Corrigendum: Phytoplasmas—The “Crouching Tiger” Threat of Australian Plant Pathology

Jian Liu1,2,3, David Gopurenko3,4, Murray J. Fletcher3, Anne C. Johnson3 and Geoff M. Gurr1,2,3*

1 State Key Laboratory of Ecological Pest Control for Fujian and Taiwan Crops, Fujian Agriculture and Forestry University, Fuzhou, China, 2 Institute of Applied Ecology, Fujian Agriculture & Forestry University, Fuzhou, China, 3 Institute of Applied Ecology, Fujian Agriculture & Forestry University, Fuzhou, China, * Correspondence: Geoff M. Gurr gurr@csu.edu.au

Open Access

Edited and reviewed by: Brigitte Mauch-Mani, University of Neuchâtel, Switzerland

*Correspondence: Geoff M. Gurr gurr@csu.edu.au

Specialty section: This article was submitted to Plant Microbe Interactions, a section of the journal Frontiers in Plant Science

Received: 21 June 2018 Accepted: 17 August 2018 Published: 26 October 2018

Citation: Liu J, Gopurenko D, Fletcher M. J., Johnson A. C., & Gurr, G. M. (2017). Front. Plant Sci. 8:599. doi: 10.3389/fpls.2017.00599

In the original article, information for phytoplasmas in Table 1 did not fully reflect recent changes in taxonomy, or showed changes only as footnotes. Corrections have been made in the sections below and in Table 1.

Abstract
Phytoplasmas are insect-vectored bacteria that cause disease in a wide range of plant species. The increasing availability of molecular DNA analyses, expertise, and additional methods in recent years has led to a proliferation of discoveries of phytoplasma-plant host associations and in the numbers of taxonomic groupings for phytoplasmas. The widespread use of common names based on the diseases with which they are associated, as well as separate phenetic and taxonomic systems for classifying phytoplasmas based on variation at the 16S rRNA-encoding gene, complicates interpretation of the literature. We explore this issue and related trends through a focus on Australian pathosystems, providing the first comprehensive compilation of information for this continent, covering the phytoplasmas, host plants, vectors, and diseases. Of the 33 16Sr groups currently defined, only groups II, XI, XII, XXIII, XXV, and XXXIII have been recorded in Australia and this highlights the need for ongoing biosecurity measures to prevent the introduction of additional pathogen groups. Many of the phytoplasmas reported in Australia have not been sufficiently well-studied to assign them to 16Sr groups so it is likely that unrecognized groups and sub-groups are present. Wide host plant ranges are apparent among well studied phytoplasmas, with multiple crop and non-crop species infected by some. Disease management is further complicated by the fact that putative vectors have been identified for few phytoplasmas, especially in Australia. Despite rapid progress in recent years using molecular approaches, phytoplasmas remain the least well-studied group of plant pathogens, making them a “crouching tiger” disease threat.

Issue 2: Complex taxonomic nomenclature, paragraphs 2 and 3
Second, as molecular methods became available, workers were able to group and phenetically classify phytoplasmas using restricted fragment length polymorphism (RFLP) analysis of a PCR amplified portion of the 16S rRNA gene with a defined set of restriction enzymes (Lee et al., 1998). The RFLP profiles generated for different phytoplasmas are generally consistent with sequence-based phylogenetic analyses of the 16S rRNA gene, particularly in the co-identification and grouping of related strains. The 33 16Sr groups currently defined each have a similarity of less
| 16Sr group | "Candidatus Phytoplasma" name | Phytoplasma trivial name | Host plant species | Potential vectors | Location* | References* |
|------------|-----------------------------|--------------------------|--------------------|------------------|----------|------------|
| II         | australasiae³ | Australian lucerne yellows | Medicago sativa, Carica papaya | Orobus argentatus, Austroagallia torriss, Orosius spp., Batracomorphus sp. | South Australia, New South Wales, Northern Territory | Padovan and Gibb, 2001¹; Pilkington et al., 2003²; Yang et al., 2013 |
| II         | Bonamia pannosa little leaf | Bonamia pannosa | | | Northern Territory | Schneider et al., 1999; Padovan and Gibb, 2001 |
| II         | Cactus witches’ broom | Carica papaya | | | Northern Territory | Padovan and Gibb, 2001 |
| II         | Cocky apple witches’ broom | Pterochonia careya | | | Queensland | Davis et al., 2001 |
| II         | Waltheria little leaf | Mitracarpus hirtus, Saccharum sp., Spermacoce sp., Waltheria indica, Carica papaya | | | Northern Territory | Schneider et al., 1999; Tran-Nguyen et al., 2000; Padovan and Gibb, 2001; Wilson et al., 2001 |
| II         | australasiae | Tomato big bud | Achyrathes aspera, Aeschynomene spp., Alysicarpus rugosus, Ameranthus sp., Apium graveolens, Arachis spp., Boerhaavia sp., Brugmansia x candida, Capsicum annum, Carica papaya, Catharanthus roseus, Cajanus cajan, Citrus paradisi, Croton coccoides, Crotalaria spp., Cenchrus ciliaris, Cichorium intybus, Cleome viscosa, Cucurbita maxima, Cynodon dactylon, Daucus carota, Eclipsia sonchifolia, Eragrostis tefzita, Eriachne obtusa, Euphorbia mili, Evolvulus sp., Gerbera sp., Goodenia sp., Guizotia abyssinica, Ipomoea spp., Lactuca sativa, Lycopersicon esculentum, Macroplium spp., Medicago sativa, Mucuna pruriens, Passiflora sp., Phlox sp., Psyllalis minima, Potobulus divsana, Rychnchosia minima, Saccharum sp., Sarcocinus hartmanii × S. falcatum, Sesamum indicum, Sida cordifolia, Lycopersicon esculentum, Solarium melongena, Stylosanthes scabra, Trifolium repens, Vigna spp., Vite vinifera, Zinnia elegans | Austroagallia torriss | Northern Territory, New South Wales, Queensland, Western Australia, Victoria | Gibb et al., 1995; Davis et al., 1997b; Gowanlock et al., 1998; De La Rue et al., 1999; Tran-Nguyen et al., 2000, 2003; Wilson et al., 2001; Pilkington et al., 2004; Streten and Gibb, 2006 |
| II         | aurantifolia | Chickpea little leaf | Cicer arietinum | | Western Australia | Saqib et al., 2005 |
| II         | australasiae | Papaya yellow crinkle | Carica papaya | | Queensland | Gibb et al., 1996; White et al., 1998 |
| II         | australasiae | Papaya mosaic | Carica papaya | | Queensland | Gibb et al., 1996; White et al., 1998 |
| II         | Tree medic witches’ broom | Medicago arborea | | | South Australia | Yang et al., 2013 |
TABLE 1 | Continued

| 16Sr group | “Candidatus Phytoplasma” name | Host plant species | Potential vectors | Location | References |
|------------|-------------------------------|-------------------|-------------------|---------|-----------|
| II         | Pigeon pea phyloidy           | Cajanus cajan     |                   | South Australia | Yang et al., 2013 |
| II         | Pigeon pea little leaf        | Arachis spp.,  Crotalaria sp.,  Desmodium triflorum,  Indigofera sp.,  Macroptilium bracteatum,  Petroselinum sp.,  Sesuvium portulacastrum,  Stylosanthes spp.,  Vigna radiata |                   | Northern Territory, Queensland, Torres Strait | Schneider et al., 1999; De La Rue et al., 2001; Padovan and Gibb, 2001; Wilson et al., 2001; Davis et al., 2003; Streten and Gibb, 2006 |
| II-D       | australasiae                  | Pale purple coneflower witches’ broom |                    | Tasmania | Peace et al., 2011 |
| XI-B       | Cynodon white leaf            | Cynodon dactylon,  Dactyloctenium aegyptium |                   | Northern Territory, Western Australia | Schneider et al., 1999; Tran-Nguyen et al., 2000; Blanche et al., 2003 |
| XI-B       | Sorghum grassy shoot          | Dactyloctenium spp.,  Sorghum stipoideum,  Whiteochloa spp.,  Chloris inflata,  Whiteochloa cymbiformis |                   | Western Australia, Northern Territory | Tran-Nguyen et al., 2000; Blanche et al., 2003 |
| XII        | Australian lucerne yellows    | Medicago sativa    |                   | New South Wales | Getachew et al., 2007 |
| XII        | Papaya dieback                | Carica papaya      |                   | Queensland | Gibb et al., 1996; White et al., 1998 |
| XII-B      | australiense                  | Pumpkin yellow leaf curl | Cucurbita maxima,  C. moschata | Queensland, Western Australia, Northern Territory | Streten et al., 2005 |
| XII-B      | australiense                  | Cenchrus bunchy shoot | Cenchrus setiger | Western Australia | Tran-Nguyen et al., 2000 |
| XII-B      | australiense                  | Strawberry green petal disease | Fragaria x ananassa | Queensland | Padovan et al., 2000 |
| XII-B      | australiense                  | Strawberry lethal yellows | Fragaria x ananassa | Queensland | Padovan et al., 2000 |
| XII-B      | australiense                  | Australian grapevine yellows | Vitis vinifera,  Carica papaya | South Australia, Queensland | Davis et al., 1997a; Davis and Sinclair, 1998; Davis et al., 2003 |
| XXIIIc     |                               | Buckland Valley grapevine yellows | Vitis vinifera | Victoria | Constable et al., 2003; Streten and Gibb, 2006; Zhao and Davis, 2016 |

(Continued)
## TABLE 1 | Continued

| 16Sr group | “Candidatus Phytoplasma” name | Host plant species | Potential vectors | Location^\(\dagger\) | References* |
|------------|-----------------------------|--------------------|------------------|-----------------|-------------|
| XXV^1      | Weeping tea tree witches’ broom | Melaleuca spp.      |                  | Queensland      | Davis et al., 2003; Zhao and Davis, 2016 |
| XXXIII     | Allocasuarina yellows        | Allocasaurina muelleriana |                | South Australia | Gibb et al., 2003; Zhao and Davis, 2016 |
|            | Poinsettia branching^b       | Euphorbia pulcherrima |                |                | Schneider et al., 1999 |
|            | Galactia little leaf         | Galactia tenuiflora  |                  | Northern Territory | Padovan and Gibb, 2001 |
|            | Sorghum bunchy shoot         | Sorghum stipoidum   |                  |                | Tran-Nguyen et al., 2000 |
|            | Stylosanthes little leaf     | Achis pintoi, Carica papaya, Saccharum sp., Sesuvium portulacastrum, Stylosanthes scabra, Orosius spp., Stylosanthes brachyophylla, Stylosanthes graminifolia | Austroagallia torrida, Orosius spp., Batracomorphus sp. | Northern Territory, Queensland, New South Wales | Schneider et al., 1999; Tran-Nguyen et al., 2000; De La Rue et al., 2001; Padovan and Gibb, 2001; Davis et al., 2003; Gopurenko et al., 2016 |
|            | Sugarcane white leaf         | Saccharum sp.       |                  | Western Australia, Queensland | Tran-Nguyen et al., 2000 |
|            | Vigna little leaf             | Vigna lanscillata, Carica papaya, Tridax procumbens | Austroagallia torrida, Batracomorphus sp. | Northern Australia | Schneider et al., 1999; De La Rue et al., 2001; Padovan and Gibb, 2001 |
|            | Mundulia yellows disease^c   | Eucalyptus camaldulensis, E. barteri, E. leucophloea |                  | South Australia | Harold et al., 2006 |
|            | Paulownia witches’ broom^g   | Paulownia sp.       |                  | Western Australia | Bayliss et al., 2005 |

*Denotes reference for vector data.
^\(\dagger\) Location data are from the listed references but not every plant species was diseased in every location.
A new taxon, Ca. Phytoplasma australasiae was proposed (White et al., 1998) to include the phytoplasma associated with papaya yellow crinkle and papaya mosaic (as well as tomato big bud) but later revised to “Ca. australiasiae” (to include the papaya-associated phytoplasmas but not TBB; Firn et al., 2003). Davis and Sinclair (1998) moved the AGY phytoplasma from the 16SrI group into the stolbur group (16SrXII) and designated it subgroup B. Constable et al. (2003) reported a close relationship to 16Sr I. Zhao and Davis (2016) subsequently placed this into a new group: 16SrXXIII. Zhao and Davis (2016) placed this into this new group and potentially a new “Ca. Phytoplasma” species. This phytoplasma has not been found in economically important field crops. Tentative data only for a phytoplasma etiology. RFLP patterns showed high similarity to “Candidatus Phytoplasma australiasiae.”
than 85% compared with any representative phytoplasma from within an established 16Sr group (Zhao and Davis, 2016). Table 1 summarizes available information on the 16Sr groups reported in Australian studies. Of the 33 16Sr groups reported internationally, only groups II, XI, XII, XXIII, XXV, and XXXIII have been recorded in Australia and this highlights the need for ongoing biosecurity measures to prevent the introduction of additional pathogen groups.

Third, phytoplasmas are classified in the provisional genus “Candidatus Phytoplasma” (IRPCM, 2004). To date, there are 42 formally described species and ten potentially novel phytoplasma species (Davis et al., 2015). This number exceeds the current number of 16s rRNA groups because some of these groups contain several “Candidatus Phytoplasma” species. At least 100 subgroups are known (Dickinson and Hodgetts, 2013). According to Phytoplasma/Spiroplasma Working Team-Phytoplasma Taxonomy Group, a novel “Ca. Phytoplasma” species description should refer to a single, unique 16S rRNA gene sequence (>1,200 bp), and a strain can be recognized as a novel “Ca. Phytoplasma” species if its 16S rRNA gene sequence has <97.5% similarity to that of any previously described “Ca. Phytoplasma” species (Duduk and Bertaccini, 2011). Additional biological characters such as antibody specificity, host range and vector transmission specificity as well as genetic markers can also be used in an integrative taxonomy approach for species differentiation. Of the 42 recognized “Ca. Phytoplasma” species, only Ca. Phytoplasma aurantifolia, Ca. Phytoplasma australasiæ and Ca. Phytoplasma australiense are reported in Australia (Table 1) but uncertainty exists because many papers appear without Ca. Phytoplasma names which are used consistently only in the case of the GenBank database.

The authors apologize for this error and state that this does not change the scientific conclusions of the article in any way. The original article has been updated.

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.