9
225. Sannazzaro, A.I.; Bergottini, V.M.; Paz, R.C.; Castagno, L.N.; Menéndez, A.B.; Ruiz, O.A.; Pieckenstain, F.L.; Estrella, M.J. Comparative symbiotic performance of native rhizobia of the Flooding Pampa and

 doi:10.20944/preprints201608.0005.v1

strains currently used for inoculating *Lotus tenuis* in this region. *Antonie van Leeuwenhoek*, **2011**, *99*, 371-379.

226. Santillana, N.; Ramírez-Bahena, M.H.; García-Fraile, P.; Velázquez, E.; Zúñiga, D. Phylogenetic diversity based on *rrs, atpD, recA* genes and 16S-23S intergenic sequence analyses of rhizobial strains isolated from *Vicia faba* and *Pisum sativum* in Peru. *Arch. Microbiol*. **2008**, *189*, 239-247.
227. Sarr, P.S.; Araki, S.; Begoude, D.A.; Yemefack, M.; Manga, G.A.; Yamakawa, T.; Htwe, A.Z. Phylogeny and nitrogen fixation potential of *Bradyrhizobium* species isolated from the legume cover crop *Pueraria phaseoloides* (Roxb.) Benth. in Eastern Cameroon. *Soil Sci. Plant Nutr*. **2016**, *62*, 13-19.
228. Schwarz, E.N.; Ruhlman, T.A.; Sabir, J.S.M.; Hajirah, N.H.; Alharbi, N.S.; Al-Malki, A.L.; Bailey, C.D.; Jansen, R.K. Plastid genome sequences of legumes reveal parallel inversions and multiple losses of *rps16* in papilionoids. *J. System. Evol.* **2015**, *53*, 458-468.
229. Shiraishi, A.; Matsushita, N.; Hougetsu, T. Nodulation in black locust by the Gammaproteobacteria *Pseudomonas* sp. and the Betaproteobacteria *Burkholderia* sp. *Syst. Appl. Microbiol.* **2010**, *33*, 269-274.
230. Silva, F.V.; de Meyer, S.E.; Simões-Araújo, J.L.; Barbé, T.daC.; Xavier, G.R.; O'Hara, G.; Ardley, J.K.; Rumjanek, N.G.; Willems, A.; Zilli, J.E. *Bradyrhizobium manausense* sp. nov., isolated from effective nodules of *Vigna unguiculata* grown in Brazilian Amazonian rainforest soils. *Int. J. Syst. Evol. Microbiol.* **2014**, *64*, 2358-2363.
231. Sinsuwongwat, S.; Nuntagij, A.; Shutsrirung, A.; Nomura, M.; Tajima, S. Characterization of local rhizobia in Thailand and distribution of malic enzymes. *Soil Sci. Plant Nutr.* **2002**, *48*, 719-727.
232. Sprent, J.I. Legume Nodulation A Global Perspective. Wiley-Blackwell: Chichester, UK, 2009.
233. Squartini, A.; Struffi, P.; Döring, H.; Selenska-Pobell, S.; Tola, E.; Giacomini, A.; Vendramin, E.; Velázquez, E.; Mateos, P.F.; Martinez-Molina, E.; Dazzo, F.B.; Casella, S.; Nuti, M.P. *Rhizobium sullae* sp. nov. (formerly '*Rhizobium hedysari*'), the root-nodule microsymbiont of *Hedysarum coronarium* L. *Int. J. Syst. Evol. Microbiol.* **2002**, *52*, 1267-1276.
234. Steenkamp, E.T.; Stępkowski, T.; Przymusiak, A.; Botha, W.J.; Law, I.J. Cowpea and peanut in southern Africa are nodulated by diverse *Bradyrhizobium* strains harboring nodulation genes that belong to the large pantropical clade common in Africa. *Mol. Phylogenet. Evol.* **2008**, *48*, 1131-1144.
235. Stepkowski, T.; Moulin, L.; Krzyżańska, A.; McInnes, A.; Law, I.J.; Howieson, J. European origin of *Bradyrhizobium* populations infecting lupins and serradella in soils of Western Australia and South Africa. *Appl. Environ. Microbiol.* **2005**, *71*, 7041-7052.
236. Stępkowski, T.; Żak, M.; Moulin, L.; Króliczak, J.; Golińska, B.; Narożna, D.; Safronova, V.I.; Mądrzak, C.J. *Bradyrhizobium canariense* and *Bradyrhizobium japonicum* are the two dominant rhizobium species in root nodules of lupin and serradella plants growing in Europe. *Syst. Appl. Microbiol.* **2011**, *34*, 368-375.
237. Stroschein, M.R.D.; Eltz, F.L.F.; Antoniolli, Z.I.; Lupatini, M.; Vargas, L.K.; Giongo, A.; Pontelli, M.P. Symbiotic efficiency and genetic characteristics of *Bradyrhizobium* sp. strain UFSM LA 1.3 isolated from *Lupinus albescens* (H. et Arn). Sci. Agric. **2010**, *67*, 702-706.
238. Suominen, L.; Luukkainen, R.; Roos, C.; Lindström, K. Activation of the *nodA* promoter by the *nodD* genes of *Rhizobium galegae* induced by synthetic flavonoids or *Galega orientalis* root exudate. *FEMS Microbiol. Lett*. 2003, 219, 225-232.
239. Sy, A.; Giraud, E.; Jourand, P.; Garcia, N.; Willems, A.; de Lajudie, P.; Prin, Y.; Neyra, M.; Gillis, M.; Boivin-Masson, C.; Dreyfus, B. Methylotrophic *Methylobacterium* bacteria nodulate and fix nitrogen in symbiosis with legumes. *J. Bacteriol*. **2001**, *183*, 214-220.
240. Talbi, C.; Delgado, M.J.; Girard, L.; Ramirez-Trujillo, A.; Caballero-Mellado, J.; Bedmar, E.J. *Burkholderia phymatum* strains capable of nodulating *Phaseolus vulgaris* are present in Moroccan soils. *Appl. Environ. Microbiol.* **2010**, *76*, 4587-4591.
241. Tan, H.W.; Heenan, P.B.; De Meyer, S.E.; Willems, A.; Andrews, M. Diverse novel mesorhizobia nodulate New Zealand native *Sophora* species. *Syst. Appl. Microbiol*. **2015**, *38*, 91-98.
242. Tan, H.W.; Heenan, P.; Ridgway, H.; Andrews, M. The New Zealand alpine endemic *Montigena novae-zelandiae* (Fabaceae) shares rhizobial symbionts with *Carmichaelia* and *Clianthus*. *New Zeal. J. Bot.* **2013**, *51*, 297-307.
243. Tan, H.W.; Weir, B.S.; Carter, N.; Heenan, P.B.; Ridgway, H.J.; James, E.K.; Sprent, J.I.; Young, J.P.Y.; Andrews, M. Rhizobia with 16S rRNA and *nifH* similar to *Mesorhizobium huakuii* but novel *recA*, *gln11*, *nodA* and *nodC* genes are symbionts of New Zealand Carmichaelinae. *PLoS ONE* **2012**, *7* (10), e47677.

244. Tan, Z.Y.; Kan, F.L.; Peng, G.X.; Wang, E.T.; Reinhold-Hurek, B.; Chen, W.X. *Rhizobium yanglingense* sp. nov., isolated from arid and semi-arid regions in China. *Int. J. Syst. Evol. Microbiol.* **2001**, *51*, 909-914.
245. Tan, Z.Y.; Wang, E.T.; Peng, G.X.; Zhu, M.E.; Martínez-Romero, E.; Chen, W.X. Characterization of bacteria isolated from wild legumes in the north-western regions of China. *Int. J. Syst. Bacteriol.* **1999**, *49*, 1457-1469.
246. Tang, J.; Bromfield, E.S.P.; Rodrigue, N.; Cloutier, S.; Tambong, J.T. Microevolution of symbiotic *Bradyrhizobium* populations associated with soybeans in east North America. *Ecol. Evol.* **2012**, *2*, 2943-2961.
247. Taulé, C.; Zabaleta, M.; Mareque, C.; Platero, R.; Sanjurjo, L.; Sicardi, M.; Frioni, L.; Battistoni, F.; Fabiano, E. New Betaproteobacterial *Rhizobium* strains able to efficiently nodulate *Parapiptadenia rigida* (Benth.) Brenan. *Appl. Environ. Microbiol.* **2012**, *78*, 1692-1700.
248. Taurian, T.; Ibañez, F.; Fabra, A.; Aguilar, O.M. Genetic diversity of rhizobia nodulating *Arachis hypogaea* L. in Central Argentinean soils. *Plant Soil* **2006**, *282*, 41-52.
249. Tian, C.F.; Wang, E.T.; Wu, L.J.; Han, T.X.; Chen, W.F.; Gu, C.T.; Gu, J.G.; Chen, W.X. *Rhizobium fabae* sp. nov., a bacterium that nodulates *Vicia faba*. *Int. J. Syst. Evol. Microbiol.* **2008**, *58*, 2871-2875.
250. Tlusty, B.; van Berkum, P.; Graham, P.H. Characteristics of the rhizobia associated with *Dalea* spp. in the Ordway, Kellogg-Weaver Dunes, and Hayden prairies. *Can. J. Microbiol.* **2005**, *51*, 15-23.
251. Toledo, I.; Lloret, L.; Martinez-Romero, E. *Sinorhizobium americanus* sp. nov., a new *Sinorhizobium* species nodulating native *Acacia* spp. in Mexico. *Syst. Appl. Microbiol.* **2003**, *26*, 54-64.
252. Trujillo, M.E.; Willems, A.; Abril, A.; Planchuelo, A-M.; Rivas, R.; Ludeña, D.; Mateos, P.F.; Martínez-Molina, E.; Velázquez, E. Nodulation of *Lupinus albus* by strains of *Ochrobactrum lupini* sp. nov. *Appl. Environ. Microbiol*. **2005**, *71*, 1318-1327.
253. Ulrich, A.; Zaspel, I. Phylogenetic diversity of rhizobial strains nodulating *Robinia pseudoacacia* L. *Microbiol*. **2000**, *146*, 2997-3005.
254. Urtz, B.E.; Elkan, G.H. Genetic diversity among Bradyrhizobium isolates that effectively nodulate peanut (*Arachis hypogaea*). *Can. J. Microbiol*. **1996**, *42*, 1121-1130.
255. Valverde, A.; Igual, J.M.; Peix, A.; Cervantes, E.; Velázquez, E. *Rhizobium lusitanum* sp. nov. a bacterium that nodulates *Phaseolus vulgaris*. *Int. J. System. Evol. Microbiol.* **2006**, *56*, 2631-2637.
256. Valverde, A.; Velázquez, E.; Fernández-Santos, F.; Vizcaíno, N.; Rivas, R.; Mateos, P.F.; Martínez-Molina, E.; Igual, J.M.; Willems, A. *Phyllobacterium trifolii* sp. nov., nodulating *Trifolium* and *Lupinus* in Spanish soils. *Int. J. System. Evol. Microbiol.* **2005**, *55*, 1985-1989.
257. van Berkum, P.; Eardly, B.D. The aquatic budding bacterium *Blastobacter denitrificans* is a nitrogen-fixing symbiont of *Aeschynomene indica*. *Appl. Environ. Microbiol.* **2002**, *68*, 1132-1136.
258. van Berkum, P.; Beyene, D.; Bao, G.; Campbell, T.A.; Eardly, B.D. *Rhizobium mongolense* sp. nov. is one of three rhizobial genotypes identified which nodulate and form nitrogen-fixing symbioses with *Medicago ruthenica* [(L.) Ledebour]. *Int. J. Syst. Bacteriol.* **1998**, *48*, 13-22.
259. Velázquez, E.; Igual, J.M.; Willems, A.; Fernández, M.P.; Muñoz, E.; Mateos, P.F.; Abril, A.; Toro, N.; Normand, P.; Cervantes, E.; Gillis, M.; Martínez-Molina, E. *Mesorhizobium chacoense* sp. nov., a novel species that nodulates *Prosopis alba* in the Chaco Arido region (Argentina*)*. *Int. J. System. Evol. Microbiol.* **2001**, *51*, 1011-1021.
260. Velázquez, E.; Valverde, A.; Rivas, R.; Gomis, V.; Peix, A.; Gantois, I.; Igual, J.M.; León-Barrios, M.; Willems, A.; Mateos, P.F.; Martínez-Molina, E. Strains nodulating *Lupinus albus* on different contintents belong to several new chromosomal and symbiotic lineages within *Bradyrhizobium*. *Antonie van Leeuwenhoek*. **2010**, *97*, 363-376.
261. Villegas, M.delC.; Rome, S.; Mauré, L.; Domergue, O.; Gardan, L.; Bailly, X.; Cleyet-Marel, J-C.; Brunel, B. Nitrogen-fixing sinorhizobia with *Medicago laciniata* constitute a novel biovar (bv. *medicaginis*) of *S. meliloti*. *Syst. Appl. Microbiol*. **2006**, *29*, 526-538.
262. Vinuesa, P.; Léon-Barrios, M.; Silva, C.; Willems, A.; Jarabo-Lorenzo, A.; Pérez-Galdona, R.; Werner, D.; Martínez-Romero, E. *Bradyrhizobium canariense* sp. nov., an acid-tolerant endosymbiont that nodulates endemic genistoid legumes (Papilionoideae: Genisteae) from the Canary Islands, along with *Bradyrhizobium japonicum* bv. genistearum, *Bradyrhizobium* genospecies alpha and *Bradyrhizobium* genospecies beta. *Int. J. Syst. Evol. Microbiol.* **2005a**, *55*, 569-575.
263. Vinuesa, P.; Rademaker, J.L.W.; de Bruijn, F.J.; Werner, D. Genotypic characterization of *Bradyrhizobium* strains nodulating endemic woody legumes of the Canary Islands by PCR-restriction fragment length

polymorphism analysis of genes encoding 16S rRNA (16S rDNA) and 16S-23S rDNA intergenic spacers, repetitive extragenic palindromic PCR genomic fingerprinting, and partial 16S rDNA sequencing. *Appl. Environ. Microbiol.* **1998**, *64*, 2096-2104.

264. Vinuesa, P.; Silva, C.; Lorite, M.J.; Izaguirre-Mayoral, M.L.; Bedmar, E.J.; Martínez-Romero, E. Molecular systematics of rhizobia based on maximum likelihood and Bayesian phylogenies inferred from rrs, atpD, recA and nifH sequences, and their use in the classification of Sesbania microsymbionts from Venezuelan wetlands. *Syst. Appl. Microbiol.* **2005b**, *28*, 702-716.
265. Vitousek, P.M.; Menge, D.N.L.; Reed, S.C.; Cleveland, C.C. Biological nitrogen fixation: rates, patterns and ecological controls in terrestrial ecosystems. *Philos. T. Roy. Soc. B* **2013**, *368*, 20130119
266. Wang, E.T.; Martínez-Romero, J.; Martínez-Romero, E. Genetic diversity of rhizobia from *Leucaena leucocephala* nodules in Mexican soils. *Mol. Ecol.* **1999a**, *8*, 711-724.
267. Wang, E.T.; van Berkum, P.; Sui, X.H.; Beyene, D.; Chen, W.X.; Martínez-Romero, E. Diversity of rhizobia associated with *Amorpha fruticosa* isolated from Chinese soils and description of *Mesorhizobium amorphae* sp. nov. *Int. J. Syst. Bacteriol.* **1999b**, *49*, 51-65.
268. Wang, E.T.; van Berkum, P.; Beyene, D.; Sui, X.H.; Dorado, O.; Chen, W.X.; Martínez-Romero, E. *Rhizobium huautlense* sp. nov., a symbiont of *Sesbania herbacea* that has a close phylogenetic relationship with *Rhizobium galegae*. *Int. J. Syst. Bacteriol.* **1998**, *48*, 687-699.
269. Wang, F.; Wang, E.T.; Wu, L.J.; Sui, X.H.; Li, Y.Jr.; Chen, W.X. *Rhizobium vallis* sp. nov., isolated from nodules of three leguminous species. *Int. J. Syst. Evol. Microbiol.* **2011**, *61*, 2582-2588.
270. Wang, H.; Man, C.X.; Wang, E.T.; Chen, W.X. Diversity of rhizobia and interactions among the host legumes and rhizobial genotypes in an agricultural-forestry ecosystem. *Plant Soil* **2009**, *314*, 169-182.
271. Wang, Y.C.; Wang, F.; Hou, B.C.; Wang, E.T.; Chen, W.F.; Sui, X.H.; Chen, W.X.; Li, Y.; Zhang, Y.B. Proposal of *Ensifer psoraleae* sp. nov., *Ensifer sesbaniae* sp. nov., *Ensifer morelense* comb. nov. and *Ensifer americanum* comb. nov. *Syst. Appl. Microbiol.* **2013a**, *36*, 467-473.
272. Wang, R.; Chang, Y.L.; Zheng, W.T.; Zhang, D.; Zhang, X.X.; Sui, X.H.; Wang, E.T.; Hu, J.Q.; Zhang, L.Y.; Chen, W.X. *Bradyrhizobium arachidis* sp. nov., isolated from effective nodules of *Arachis hypogaea* grown in China. *Syst. Appl. Microbiol.* **2013b**, *36*, 101-105.
273. Wang, J.Y.; Wang, R.; Zhang, Y.M.; Liu, H.C.; Chen, W.F.; Wang, E.T.; Sui, X.H.; Chen, W.X. *Bradyrhizobium daqingense* sp. nov., isolated from soybean nodules. *Int. J. Syst. Evol. Microbiol.* **2013c**, *63*, 616-624.
274. Wang, L.; Cao, Y.; Wang, E.T.; Qiao, Y.J.; Jiao, S.; Liu, Z.S.; Zhao, L.; Wei, G.H. Biodiversity and biogeography of rhizobia associated with common bean (*Phaseolus vulgaris* L.) in Shaanxi Province. *Syst. Appl. Microbiol.* **2016**, *39*, 211-219.
275. Wei G.; Chen, W.; Young, J.P.W.; Bontemps, C. A new clade of *Mesorhizobium* nodulating *Alhagi sparsifolia*. *Syst. Appl. Microbiol*. **2009**, *32*, 8-16.
276. Wei, G.H.; Yang, X-Y.; Zhang, Z-X.; Yang, Y-Z.; Lindström, K. Strain *Mesorhizobium* sp. CCNWGX035: a stress-tolerant isolate from *Glycyrrhiza glabra* displaying a wide host range of nodulation. *Pedosphere* **2008a**, *18*, 102-112.
277. Wei, G.H.; Zhang, Z.X.; Chen, C.; Chen, W.M.; Ju, W.T. Phenotypic and genetic diversity of rhizobia isolated from nodules of the legume genera *Astragalus, Lespedeza* and *Hedysarum* in northwestern China. *Microbial. Res.* **2008b**, *163*, 651-662.
278. Wojciechowski, M.F.; Lavin, M.; Sanderson, M.J. A phylogeny of legumes (Leguminosae) based on analysis of the plastid *MATK* gene resolves many well-supported subclades withing the family. *Amer. J. Bot.* **2004**, *91*, 1846-1862.
279. Wu, L.J.; Wang, H.Q.; Wang, E.T.; Chen, W.X.; Tian, C.F. Genetic diversity of nodulating and non-nodulating rhizobia associated with wild soybean (*Glycine soja* Sieb. & Zucc.) in different ecoregions of China. *FEMS Microbiol. Ecol.* **2011**, *76*, 439-450.
280. Xu, K.W.; Penttinen, P.; Chen, Y.X.; Chen, Q.; Zhang, X. Symbiotic efficiency and phylogeny of the rhizobia isolated from *Leucaena leucocephala* in arid-hot river valley area in Panxi, Sichuan, China. *Appl. Microbiol. Biotchnol.* **2013**, *97*, 783-793.
281. Xu, K.W.; Zou, L.; Penttinen, P.; Wang, K.p; Heng, N.N.; Zhang, X.P.; Chen, Q.; Zhao, K.; Chen, Y.X. Symbiotic effectiveness and phylogeny of rhizobia isolated from faba bean (*Vicia faba* L.) in Sichuan hilly areas, China. *Syst. Appl. Microbiol.* **2015**, *38*, 515-523.

282. Xu, K.W.; Zou, L.; Penttinen, P.; Zeng, X.; Liu, M.; Zhao, K.; Chen, C.; Chen, Y.X.; Zhang, X. Diversity and phylogeny of rhizobia associated with *Desmodium* spp. in Panxi, Sichuan, China. *Syst. Appl. Microbiol.* **2016**, *39*, 33-40.
283. Xu, L.M.; Ge, C.; Cui, Z.; Li, J.; Fan, H. *Bradyrhizobium liaoningense* sp. nov., isolated from the root nodules of soybeans. *Int. J. Syst. Bacteriol*. **1995**, *45*, 706-711.
284. Xu, L.; Shi, J.F.; Zhao, P.; Chen, W.M.; Qin, W.; Tang, M.; Wei, G.H. *Rhizobium sphaerophysae* sp. nov., a novel species isolated from root nodules of *Sphaerophysa salsula* in China. *Antonie van Leeuwenhoek*. **2011**, *99*, 845-854.
285. www.tropicalforages.info
286. Yan, A.M.; Wang, E.T.; Kan, F.L.; Tan, Z.Y.; Sui, X.H.; Reinhold-Hurek, B.; Chen, W.X. *Sinorhizobium meliloti* associated with *Medicago sativa* and *Melilotus* spp. in arid saline soils in Xinjiang, China. *Int. J. Syst. Evol. Microbiol*. **2000**, *50*, 1887-1891.
287. Yan, H.; Ji, Z.J.; Jiao, Y.S.; Wang, E.T.; Chen, W.F.; Guo, B.L.; Chen, W.X. Genetic diversity and distribution of rhizobia associated with the medicinal legumes *Astragalus* spp. and *Hedysarum polybotrys* in agricultural soils. *Syst. Appl. Microbiol.* **2016**, *39*, 141-149.
288. Yang, J.K.; Xie, F.L.; Zou, J.; Zhou, Q.; Zhou, J.C. Polyphasic characteristics of bradyrhizobia isolated from nodules of peanut (*Arachis hypogaea*) in China. *Soil Biol. Biochem.* **2005**, *37*, 141-153.
289. Yang, W.; Kong, Z.; Chen, W. Wei, G. Genetic diversity and symbiotic evolution of rhizobia from root nodules of *Coronilla varia*. *Syst. Appl. Microbiol.* **2013**, *36*, 49-55.
290. Yao, Y.; Wang, R.; Lu, J.K.; Sui, X.H.; Wang, E.T.; Chen, W.X. Genetic diversity and evolution of *Bradyrhizobium* populations nodulating *Erythrophleum fordii*, an evergreen tree indigenous to the southern subtropical region of China. *Appl. Environ. Microbiol.* **2014**, *80*, 6184-6194.
291. Yao, Z.Y.; Kan, F.L.; Wang, E.T.; Wei, G.H.; Chen, W.X. Characterization of rhizobia that nodulate legume species of the genus *Lespedeza* and description of *Bradyrhizobium yuanmingense* sp. nov. *Int. J. Syst. Evol. Microbiol*. **2002**, *52*, 2219-2230.
292. Yates, R.J.; Howieson, J.G.; Reeve, W.G.; Nandasena, K.G.; Law, I.J.; Bräu, L.; Ardley, J.K.; Nistelberger, H.M.; Real, D.; O'Hara, G.W. *Lotononis angolensis* forms nitrogen fixing, lupinoid nodules with phylogenetically unique, fast growing, pink-pigmented bacteria, which do not nodulate *L. bainesii* or *L. listii*. *Soil Biol. Biochem.* **2007**, *39*, 1680-1688.
293. Youseif, S.H.; Abd El-Megeed, F.H.; Ageez, A.; Cocking, E.C. Saleh, S.A. Phylogenetic multilocus sequence analysis of native rhizobia nodulating faba bean (*Vicia faba* L.) in Egypt. *Syst. Appl. Microbiol.* **2014**, *37*, 560-569.
294. Zahran, H.H.; Chahboune, R.; Moreno, S.; Bedmar, E.J.; Abdel-Fattah, M.; Yasser, M.M.; Mahmoud, A.M. Identification of rhizobial strains nodulating Egyptian grain legumes. *Int. Microbiol*. **2013**, *16*, 157-163.
295. Zhang, J.; Yang, X.; Guo, C.; de Lajudie, P.; Singh, R.P.; Wang, E.; Chen, W. *Mesorhizobium muleiense* and *Mesorhizobium* gsp. Nov. are symbionts of *Cicer arietinum* L. in alkaline soils of Gansu, Northwest China. Plant Soil 2016, doi: 10.1007/s11104-016-2987-x.
296. Zhang, J.J.; Jing, X.Y.; de Lajudie, P.; Ma, C.; He, P.X.; Singh, R.P.; Chen, W.F.; Wang, E.T. Association of white clover (*Trifolium repens* L.) with rhizobia of sv. *trifolii* belonging to three genomic species in alkaline soils in North and East China. *Plant Soil* **2016**, doi 10.1007/s11104-016-2899-9.
297. Zhang, J.J.; Lou, K.; Jin, X.; Mao, P.H.; Wang, E.T.; Tian, C.F.; Sui, X.H.; Chen, W.F.; Chen, W.X. Distinctive *Mesorhizobium* populations associated with *Cicer arietinum* L. in alkaline soils of Xinjiang, China. *Plant Soil*. **2012**, *353*, 123-134.
298. Zhang, Y.F.; Wang, E.T.; Tian, C.F.; Wang, F.Q.; Han, L.L.; Chen, W.F.; Chen, W.X. *Bradyrhizobium elkanii, Bradyrhizobium yuanmingense* and *Bradyrhizobium japonicum* are the main rhizobia associated with *Vigna unguiculata* and *Vigna radiata* in the subtropical region of China. *FEMS Microbiol. Lett.* **2008**, *285*, 146-154.
299. Zhang, Y.M.; Li, Y.Jr.; Chen, W.F.; Wang, E.T.; Tian, C.F.; Li, Q.Q.; Zhang, Y.Z.; Sui, X.H.; Chen, W.X. Biodiversity and biogeography of rhizobia associated with soybean plants grown in the North China Plain. *Appl. Environ. Microbiol.* **2011**, *77*, 6331-6342.
300. Zhang, Y.J.; Zheng, W.T.; Everall, I.; Young, J.P.W.; Zhang, X.X.; Tian, C.F.; Sui, X.H.; Wang, E.T.; Chen, W.X.; *Rhizobium anhuiense* sp. nov., isolated from effective nodules of *Vicia faba* and *Pisum sativum*. *Int. J. Syst. Evol. Microbiol.* **2015**, *65*, 2960-2967.

 doi:10.20944/preprints201608.0005.v1

301. Zhao, C.T.; Wang, E.T.; Zhang, Y.M.; Chen, W.F.; Sui, X.H.; Chen, W.X.; Liu, H.C.; Zhang, X.X. *Mesorhizobium silamurunense* sp. nov., isolated from root nodules of *Astragalus* species. *Int. J. Syst. Evol. Microbiol.* **2012**, *62*, 2180-2186.
302. Zhao, L.; Deng, Z.; Yang, W.; Cao, Y.; Wang, E.; Wei, G. Diverse rhizobia associated with *Sophora alopecuroides* grown in different regions of Loess Plateau in China. *Syst. Appl. Microbiol.* **2010**, *33*, 468-477.
303. Zhao, L.; Fan, M.; Zhang, D.; Yang, R.; Zhang, F.; Xu, L.; Wei, X.; Shen, Y.; Wei, G. Distribution and diversity of rhizobia associated with wild soybean (*Glycine soja* Sieb. & Zucc.) in Northwest China. *Syst. Appl. Microbiol*. **2014**, *37*, 449-456.
304. Zhao, L.; Wang, X.; Huo, H.; Yuan, G.; Sun, Y.; Zhang, D.; Cao, Y.; Xu, L.; Wei, G. Phylogenetic diversity of *Ammopiptanthus* rhizobia and distribution of rhizobia associated with *Ammopiptanthus mongolicus* in diverse regions of Northwest China. *Microb. Ecol.* **2016**, doi 10.1007/s00248-016-0759-z
305. Zilli, J.E.; Baraúna, A.C.; da Silva, K.; De Meyer, S.E.; Farias, E.N.C.; Kaminski, P.E.; da Costa, I.B.; Ardley, J.K.; Willems, A.; Camacho, N.N.; Dourado, F.dosS.; O'Hara, G. *Bradyrhizobium neotropicale* sp. nov., isolate from effective nodules of *Centrolobium paraense*. *Int. J. Syst. Evol. Microbiol.* **2014**, *64*, 3950-3957.

Table 1. Legume-rhizobia symbioses in the legume sub-family Mimosoideae. All species have indeterminate nodules.

Mimosoideae Tribes and genera	Rhizobia – field
Ingeae	
Acacia *auriculiformis*	*Bradyrhizobium* [Manassila et al. 2007; Le Roux et al. 2009; Helene et al. 2015]
Acacia mangium	*Bradyrhizobium* [Sinsuwongwat et al. 2002; Ngom et al. 2004; Manassila et al. 2007; Le Roux et al. 2009], *Ochrobactrum* [Ngom et al. 2004], *Rhizobium* [Ngom et al. 2004]
Acacia mangium × *A. auriculiformis*	*Bradyrhizobium* [Le Roux et al. 2009]
Acacia mearnsii	*Ensifer* [Lortet et al. 1996; Räsänen et al. 2001]
Acacia melanoxylon	*Bradyrhizobium* [Lu et al. 2014]
Acacia saligna	*Bradyrhizobium* [Marsudi et al. 1999; Helene et al. 2015], *Ensifer* [Khbaya et al. 1998], *Rhizobium* [Marsudi et al. 1999]
Acaciella *angustissima*	*Ensifer* [Lloret et al. 2007; Rincon-Rosales et al. 2009]
Calliandra *calothyrsis*	*Ensifer* [Bala & Giller, 2001], *Rhizobium* [Bala & Giller, 2001]
Calliandra grandiflora	*Ensifer* [Rincón-Rosales et al. 2013], *Mesorhizobium* [Rincón-Rosales et al. 2013], *Rhizobium* [Rincón-Rosales et al. 2013]
Faidherbia *albida*	*Bradyrhizobium* [Odee et al. 2002]
Inga *edulis*	*Bradyrhizobium* [Leblanc et al. 2005]
Inga laurina	*Bradyrhizobium* [da Silva et al. 2014]
Mariosousa *acatlensis*	*Ensifer* [Toledo et al. 2003]
Senegalia *laeta*	*Ensifer* [Lortet et al. 1996]
Senegalia macilenta	*Ensifer* [Toledo et al. 2003],
Senegalia senegal	*Ensifer* [Lortet et al. 1996; Räsänen et al. 2001], *Rhizobium* [Lortet et al. 1996; Fall et al. 2008], *Mesorhizobium* [Fall et al. 2008]
Mimoseae	
Anadenanthera *peregrina*	*Burkholderia* [Bournaud et al. 2013]

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 1 August 2016 doi:10.20944/preprints201608.0005.v1

***Desmanthus** illinoensis*	*Rhizobium* [Beyhaut et al. 2006]
Desmanthus paspalaceus	*Mesorhizobium* [Fornasero et al. 2014], *Rhizobium* [Fornasero et al. 2014]
Desmanthus virgatus	*Rhizobium* [Sinsuwongwat et al. 2002]
***Leucaena** leucocephala*	*Ensifer* [Wang et al. 1999a; Bala & Giller, 2001; Xu et al. 2013], *Mesorhizobium* [Wang et al. 1999a; Bala & Giller, 2001; Xu et al. 2013], *Rhizobium* [Wang et al. 1999a; Bala & Giller, 2001; López-López et al. 2012]
***Microlobius** foetidus*	*Bradyrhizobium* [Bournaud et al. 2013], *Rhizobium* [Bournaud et al. 2013]
~ 50 ***Mimosa*** spp.	*Burkholderia* [Chen et al. 2003, 2005a,b; Barrett & Parker 2005, 2006; Liu et al. 2007; Parker et al. 2007; Elliott et al. 2009; Bontemps et al. 2010; Liu et al. 2011; Liu et al. 2012; Gehlot et al. 2013].
Mimosa affinis	*Rhizobium* [Elliot et al. 2009]
Mimosa asperata	*Cupriavidus* [Andam et al. 2007]
Mimosa borealis	*Ensifer* [Bontemps et al. 2016]
Mimosa ceratonia	*Rhizobium* [Elliot et al. 2009]
Mimosa cruenta	*Cupriavidus* [Platero et al. 2016]
Mimosa diplotricha	*Cupriavidus* [Chen et al. 2003, Liu et al. 2011; Liu et al. 2012], *Rhizobium* [Chen et al. 2003; Elliott et al. 2009]
Mimosa hamata, Mimosa himalayana	*Ensifer* [Gehlot et al. 2013]
Mimosa invisa	*Rhizobium* [Liu et al. 2007]
Mimosa magnate	*Cupriavidus* [Platero et al. 2016]
Mimosa pigra	*Cupriavidus* [Chen et al. 2005b; Barrett & Parker 2006]
Mimosa polyantha	*Rhizobium* [Bontemps et al. 2016]
Mimosa pudica	*Bradyrhizobium* [Liu et al. 2007], *Cupriavidus* [Chen et al. 2003; Barrett & Parker, 2006; Elliott et al. 2009; Liu et al. 2011; Liu et al. 2012; Gehlot et al. 2013], *Rhizobium* [Barrett & Parker, 2006; Liu et al. 2007]
Mimosa ramulosa, Mimosa reptans, Mimosa schleidenii	*Cupriavidus* [Platero et al. 2016]
Mimosa strigillosa	*Ensifer* [Andam et al. 2007]
Mimosa tequilana	*Rhizobium* [Bontemps et al. 2016]
***Neptunia** natans*	*Allorhizobium* [de Lajudie 1998], *Devosia* [Rivas et al. 2002]
***Parapiptadenia** pterosperma*	*Burkholderia* [Bournaud et al. 2013]
Parapiptadenia rigida	*Burkholderia* [Bournaud et al. 2013], *Cupriavidus* [Taulé et al. 2012], *Rhizobium* [Bournaud et al. 2013]
***Piptadenia** adiantoides, Piptadenia flava*	*Rhizobium* [Bournaud et al. 2013]
Piptadenia gonoacantha	*Burkholderia* [Bournaud et al. 2013], *Rhizobium* [Bournaud et al. 2013]
Piptadenia paniculata	*Burkholderia* [Bournaud et al. 2013], *Rhizobium* [Bournaud et al. 2013]
Piptadenia stipulacea, Piptadenia trisperma, Piptadenia vividiflora	*Burkholderia* [Bournaud et al. 2013]
***Prosopis** alba*	*Bradyrhizobium* [Diaz et al. 2013], Ensifer [Iglesias et al. 2007; Diaz et al. 2013], *Mesorhizobium* [Velázquez et al. 2001; Diaz et al. 2013], *Rhizobium* [Iglesias et al. 2007]
Prosopis chilensis	*Ensifer* [Nick et al. 1999; Räsänen et al. 2001]

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 1 August 2016 doi:10.20944/preprints201608.0005.v1

Prosopis cineraria	*Ensifer* [Gehlot et al. 2012]
Prosopis farcta	*Ensifer* [Fterich et al. 2011], *Mesorhizobium* [Fterich et al. 2011]
Prosopis juliflora	*Achromobacter* [Benata et al. 2008], *Ensifer* [Benata et al. 2008], *Rhizobium* [Benata et al. 2008]
Pseudopiptadenia *contorta*	*Burkholderia* [Bournaud et al. 2013]
Stryphnodendron sp.	*Bradyrhizobium* [Bournaud et al. 2013]
Vachellia *abyssinica*	*Mesorhizobium* [Degefu et al. 2011], *Ensifer* [Degefu et al. 2012]
Vachellia cochliacantha, Vachellia farnesiana	*Ensifer* [Toledo et al. 2003]
Vachellia gummifera	*Ensifer* [Khbaya et al. 1998]
Vachellia horrida	*Ensifer* [Lortet et al. 1996; Khbaya et al. 1998]
Vachellia jacquemontii	*Ensifer* [Gehlot et al. 2012; Sankhla et al. 2016]
Vachellia macracantha	*Ensifer* [Cordero et al. 2016], *Rhizobium* [Cordero et al. 2016]
Vachellia nubica	*Bradyrhizobium* [Odee et al. 2002]
Vachellia seyal	*Rhizobium* [Lortet et al. 1996], *Ensifer* [Degefu et al. 2012]
Vachellia pennatula	*Ensifer* [Toledo et al. 2003]
Vachellia tortilis	*Ensifer* [Lortet et al. 1996; Khbaya et al. 1998; Ba et al. 2002; Degefu et al. 2012], *Mesorhizobium* [Lortet et al. 1996; Ba et al. 2002; Odee et al. 2002; Degefu et al. 2011], *Rhizobium* [Ba et al. 2002]
Vachellia xanthophloea	*Mesorhizobium* [Odee et al. 2002]
Xylia *xylocarpa*	*Bradyrhizobium* [Sinsuwongwat et al. 2002; Manasila et al. 2007]

Table 2. Legume-rhizobia symbioses in the inverted repeat lacking clade (IRLC) of the legume sub-family Papilionoideae. All species in the IRLC have indeterminate nodules.

Papilionoidieae Tribes and genera	Rhizobia – field
Cicereae	
Cicer *arietinum*	*Mesorhizobium* [Nour et al. 1994; Aouani et al. 2001; Maâtallah et al. 2002; Rivas et al. 2007; Ben Romdhane et al. 2009; Zhang et al. 2012; Zahran et al. 2013; Zhang et al. 2016]
Cicer canariense	*Mesorhizobium* [Armas-Capote et al. 2014]
Fabeae	
Lathyrus *aphaca, Lathyrus nissolia, Lathyrus pratensis*	*Rhizobium* [Mutch & Young, 2004]
Lathyrus japonicus	*Rhizobium* [Aoki et al. 2010]
Lathyrus odoratus	*Rhizobium* [Han et al. 2008b]
Lens *culinaris*	*Rhizobium* [Rashid et al. 2012; Zahran et al. 2013; Riah et al. 2014]
Pisum *sativum*	*Rhizobium* [Mutch & Young, 2004; Zahran et al. 2013; Riah et al. 2014; Zhang et al. 2015]
Vicia *amoena*	*Rhizobium* [Kan et al. 2007]
Vicia bungei	*Rhizobium* [Kan et al. 2007]
Vicia cracca	*Rhizobium* [Mutch & Young, 2004; Kan et al. 2007; Ampomah & Huss-Danell, 2016]
Vicia hirsuta	*Rhizobium* [Mutch & Young, 2004; Han et al. 2008b; Ampomah & Huss-Danell, 2016]
Vicia faba	*Rhizobium* [Mutch & Young, 2004; Kan et al. 2007;

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 1 August 2016 doi:10.20944/preprints201608.0005.v1

	Santillana et al. 2008; Saidi et al. 2013; Zahran et al. 2013; Youseif et al. 2014; Xu et al. 2015; Zhang et al. 2015]
Vicia multicaulis	*Rhizobium* [Ampomah & Huss-Danell, 2016]
Vicia sativa	*Rhizobium* [Mutch & Young, 2004; Kan et al. 2007; Lei et al. 2008; Tian et al. 2008; Alvarez-Martinez et al. 2009; Rejili et al. 2012]
Vicia sepium	*Rhizobium* [Kan et al. 2007; Ampomah & Huss-Danell, 2016]
Vicia sylvatica	*Rhizobium* [Ampomah & Huss-Danell, 2016]
Vicia tetrasperma	*Rhizobium* [Ampomah & Huss-Danell, 2016]
Vicia villosa	*Rhizobium* [Kan et al. 2007]
Galegeae	
***Astragalus** adsurgense*	*Ensifer* [Chen et al. 2015], *Mesorhizobium* [Chen et al. 2015], *Rhizobium* [Wei et al. 2008b]
Astragalus aksuensis	*Rhizobium* [Han et al. 2008b]
Astragalus betetovii	*Rhizobium* [Han et al. 2008b]
Astragalus complanatus	*Ensifer* [Chen et al. 2015], *Mesorhizobium* [Chen et al. 2015], *Rhizobium* [Wei et al. 2008b]
Astragalus chrysopterus	*Rhizobium* [Wei et al. 2008b]
Astragalus discolor, *Astragalus efoliolatus*, *Astragalus kifonsanicus*	*Mesorhizobium* [Chen et al. 2015]
Astragalus melilotoides	*Ensifer* [Chen et al. 2015], *Mesorhizobium* [Chen et al. 2015]
Astragalus membranaceus	*Mesorhizobium* [Zhao et al. 2012; Chen et al. 2015; Yan et al. 2016]
Astragalus mongholicus	*Mesorhizobium* [Yan et al. 2016]
Astragalus polycladus	*Rhizobium* [Chen et al. 2015]
Astragalus scaberrimus	*Mesorhizobium* [Chen et al. 2015], *Rhizobium* [Wei et al. 2008b]
***Biserrula** pelecinus*	*Mesorhizobium* [Nandasena et al. 2001; Nandasena et al. 2009]
***Carmichaelia** australis*, *Carmichaelia monroi*,	*Mesorhizobium* [Tan et al. 2012]
***Clianthus** puniceus*	*Mesorhizobium* [Tan et al. 2012]
***Colutea** arborescens*	Ensifer [Ourarhi et al. 2011], Mesorhizobium [Ruiz-Diéz et al. 2009; Ourarhi et al. 2011], *Rhizobium* [Ourarhi et al. 2011]
***Galega** officinalis*	*Neorhizobium* [Radeva et al. 2001; Liu et al. 2012]
Galega orientalis	*Neorhizobium* [Radeva et al. 2001]
***Glycyrrhiza** eurycarpa*	*Ensifer* [Li et al. 2012]
Glycyrrhiza glabra	*Mesorhizobium* [Wei et al. 2008a; Li et al. 2012], *Rhizobium* [Li et al. 2012]
Glycyrrhiza inflata	*Ensifer* [Li et al. 2012]
Glycyrrhiza multiflora	*Mesorhizobium* [Tan et al. 1999]
Glycyrrhiza pallidiflora	*Mesorhizobium* [Chen et al. 1995]
Glycyrrhiza uralensis	*Mesorhizobium* Tan et al. 1999; Li et al. 2012], *Rhizobium* [Li et al. 2012]
Glycyrrhiza sp.	*Mesorhizobium* [Li et al. 2012]
***Gueldenstaedtia** multiflora*	*Mesorhizobium* [Tan et al. 1999], *Rhizobium* [Tan et al. 1999; Tan et al. 2001]
***Lessertia** annulans*, *Lessertia capitata*, *Lessertia diffusa*, *Lessertia excisa*, *Lessertia frutescens*, *Lessertia herbacea*,	*Mesorhizobium* [Gerding et al. 2012]

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 1 August 2016 doi:10.20944/preprints201608.0005.v1

Lessertia microphylla, Lessertia pauciflora	
Lessertia sp.	*Ensifer* [Lemaire et al. 2015]
***Montigena** novae-zelandiae*	*Mesorhizobium* [Tan et al. 2013]
***Oxytropis** glabra*	*Ensifer* [Kan et al. 2007], *Mesorhizobium* [Han et al. 2008a], *Rhizobium* [Kan et al. 2007; Han et al. 2008b]
Oxytropis kansuenses	*Rhizobium* [Kan et al. 2007]
Oxytropis meinshausenii	*Rhizobium* [Han et al. 2008b]
Oxytropis myriophylla	*Mesorhizobium* [Kan et al. 2007]
Oxytropis ochrocephala	Mesorhizobium [Kan et al. 2007], *Rhizobium* [Kan et al. 2007]
Oxytropis psammocharis	*Rhizobium* [Kan et al. 2007]
Oxytropis sp.	*Phyllobacterium* [Kan et al. 2007]
***Sphaerophysa** salsula*	Ensifer [Deng et al. 2011], Mesorhizobium [Deng et al. 2011], Rhizobium [Deng et al. 2011; Xu et al. 2011]
***Swainsona** leeana, Swainsona pterostylis*	*Ensifer* [Yates et al. 2004]
Swainsona galegifolia	*Mesorhizobium* [Tan et al. 2013]
Hedysareae	
***Alhagi** sparsifolia*	*Mesorhizobium* [Wei et al. 2009]
Alhagi toum	*Rhizobium* [Han et al 2008b]
***Caragana** bicolor, Caragana erinacea*	*Mesorhizobium, Rhizobium* [Lu et al. 2009]
Caragana franchetiana	*Mesorhizobium,* [Lu et al. 2009]
Caragana intermedia	*Bradyrhizobium* [Lu et al. 2009], *Mesorhizobium* [Tan et al. 1999; Lu et al. 2009], *Rhizobium* [Lu et al. 2009]
Caragana jubata	*Rhizobium* [Han et al. 2008b]
Caragana microphylla	*Mesorhizobium* [Guan et al. 2008]
***Halimodendron** halodendron*	*Rhizobium* [Han et al 2008b]
***Hedysarum** coronarium*	*Rhizobium* [Squartini et al. 2002; Liu et al. 2012]
Hedysarum polybotrys	*Rhizobium* [Wei et al. 2008b], *Mesorhizobium* [Yan et al. 2016]
Hedysarum scoparium	*Rhizobium* [Wei et al. 2008b]
Hedysarum spinosissimum	*Ensifer* [Rejilli et al. 2012]
***Onobrychis** viciifolia*	*Phyllobacterium* [Baimiev et al. 2007]
Millettieae	
***Milletia** leucantha*	*Bradyrhizobium* [Manassila et al. 2007]
Millettia pinnata	*Rhizobium* [Kesari et al. 2013]
***Tephrosia** capensis*	*Bradyrhizobium* [Lemaire et al. 2015]
Tephrosia falciformis	*Bradyrhizobium* [Gehlot et al. 2012], *Ensifer* [Gehlot et al. 2012]
Tephrosia purpurea	*Bradyrhizobium* [Doignon-Bourcier et al. 1999], *Ensifer* [Gehlot et al. 2012], *Rhizobium* [Gehlot et al. 2012]
Tephrosia villosa	*Bradyrhizobium* [Doignon-Bourcier et al. 1999; Gehlot et al. 2012], *Ensifer* [Gehlot et al. 2012]
Tephrosia wallichii	*Ensifer* [Gehlot et al. 2012]
Trifolieae	
***Medicago** archiducis-nicolai*	*Rhizobium* [Kan et al. 2007]
Medicago intertexta	*Ensifer* [El Batanony et al. 2015]
Medicago laciniata	*Ensifer* [Villegas et al. 2006; Badri et al. 2007; Mnasri et al. 2009; El Batonany et al. 2015], *Neorhizobium* [El Batonany et al. 2015]
Medicago lupulina	*Ensifer* [Kan et al. 2007; Wang et al. 2009]
Medicago orbicularis	*Ensifer* [Rome et al. 1996]

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 1 August 2016 doi:10.20944/preprints201608.0005.v1

Medicago polymorpha	*Ensifer* [El Batanony et al. 2015], *Neorhizobium* [El Batonany et al. 2015]
Medicago rigiduloides	*Ensifer* [Gubry-Rangin et al. 2013]
Medicago ruthenica	*Rhizobium* [van Berkum et al. 1998]
Medicago sativa	*Ensifer* [Yan et al. 2000; Kan et al. 2007; Mnsasri et al. 2009; Bromfield et al. 2010; Merabet et al. 2010; Djedidi et al. 2011], *Neorhizobium* [El Batanony et al. 2015], *Rhizobium* [Bromfield et al. 2010]
Medicago scutellata	*Ensifer* [Mnasri et al. 2009]
Medicago truncatula	*Ensifer* [Rome et al. 1996; Badri et al. 2007; Mnasri et al. 2009]
***Melilotus** alba*	*Ensifer* [Bromfield et al. 2010], *Rhizobium* [Bromfield et al. 2010]
Melilotus indicus, Melilotus messanensis	*Ensifer* [El Batanony et al. 2015]
Melilotus officinalis	*Ensifer* [Kan et al. 2007; Wang et al. 2009]
Melilotus siculus	*Ensifer* [El Batanony et al. 2015]
***Trifolium** fragiferum*	*Bradyrhizobium* [Liu et al. 2007], *Mesorhizobium* [Liu et al. 2007], *Rhizobium* [Liu et al. 2007]
Trifolium pratense	*Phyllobacterium* [Valverde et al. 2005],
Trifolium repens	*Bradyrhizobium* [Liu et al. 2007], *Ensifer* [Liu et al. 2007], *Rhizobium* [Liu et al. 2007; Zhang et al. 2016]
***Trigonella** maritima*	*Ensifer* [Rejili et al. 2012; El Batanony et al. 2015]

Table 3. Legume-rhizobia symbioses of species in the sub-family Papilionoideae with indeterminate nodules excluding the inverted repeat lacking clade.

Papilionoideae Tribes (genera)	Rhizobia – field
Abreae	
***Abrus** precatorius*	*Ensifer* [Ogasawara et al. 2003]
Amorpheae	
***Amorpha** fruticosa*	*Bradyrhizobium* [Wang et al. 1999b], *Mesorhizobium* [Tan et al. 1999; Wang et al. 1999b; Wang et al. 2009]
***Dalea** purpurea*	*Mesorhizobium* [Tlusty et al. 2005], *Rhizobium* [Tlusty et al. 2005]
Crotalarieae	
***Aspalathus** callosa*	*Burkholderia* [Lemaire et al. 2015]
Aspalathus ciliaris, Aspalathus uniflora	*Mesorhizobium* [Lemaire et al. 2015]
Aspalathus linearis	*Bradyrhizobium* [Hassen et al. 2012], *Burkholderia* [Hassen et al. 2012], *Herbaspirillum* [Hassen et al. 2012], *Mesorhizobium* [Hassen et al. 2012], *Rhizobium* [Hassen et al. 2012]
***Crotalaria** comosa, Crotalaria hyssopifolia, Crotalaria lathyroides*	*Bradyrhizobium* [Sy et al. 2001]
Crotalaria pallida	*Bradyrhizobium* [Liu et al. 2007], *Burkholderia* [Liu et al. 2007], *Rhizobium* [Liu et al. 2007]
Crotalaria perrotteti, Crotalaria podocarpa	*Methylobacterium* [Sy et al. 2001]
Crotalaria sp.	*Burkholderia* [Lemaire et al. 2015]
***Lebeckia** ambigua*	*Burkholderia* [Howieson et al. 2013]
***Listia** angolensis*	*Microvirga* [Ardley et al. 2012]
Listia bainesii, Listia solitudinis, Listia listii	*Methylobacterium* [Yates et al. 2007]
Rafnia sp.	*Burkholderia* [Lemaire et al. 2015]

 doi:10.20944/preprints201608.0005.v1

Genisteae	
***Adenocarpus** hispanicus*	*Phyllobacterium* [Ruiz-Diéz et al. 2009]
***Argyrolobium** uniflorum*	*Ensifer* [Mnasri et al. 2009; Merabet et al. 2010]
Argyrolobium sp.	*Mesorhizobium* [Lemaire et al. 2015]
***Cytisus** aeolicus*	*Bradyrhizobium* [Cardinale et al. 2008]
Cytisus balansae	*Bradyrhizobium* [Rodriguez-Echeverria et al. 2003]
Cytisus laburnum	*Bradyrhizobium* [Ruiz-Diez et al. 2009]
Cytisus multiflorus	*Bradyrhizobium* [Rodriguez-Echeverria et al. 2003]
Cytisus proliferus	*Bradyrhizobium* [Vinuesa et al. 1998; Jarabo-Lorenzo et al. 2000; Jarabo-Lorenzo et al 2003; Vinuesa et al. 2005a]
Cytisus purgans	*Bradyrhizobium* [Ruiz-Diez et al. 2009]
Cytisus scoparius	*Bradyrhizobium* [Kalita et al. 2004; Horn et al. 2014]
Cytisus striatus	*Bradyrhizobium* [Rodriguez-Echeverria et al. 2003]
Cytisus villosus	*Bradyrhizobium* [Chahboune et al. 2011]
***Genista** hystrix*	*Bradyrhizobium* [Rodriguez-Echeverria, 2003]
Genista stenopetula	*Bradyrhizobium* [Vinuesa et al. 2005a]
Genista versicolor	*Bradyrhizobium* [Cobo-Diaz et al. 2014]
***Lupinus** albescens*	*Bradyrhizobium* [Stroschein et al. 2010; Granada et al. 2015]
Lupinus albus	*Bradyrhizobium* [Jarabo-Lorenzo 2003, Velazquez et al. 2010; Stepkowski et al. 2011]
Lupinus angustifolius	*Bradyrhizobium* [Jarabo-Lorenzo 2003; Stepkowski et al. 2011]
Lupinus honoratus	*Ochrobactrum* [Trujillo et al. 2005]
Lupinus luteus	*Bradyrhizobium* [Jarabo-Lorenzo et al. 2003; Stepkowski et al. 2011]
Lupinus mariae-josephae	*Bradyrhizobium* [Sánchez-Cañizares et al. 2011; Duran et al. 2013]
Lupinus montanus	*Bradyrhizobium* [Vinuesa et al. 2005]
Lupinus polyphyllus	*Bradyrhizobium* [Vinuesa et al. 2005; Ryan-Salter et al. 2014]
Lupinus texensis	*Microvirga* [Ardley et al. 2012]
Lupinus sp.	*Bradyrhizobium* [Jarabo-Lorenzo et al. 2003]
***Retama** monosperma*	*Bradyrhizobium* [Guerrouj et al. 2013]
Retama raetam	*Bradyrhizobium* [Farida et al. 2009]
Retama sphaerocarpa	*Bradyrhizobium* [Rodriguez-Echeverria, 2003; Farida et al. 2009; Guerrouj et al. 2013; Rodriguez –Echeverria, 2014], *Phyllobacterium* [Ruiz-Diez et al. 2009]
***Spartium** junceum*	*Bradyrhizobium* [Quatrini et al. 2002; Cardinale et al. 2008; Ruiz-Diéz et al. 2009], *Phyllobacterium* [Ruiz-Diez et al. 2009]
***Ulex** europaeus*	*Bradyrhizobium* [Liu 2014]
Hypocalypteae	
***Hypocalyptus** coluteoides, Hypocalyptus oxalidifolius, Hypocalyptus sophoroides*	*Burkholderia* [Beukes et al. 2013]
Indigofereae	
Indigofera angustifolia	*Burkholderia* [Lemaire et al. 2015]
Indigofera astragalina	*Bradyrhizobium* [Doignon-Bourcier et al. 1999]
Indigofera hirsuta	*Bradyrhizobium* [Doignon-Bourcier et al. 1999]
Indigofera senegalensis	*Bradyrhizobium* [Doignon-Bourcier et al. 1999]
Indigofera tinctoria	*Bradyrhizobium* [Doignon-Bourcier et al. 1999]

Loteae	
***Coronilla** varia*	Mesorhizobium [Yang et al. 2013], Rhizobium [Tan et al. 1999; Tan et al. 2001; Yang et al. 2013]
***Ornithopus** compressus, Ornithopus sativus*	*Bradyrhizobium* [Stepkowski et al. 2005]
Podalyrieae	
***Cyclopia** buxifolia, Cyclopia genistoides, Cyclopia glabra, Cyclopia intemedia, Cyclopia longifolia, Cyclopia maculata, Cyclopia meyeriana, Cyclopia pubescens, Cyclopia sessiflora, Cyclopia subternata*	*Burkholderia* [Beukes et al. 2013]
***Podalyria** burchelli*	*Burkholderia* [Lemaire et al. 2015]
Podalyria calyptrata	*Burkholderia* [Beukes et al. 2013; Lemaire et al. 2015; Lemaire et al. 2016]
Podalyria sericea	*Burkholderia* [Lemaire et al. 2015]
***Virgilia** divaricata*	*Rhizobium* [Lemaire et al. 2015]
Virgilia oroboides	*Burkholderia* [Beukes et al. 2013; Lemaire et al. 2015]
Robineae	
***Gliricidia** sepium*	*Ensifer* [Bala & Giller, 2001], *Rhizobium* [Bala & Giller, 2001]
***Robinia** pseudocacia*	*Mesorhizobium* [Ulrich & Zaspel 2000; Mierzwa et al. 2009], *Rhizobium* [Ulrich & Zaspel 2000; Han et al. 2008b]
Sesbanieae	
***Sesbania** aculeata*	*Ensifer* [Lortet et al. 1996]
Sesbania cannabina	*Ensifer* [Lortet et al. 1996; Chen & Lee, 2001; Wang et al. 2013a; Li et al. 2016], *Neorhizobium* [Li et al. 2016], *Rhizobium* [Chen & Lee 2001; Li et al. 2016]
Sesbania exasperata	*Rhizobium* [Vinuesa et al. 2005b]
Sesbania grandiflora	*Ensifer* [Lortet et al. 1996]
Sesbania herbacea	*Rhizobium* [Wang et al. 1998]
Sesbania pachycarpa	*Ensifer* [Lortet et al. 1996]
Sesbania punicea	*Azorhizobium* [Blanco et al. 2008; Lemaire et al. 2015], *Mesorhizobium* [Vinuesa et al. 2005b], *Rhizobium* [Blanco et al. 2008]
Sesbania rostrata	Azorhizobium [Dreyfus et al. 1988; Moreira et al. 2006], *Bradyrhizobium* [Sinsuwongwat et al. 2002], *Ensifer* [Lortet et al. 1996; Ogasawara et al. 2003], *Rhizobium* [Sinsuwongwat et al. 2002]
Sesbania sericea	*Mesorhizobium* [Vinuesa et al. 2005b], *Rhizobium* [Vinuesa et al. 2005b]
Sesbania sesban	*Ensifer* [Lortet et al. 1996; Bala & Giller, 2001; Degefu et al. 2012], *Mesorhizobium* [Bala & Giller 2001; Odee et al. 2002; Degefu et al. 2011], *Rhizobium* [Bala & Giller 2001; Odee et al. 2002]
Sesbania virgata	*Azorhizobium* [Moreira et al. 2006], *Rhizobium* [Blanco et al. 2008]
Sesbania sp.	*Ensifer* [Lortet et al. 1996]
Sophoreae	
***Sophora** alopecuroides*	*Ensifer* [Zhao et al. 2010] *Mesorhizobium* [Zhao et al. 2010], *Phyllobacterium* [Zhao et al. 2010], *Rhizobium* [Han et al. 2008b; Zhao et al. 2010]
Sophora flavescens	*Bradyrhizobium* [Jiao et al. 2015a], *Ensifer* [Jiao et al. 2015a], *Mesorhizobium* [Jiao et al. 2015a], *Phyllobacterium* [Jiao et al 2015b], *Rhizobium* [Jiao et

 doi:10.20944/preprints201608.0005.v1

	al. 2015a]
Sophora longicarinata, S. microphylla, S. prostrata, S. tetraptera	*Mesorhizobium* [Tan et al. 2015]
Sophora viciifolia	*Mesorhizobium* [Tan et al. 1999]
Thermopsideae	
***Ammopiptanthus** nanus, Ammopiptanthus mongolicus*	*Ensifer* [Zhao et al. 2016], *Neorhizobium* [Zhao et al. 2016], *Pararhizobium* [Zhao et al. 2016], *Rhizobium* [Zhao et al. 2016]
***Anagyris** latifolia*	*Mesorhizobium* [Donate-Correa et al. 2007]
***Thermopsis** lupinoides*	*Mesorhizobium* [Ampomah & Huss-Danell, 2011]

Table 4. Legume-rhizobia symbioses of species in the sub-family Papilionoideae with determinate nodules.

Papilionoideae Tribes and genera	Rhizobia – field
Dalbergieae	
***Adesmia** bicolor*	*Rhizobium* [Bianco et al. 2013]
***Aeschynomene** afraspera*	*Bradyrhizobium* [Miché et al. 2010]
Aeschynomene americana	*Bradyrhizobium* [Miché et al. 2010; Noisangian et al. 2012]
Aeschynomene ciliata, Aeschynomene elaphroxylon	*Bradyrhizobium* [Miché et al. 2010]
Aeschynomene indica	*Bradyrhizobium* [Van Berkum & Eardly, 2002; Miché et al. 2010]
Aeschynomene rudis	*Bradyrhizobium* [Montecchia et al. 2002; Miché et al. 2010]
Aeschynomene scabra, Aeschynomene sensitiva, Aeschynomene shimperi	*Bradyrhizobium* [Miché et al. 2010]
***Arachis** duranensis*	*Bradyrhizobium* [Chen et al. 2014]
Arachis hypogaea	*Bradyrhizobium* [Urtz & Elkan, 1996; Sinsuwongwat et al. 2002; Yang et al. 2005; Taurian et al. 2006; El-Akhal et al. 2008; Steenkamp et al. 2008; Chang et al. 2011; Munoz et al. 2011; Wang et al. 2013b; Grönemeyer et al. 2014; Li et al. 2015; Chen et al. 2016], *Rhizobium* [Taurian et al. 2006; El-Akhal et al. 2008]
***Centrolobium** paraense*	*Bradyrhizobium* [Baraúna et al. 2014; Zilli et al. 2014]
***Dalbergia** baroni, Dalbergia louveli, Dalbergia madagascariensis, Dalbergia maritima, Dalbergia monticola,*	*Bradyrhizobium* [Rasolomampianina et al. 2005]
Dalbergia odorifera	*Burkholderia* [Lu et al. 2012]
Dalbergia purpurascens	*Bradyrhizobium* [Rasolomampianina et al. 2005]
Dalbergia sp.	*Bradyrhizobium* [Rasolomampianina et al. 2005]
***Pterocarpus** officinalis*	*Bradyrhizobium* [Le Roux et al. 2014]
Pterocarpus indicus	*Bradyrhizobium* [Sinsuwongwat et al. 2002; Manassila et al. 2007]
Zornia glochidiata	*Bradyrhizobium* [Gueye et al. 2009]
Desmodieae	
***Desmodium** caudatum*	*Bradyrhizobium* [Gu et al. 2007]
Desmodium elegans	*Bradyrhizobium* [Gu et al. 2007; Xu et al. 2016], *Pararhizobium* [Xu et al. 2016]

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 1 August 2016 doi:10.20944/preprints201608.0005.v1

Desmodium fallax	*Bradyrhizobium* [Gu et al. 2007]
Desmodium gangeticum	*Bradyrhizobium* [Gu et al. 2007; Xu et al. 2016]
Desmodium heterocarpan	*Bradyrhizobium* [Gu et al. 2007; Delamuta et al. 2015]
Desmodium microphyllum	*Bradyrhizobium* [Gu et al. 2007], *Mesorhizobium* [Gu et al. 2007], *Rhizobium* [Gu et al. 2007]
Desmodium oldhami	*Rhizobium* [Xu et al. 2016]
Desmodium racemosum	*Bradyrhizobium* [Gu et al. 2007], *Ensifer* [Gu et al. 2007], *Rhizobium* [Gu et al. 2007]
Desmodium sequax	*Bradyrhizobium* [Gu et al. 2007], *Ensifer* [Gu et al. 2007], *Mesorhizobium* [Xu et al. 2016], *Pararhizobium* [Xu et al. 2016], *Rhizobium* [Gu et al. 2007; Xu et al. 2016]
Desmodium sinuatum	*Rhizobium* [Chen et al. 1997]
Desmodium triflorum	*Bradyrhizobium* [Gu et al. 2007]
***Kummerowia** stipulacea*	*Bradyrhizobium* [Lin et al. 2007; Wang et al. 2009], *Rhizobium* [Lin et al. 2007]
Kummerowia striata	*Bradyrhizobium* [Lin et al. 2007], *Ensifer* [Lin et al. 2007], *Rhizobium* [Lin et al. 2007]
***Lespedeza** bicolor*	*Bradyrhizobium* [Yao et al. 2002], *Ensifer* [Yao et al. 2002], *Mesorhizobium* [Wang et al. 2009] *Rhizobium* [Yao et al. 2002]
Lespedeza capitata, Lespedeza cuneata	*Bradyrhizobium* [Yao et al. 2002]
Lespedeza cystobotrya	*Ensifer* [Yao et al. 2002], *Rhizobium* [Wei et al. 2008b]
Lespedeza daurica	*Bradyrhizobium* [Yao et al. 2002], *Ensifer* [Yao et al. 2002], *Mesorhizobium* [Yao et al. 2002]
Lespedeza davidii	*Rhizobium* [Wei et al. 2008b]
Lespedeza inschanica	*Ensifer* [Yao et al. 2002]
Lespedeza juncea, Lespedeza procumbens, Lespedeza stipulacea, Lespedeza striata	*Bradyrhizobium* [Yao et al. 2002]
Lespedeza tomentosa	*Ensifer* [Yao et al. 2002]
Phaseoleae	
***Amphicarpaea** bracteata, Amphicarpaea edgeworthii*	*Bradyrhizobium* [Parker et al. 2004]
Amphicarpaea trisperma	*Rhizobium* [Tan et al. 1999]
***Bolusafra** bituminosa*	*Burkholderia* [Lemaire et al. 2015]
***Cajanus** cajan*	*Bradyrhizobium* [Araujo et al. 2015]
***Canavalia** rosea*	*Ensifer* [Chen et al. 2000]
***Centrosema** pascuorum*	*Bradyrhizobium* [Sinsuwongwat et al. 2002]
Centrosema pubescens	*Bradyrhizobium* [Hélene et al. 2015]
***Dipogon** lignosus*	*Burkholderia* [Liu et al. 2014]
***Glycine** max*	*Bradyrhizobium* [Xu et al. 1995; Sinsuwongwat et al. 2002; Barcellos et al. 2007; Appunu et al. 2009; Wang et al. 2009; Zhang et al. 2011; Jaiswal et al. 2012; Tang et al. 2012; Wang et al. 2013c; Ribeiro et al. 2015], *Ensifer* [Peng et al. 2002; Barcellos et al. 2007; Appunu et al. 2009; Li et al. 2011; Zhang et al. 2011], *Rhizobium* [Alam et al. 2015]
Glycine soja	*Bradyrhizobium* [Wang et al. 2009; Wu et al. 2011], *Ensifer* [Wu et al.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 1 August 2016 doi:10.20944/preprints201608.0005.v1

	2011], *Rhizobium* [Zhao et al. 2014]
Lablab *purpureus*	*Bradyrhizobium* [Chang et al. 2011; Wang et al. 2013b; Grönemeyer et al. 2014]
Neonotonia *wightii*	*Bradyrhizobium* [Delamuta et al. 2015]
Pachyrhizus *erosus*	*Bradyrhizobium* [Fuentes et al. 2002; Rodriguez-Navarro et al. 2004; Ramirez-Bahena et al. 2009], *Rhizobium* [Fuentes et al. 2002]
Pachyrhizus ferrugineus	*Bradyrhizobium* [Rodriguez-Navarro et al. 2004]
Pachyrhizus tuberosus	*Bradyrhizobium* [Rodriguez-Navarro et al. 2004]
Phaseolus *lunatus*	*Bradyrhizobium* [López-López et al. 2013; Durán et al. 2014; Matsubara & Zúñiga-Dávila 2015], *Rhizobium* [Matsubara & Zúñiga-Dávila 2015]
Phaseolus vulgaris	*Bradyrhizobium* [López-López et al. 2013; Wang et al. 2016], *Burkholderia* [Talbi et al. 2010; Dall'Agnol et al. 2016], *Ensifer* [Mhamdi et al. 2002; Mnasri et al. 2007; Mnasri et al. 2012; Wang et al. 2016], *Pararhizobium* [Wang et al. 2016], *Rhizobium* [Martinez-Romero et al. 1991; Amarger et al. 1997; Mhamdi et al. 2002; Mostasso et al. 2002; Valverde et al. 2006; Mnasri et al. 2007; Wang et al. 2009; Wang et al. 2011; López-López et al. 2012; Mnasri et al. 2012; Ribeiro et al. 2013; Zahran et al. 2013; Cao et al. 2014; Grönemeyer et al. 2014; Wang et al. 2016]
Pueraria *phaseoloides*	*Bradyrhizobium* [Sarr et al. 2016]
Rhynchosia *aurea*	*Ensifer* [Gehlot et al. 2012]
Rhynchosia ferulifolia	*Burkholderia* [Garau et al. 2009; De Meyer et al. 2013]
Rhynchosia minima	*Bradyrhizobium* [Doignon-Bourcier et al. 1999; Garau et al. 2009]
Rhynchosia totta	*Bradyrhizobium* [Garau et al. 2009]
Vigna *angularis*	*Bradyrhizobium* [Han et al. 2009], *Ensifer* [Han et al. 2009], *Rhizobium* [Han et al. 2009]
Vigna radiata	*Bradyrhizobium* [Zhang et al. 2008; Risal et al. 2012], *Ensifer* [Zhang et al. 2008], *Rhizobium* [Zhang et al. 2008]
Vigna sinensis	*Bradyrhizobium* [Sinsuwongwat et al. 2002]
Vigna subterranea	*Bradyrhizobium* [Grönemeyer et al. 2014; Onyango et al. 2015], *Burkholderia* [Onyango et al. 2015], *Rhizobium* [Onyango et al. 2015]
Vigna ungiuculata	*Achromobacter* [Guimarães et al. 2012], *Bradyrhizobium* [Steenkamp et al. 2008; Zhang et al. 2008; Guimarães et al. 2012; Bejarano et al. 2014; Grönemeyer et al. 2014; Silva et al. 2014], *Burkholderia* [Guimarães et al. 2012], *Rhizobium* [Zhang et al. 2008; Guimarães et al. 2012]
Psoraleae	
Otholobium *bracteolatum, Otholobium hirtum, Otholobium virgatum, Otholobium zeyhari, Otholobium* sp	*Mesorhizobium* [Lemaire et al. 2015]
Psoralea *asarina*	*Burkholderia* [Kanu & Dakora, 2012]
Psoralea corylifolia	*Ensifer* [Wang et al. 2013a]
Psoralea pinnata	*Burkholderia* [Kanu & Dakora, 2012], *Mesorhizobium* [Kanu & Dakora, 2012; Lemaire et al. 2015]
Loteae	
Lotus arabicus, Lotus arinagensis	*Ensifer* [Merabet et al. 2010]
Lotus bertheloti, Lotus callis-viridis, Lotus campylocladus	*Mesorhizobium* [Lorite et al. 2010a]
Lotus corniculatus	*Geobacillus* [Ampomah & Huss-Danell, 2011], *Mesorhizobium* [Jarvis et al. 1997; Lorite et al. 2010a; Lorite et al. 2010b; Ampomah & Huss-Danell, 2011; Marcos-Garcia et al. 2015], *Paenibacillus*

	[Ampomah & Huss-Danell, 2011], *Rhodococcus* [Ampomah & Huss-Danell, 2011]
Lotus creticus	*Ensifer* [Merabet et al. 2010; Rejili et al. 2012], *Mesorhizobium* [Merabet et al. 2010; Rejili et al. 2012], *Rhizobium* [Merabet et al. 2010; Rejili et al. 2012],
Lotus frondosus	*Mesorhizobium* [Han et al. 2008a], *Rhizobium* [Han et al. 2008b]
Lotus halophyllus	*Ensifer* [Rejili et al. 2012]
Lotus kunkeli, Lotus lancerottensis, Lotus maculatus	*Ensifer* [Léon-Barrios et al. 2009]
Lotus pyranthus	*Mesorhizobium* [Lorite et al. 2010a]
Lotus sessilifolius	*Ensifer* [Léon-Barrios et al. 2009], *Mesorhizobium* [Lorite et al. 2010a]
Lotus tenuis	*Mesorhizobium* [Estrella et al. 2009; Lorite et al. 2010b; Sannazzaro et al. 2011], *Rhizobium* [Han et al. 2008b; Estrella et al. 2009]
Lotus uliginosus	*Bradyrhizobium* [Lorite et al. 2012]