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Wattle gall—the quintessential Australian plant disease

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ABSTRACT

Acacia (the wattles) is the largest genus of plants in Australia and its species occupy almost every habitat in the country. Hard galls on the branches, phyllodes and flower parts of wattle trees were noticed from the very early days of British colonisation, but their causes were unknown. Some insects were believed to be involved, but they were not the only cause of wattle galls. In 1889, the Italian mycologist Pier Andrea Saccardo described the rust fungus *Uromyces tepperianus* from the galls on *Acacia salicina*, and later, the Victorian government vegetable pathologist, Daniel McAlpine transferred the species *tepperianus* to his new genus *Uromycladium* which also included six new species. A total of 28 valid species of *Uromycladium*, most endemic to Australia, are currently described. Several species of *Uromycladium* were somehow introduced into South Africa and countries in southeast Asia where they cause significant losses in *Acacia* plantations, while others are used as biocontrol agents for invasive *Acacia* species. Short biographies of two of the early collectors of rust galls, the South Australian naturalist and later entomologist Johann Gottlieb Otto Tepper and the Victorian plant pathologist Charles Clifton Brittlebank are also presented.

Keywords: *Acacia*, Charles Brittlebank, Daniel McAlpine, galls, Otto Tepper, *Uromycladium*, Walter Froggatt, wattle.

Introduction

The genus *Acacia* (wattles) is the largest of the Australian flora, with over 1100 species.[1] Since the beginning of British colonisation in 1788, wattles have been commercially valued, being used in the tanning, building, cabinetmaking, and horticultural industries, as well as utilised for other purposes. Hard galls on the branches, phyllodes and flower parts of wattle trees were noticed by early settlers, but their causes were, at that time, unknown. The growing tanning industry in early Australia was reliant on the bark harvested from gum (species of *Eucalyptus* and *Corymbia*) and wattle trees, but there is no evidence that wattle galls were specifically used for extracting tannins.[2]

Although insects were suspected of being the culprits in the development of wattle galls it was not until the latter part of the nineteenth century that entomologists including Walter Wilson Froggatt (1858–1937) began systematic studies on their identities. Nevertheless, insects were not the only cause of wattle galls. In 1889, the Italian mycologist Pier Andrea Saccardo (1845–1920) described the rust fungus *Uromyces tepperianus* from the galls on *Acacia salicina* collected by Otto Tepper (1841–1923) in South Australia.

In this paper I focus primarily on the colonial and early twentieth-century history of the fungal rust genus *Uromycladium*, which was described by the Victorian government vegetable pathologist Daniel McAlpine (1849–1932). I discuss the role that the wattle played in the early development of a tanning industry in Australia, and as the basis of an export industry to the United Kingdom. I also outline the development of a scientific explanation for the development of wattle galls by insects and *Uromycladium*, and detail

[1] Barlow (1981) p. 59.
[2] Maiden (1906) p. 30.

the identification of the species of *Uromycladium* in Australia and overseas. Finally, I provide short biographies of the South Australian naturalist, entomologist and collector Otto Tepper and the Victorian plant pathologist and biologist Charles Clifton Brittlebank (1863–1945), both of whom provided specimens of *Uromycladium* to Daniel McAlpine for taxonomic studies.

In this paper I have gathered and distilled information from early newspaper articles (Trove, https://trove.nla.gov.au/newspaper), correspondence in *Historical Records of Australia*, scientific papers published in relevant journals, books on various subjects, biographies, and other sources to write this paper. Several e-libraries, including Biodiversity Heritage Library (https://www.biodiversitylibrary.org/), HathiTrust Digital Library (https://www.hathitrust.org/) and Internet Archive (https://archive.org/) were interrogated for relevant books and articles.

Uses of wattles in early colonial Australia

Soon after the First Fleet arrived at Sydney Cove in late January 1788, an export trade in indigenous flora and fauna developed. The first seeds from the new colony arrived in England in *Prince of Wales*, in March 1789, and were distributed to British naturalist Sir Joseph Banks (1743–1820), the Royal Botanic Gardens at Kew and the seedsmen Lee and Kennedy of the Vineyard Nursery, Hammersmith, England. By 1800, fifteen species of *Acacia* that had been introduced by Banks; the barrister, politician and gardener John Ord (1729–1814); and the botanist and gardener Thomas Hoy (~1750–1822), were growing at various localities in England.[3]

As settlements developed around Sydney and in Tasmania, the tanning of leather became a priority for sale in local markets, initially using ingredients from the bark of gum trees.[4] The colonial office soon saw the possibly of developing an export industry in bark for tanning to England.[5] The first mention of the suitability of wattle bark for tanning was in a report to Governor Lachlan Macquarie (1762–1824) by John Hutchinson, who stated that the bark of the 'green wattle' was superior to any other bark sent to Europe, possessing a 'great deal of the astringent'.[6] The first commercial tannery in Sydney was established by James Wilson, between Pitt and George Streets in 1814. To produce tannin, bark was stripped from *Acacia* trees, dried, ground and soaked in hot water in tanning pits.[7]

A Mr Cooper of the Australian Brewery in George St, Sydney Town allowed his customers to trade goods, including wattle bark, for beer rather than paying five shillings in Spanish coins (the local currency at the time).[8] In Tasmania, bark was being sold for 28–35 shillings per ton,[9] and the trees soon became very scarce in some places,[10] prompting one newspaper correspondent to suggest that plantations of black wattle saplings should be established.[11] Individuals trying to make a quick return were even stripping bark from trees on other people's properties.[12]

Other uses for wattles, apart from tanning, were also found by settlers. These included timber for building houses and other structures, boats, cabinet-making, turnery, buggy poles, walking sticks, umbrella and axe handles, tobacco pipes, food for stock in times of drought, and perfume.[13] An article in the *Hobart Town Gazette and Southern Reporter* in May 1819 stated that a boiled and drained 'lixivium' of burnt ashes of the black wattle, 'green gum', slaked lime and water made an excellent soap for washing linen.[14] Wattle trees also had the 'whitest and purest gum, galls for producing tannins, flowers for a yellow dye, seeds for feeding poultry, pods for replacing soda used for washing clothes and a decoction of bark to produce Japan Earth'.[15]

Aborigines had been using various parts of *Acacia* trees and shrubs before the English arrived in Australia. The wood of some species had been used to fashion spears, boomerangs and nulla-nullas; the gum, galls, roots and seeds for food; the fibres from bark for fishing nets; and a mixture of ashes of the burnt green leaves of *Acacia hakeoides* and

3 Cavanagh (1990) pp. 276, 278.
4 King (1915*a*) p. 439.
5 Hobart (1915) p. 571. King (1915*b*) p. 106.
6 Hutchinson (1916) p. 235. This person was most likely the Rev. John Hutchinson (1792–1866) who was superintendent of the female factory in Hobart, Tasmania.
7 Anonymous (2023*a*).
8 Anonymous (1824).
9 Anonymous (1825*a*).
10 Agricola (1825).
11 Anonymous (1825*a*).
12 Anonymous (1825*b*).
13 Anonymous (1820). von Mueller (1881) pp. 1–8. Simmonds (1900) pp. 478–517.
14 Anonymous (1819).
15 Anonymous (1841). There is no evidence that wattle galls were ever used to produce tannins in Australia. Japan Earth, also called catechu and cutch, was originally made overseas by boiling the bark of *Senegalia catechu* (synonym *Acacia catechu*) and evaporating the liquid (Anonymous 2020).

psychoactive pituri (dried and crushed leaves of some *Nicotiana* species and *Duboisia hopwoodii*) for chewing.[16]

In the 1870s, the medicinal use of wattles was promoted by Adelaide surgeon and politician Sylvanus James Magarey (1850–1901). He waxed lyrically about the healing qualities of concoctions of boiled wattle bark. Apart from being the 'most valuable tanning bark in the world', he claimed that it had been successfully used by him to treat patients who had indigestion, diarrhoea, catarrhal ophthalmia, otorrhoea, sore throat, chapped lips, eczema, wounds and sweating feet. For disorders that required oral doses he advised his patients to boil ½–1 drachm (0.9–1.8 g) of wattle bark in a cup of warm water, then drink the liquid after it became warm. He also stated that in a few cases he had used wattle to slow or stop the development of 'incipient' typhoid fever.[17] Perhaps a modern Australian entrepreneur can manufacture and market the magic medicine as an alternative tea!

The export of wattle products, particularly bark, became a viable commercial operation. For example, in 1844, 1033 t of wattle bark were exported from South Australia,[18] and in 1890, 4372 t were exported from the colony.[19] In Victoria, forestry authorities stated that wattle (bark) gave the best returns of all forestry products, with the government receiving royalties of between £2 10s and £5 10s per ton of bark.[20] Plantations in that colony were sown with the best varieties of wattle for the production of tanning bark.[21] In 1902 alone, over 928 000 hides were tanned in Victoria.[22]

In 1913, Alfred James Ewart (1872–1937), professor of botany at the University of Melbourne, published a comparative analysis of tannins from oak and wattle bark. He stated that although oak bark could be bought in the English market for £5 6s 8d per ton and wattle bark for £10 3s 2 d per ton, the average percentage of tannin in wattle bark (33%) was significantly higher than that in oak bark (9%), and consequently the cost of tannin per pound (lb $\sim$ 0.45 kg) bark for wattle was 3.25 pence per pound bark, which was just over half that of oak bark.[23]

In the late eighteenth century and into the nineteenth century, there was a high demand for tanning agents in Europe, which were mostly imported as bark from South America, South Africa, and Australasia. The black wattle (*Acacia mearnsii*), which was easily raised, quick-growing and tolerant of a wide variety of soils,[24] was one of the most important sources, because its bark contains 22–48% tannin.[25] In the early years of the twentieth century, the export of tanning bark from Australia increased rapidly. In 1901, almost 6000 t were exported overseas (predominantly to New Zealand and the United Kingdom) while in 1906, just under 21 600 t were exported, 85% to Germany.[26] The downturn in exports was due mostly to the rapid increase in wattle bark production in Natal (southern Africa), where labour was relatively cheap and the trees were grown in plantations, unlike in Australia where bark was harvested mostly from wild trees.[27]

Nevertheless, the ratio of exports to imports of tanning bark decreased dramatically in the second decade of the twentieth century. In 1906, Australia imported just 3 t of wattle bark and exported 21 600 t (ratio 7200:1),[28] but only five years later imports were about 3620 t and exports had dramatically decreased (ratio 3.5:1).[29] Almost all tanning bark was imported from South Africa, where plantations of the Australian species *A. decurrens* and *A. mollissima* had been established.[30] Australian production continued, but could not keep pace with the requirements of Australian tanners.[31] Just over 8650 t of tanning substances were imported in 1958, mostly from South Africa.[32] Currently, in parts of southern Australia, trees of *A. mearnsii* are generally found only in small, isolated, hard-to-access pockets and the utilisation of bark and timber is on a very small scale.[33]

Wattle galls

The first mention of wattle galls in an Australian newspaper was on 9 September 1830 in the *Sydney Gazette and*

16 von Mueller (1881) pp. 1–8. Maiden (1888) pp. 483–5. Simmonds (1900) pp. 478–517.
17 Magarey (1879) pp. xv–xvi.
18 Anonymous (1844).
19 Anonymous (1892*a*) p. 11.
20 Anonymous (1892*b*) pp. 262, 478.
21 Anonymous (1892*b*) p. 478.
22 Anonymous (1892*b*) p. 256.
23 Ewart (1913) p. 7.
24 von Mueller (1881) pp. 3–4.
25 Falcão and Araújo (2018) p. 7.
26 Anonymous (1908).
27 Maiden (1906) pp. 4–6.
28 Anonymous (1908).
29 Ewart (1913) p. 7.
30 Anonymous (1926*a*) p. 708.
31 Anonymous (1958) p. 985.
32 Anonymous (1958) p. 988.
33 Brown and Ko (1997) p. 4.

New South Wales Advertiser. A reader asked for details about making dyes from galls of the wattle tree, which he had read were better than galls of the Aleppo oak (*Quercus infectoria*).[34] The galls of the Aleppo oak (also called Turkish galls and Levant galls) were produced after attack by a wasp called *Cynips gallae-tinctoriae* and they contained between 40 and 70% tannin.[35] There was public disagreement about what the galls were, because 'Owen Smith' believed that they were the fruits of the wattle, whereas 'Delta' believed them to be the work of insects.[36] 'An old F.L.S.' (presumably a Fellow of the Linnaean Society) chastised 'Owen Smith' when he wrote: 'The slightest knowledge of physiological botany is sufficient to disprove the ridiculous notion that the wattle gall is a fruit'. The insect theory was reinforced when an anonymous newspaper correspondent wrote that the wattle galls were caused by an insect resembling *Diplotepis gullae tinctorum* (= *C. gallae-tinctoriae*).[37]

In giving suggestions for scientific investigations to the Field Naturalists' Club of Victoria in 1884, Professor (and later Sir) Frederick McCoy (1817–1899), Professor of Natural Science at the University of Melbourne, wrote: 'Another nearly allied line of investigation, in which little has been done in this country, specially requiring such an association as the club to multiply and record the necessary out-of-door observation, is the determination, descriptions, and figuring of all the galls and their contents in the colony, and the settling the fact of whether each gall insect forms its galls on only one, or also on other, and if so, what plants?'[38]

It was not until the late nineteenth century that the identities of some of the gall-inducing wasps were revealed. In 1892, the Australian entomologist Walter Wilson Froggatt[39] (1858–1937) described three of the true (not merely associated with) gall makers, *Cynips acacia-discoloris* (now *Perilampella acaciaediscoloris*), on the leaf buds and small twigs of *Acacia discolor*, *C. acacia-longifoliae* (now *Trichilogaster acaciaelongifoliae*) on flower stalks of *A. discolor* and *A. longifolia*, and *C. maideni* (now *Trichilogaster maideni*) on the small twigs and branches of *A. longifolia*. He described the galls of *C. acacia-longifoliae* as being round and fleshy and the size of a 'filbert nut' (hazelnut) and those of *C. maideni* being thick, fleshy, 5–6″ (12.5–15 cm) long and several inches in diameter. Those of the first species were called 'wattle apples' in Victoria.[40]

Norman Noble (1906–1983), an assistant entomologist in the New South Wales Department of Agriculture, studied the insects associated with insect galls on *Acacia implexa* (hickory) in the Sydney region and found that twelve species of Hymenoptera, including nine challids, emerged from mature galls. Of these, the females of only one, *T. maideni*, oviposited and caused galls on young branches of hickory.[41] Noble provided detailed descriptions of the various stages of the wasp and its biology, and described the mature galls as being hard, woody, dark brown to black, with a rough, irregular surface. Within each gall there were from one to sixteen partitions in which individual larvae developed.[42]

Other insects colonised the galls made by *T. acaciaelongifoliae*, including twelve species of Hymenoptera, two species of Lepidoptera and one of Coleoptera. Of these, nine species (in the genera *Coelocyba, Epimegastigmus, Eurytoma* and *Megastigmus*) were chalcid wasps. Larvae of several of these (*M. trisulcus* and species of *Eurytoma*) were found to devour the larvae of *T. acaciaelongifoliae* inside the galls.[43] The CSIRO entomologist Rosalind Blanche listed thirteen genera of gall-forming insects on *Acacia* in Australia, belonging in the Orders Hemiptera (true bugs such as cicadas, aphids and leafhoppers), Hymenoptera (such as wasps and sawflies), Thysanoptera (thrips) and Diptera (midges, true flies, mosquitoes). The twenty-five species in three genera in the Hymenoptera (*Trichilogaster, Encytrocephalus* and *Coelocyba* were considered to be the most important gall-forming insects.[44]

The wattle gall rust genus *Uromycladium*

The first fungus to be associated with galls on *Acacia* from Australia, was *Uromyces tepperianus* (now *Uromycladium tepperianum*) which was described by the famous Italian mycologist Pier Andrea Saccardo (1845–1920) in 1889. It was one of fifteen fungi that had been collected and sent to him by the natural history collector at the South Australian museum, Johann Gottlieb Otto Tepper (1841–1923), who had found the specimen on *Acacia salicina* at several locations in South Australia. It is not known why Tepper sent the gall specimens to Saccardo; perhaps he recognised that the galls were not typical of those caused by insects. It is now

[34]Anonymous (1830).
[35]Falcão and Araújo (2018) p. 12.
[36]Anonymous (1844).
[37]Anonymous (1855).
[38]McCoy (1884) p. 41.
[39]Froggatt started his career as a collector on expeditions and for individuals, was appointed as an assistant at the Sydney Technology Museum in 1889, then as the first entomologist in the New South Wales Department of Mines and Agriculture in 1896 and the Department of Forestry in 1923, until 1927 Anonymous (2021*a*).
[40]Froggatt (1892) pp. 153–155.
[41]Noble (1941) pp. 184–185.
[42]Noble (1941) pp. 179–185.
[43]Noble (1941) pp. 186–190.
[44]Blanche (1995) appendix 1.

Fig. 1. Gall of the epitype specimen of *Uromycladium tepperianum* on *Acacia ligulata* (BRIP 59895a), photo courtesy of Andrew Geering.

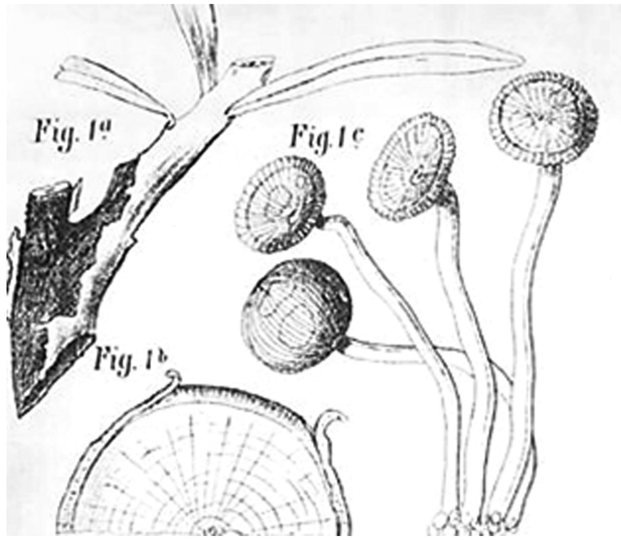

Fig. 2. *Uromyces tepperianus* Sacc. **1a** infected branch of *Acacia*; **1b** transverse section of infected branch; **1c** teleutospores (teliospores), front and lateral (translated from the Latin), Saccardo (1889), *Hedwigia* **28**, plate 2, Fig. 1.

believed that Tepper collected the specimen from *Acacia ligulata*, which at the time was considered to be conspecific with *A. salicina*.

Saccardo described the galls as being long and effuse, developing on branches, later becoming cinnamon and dusty on the surface and ultimately killing the branches (Fig. 1). He described the teliospores which developed on the surfaces of galls as being depressed-globose, cinnamon-coloured, 20–24 × 18–20 µm with longitudinal grooves appearing to be scalloped, and formed on rod-shaped, hyaline pedicels, 40–60 × 3–5 µm arranged in bundles (Fig. 2).[45] The British mycologist Mordecai Cubit Cooke (1825–1914) provided the same description,[46] and a few years later, Daniel McAlpine had recorded the rust on *Acacia hakeoides*, *A. myrtifolia* and *A. salicina* from Victoria and South Australia.[47]

In a study of the fungi on *Acacia* in Australia, McAlpine realised that Saccardo had been in error about the arrangement of the teliospores and found that the three teliospores of *Ur. tepperianus* were actually formed together at the apex of a stalk (pedicel).[48] Consequently he erected a new genus *Uromycladium* (*Um.*), noting that *Uromycladium* differed from *Uromyces* whose species have just one teliospore at the apex of a stipe, the shape of the teliospores (*Uromyces* has ellipsoidal rather than depressed globose teliospores) and the presence in some cases of a vesicle.[49]

McAlpine transferred or described seven species of *Uromycladium*, namely *Um. simplex*, *Um. robinsonii* (as *robinsoni*) (both with one teliospore and a hyaline vesicle at the apex of a stipe), *Um. bisporum* (with two teliospores at the apex of a stipe), *Um. alpinum*, *Um. maritimum* both with two telia and a colourless vesicle at the apex of stalk), *Um. notabile* and *Um. tepperianum* (both with three teliospores at the apex) (Figs 3 and 4).[50]

In his landmark text, *Rusts of Australia*, McAlpine listed, in addition to the seven *Um.* species, three species of *Uromyces* (*Ur.*), namely *Ur. bicinctus* (now *Endoraecium bicinctum*), *Ur. fusisporus* (now *Uromycladium fusisporum*) and *Ur. phyllodiorum* (now *Endoraecium phyllodiorum*) whose uredinia and telia were found on phyllodes on species of *Acacia*. The latter species was found on seven species of *Acacia* in all mainland states except Western Australia.[51] At that time, *Uromycladium notabile* and *Um. tepperianum* were the only rusts known to cause galls on the branches of *Acacia*. The teliospores developed on the surface of the galls, causing them to become cinnamon-coloured and powdery.[52] Some of those, particularly those caused by *Um. tepperianum* on branches of *A. pycnantha*, were as 'large

[45]Saccardo (1889) p. 126.
[46]Cooke (1892) pp. 331–332.
[47]McAlpine (1895) pp. 102–103.
[48]McAlpine (1905) p. 310.
[49]McAlpine (1905, p. 313, 1906, pp. 83, 104–105).
[50]McAlpine (1905, pp. 305–312, 1906, pp. 104–112).
[51]McAlpine (1906) pp. 93–96.
[52]McAlpine (1905, pp. 309–312, 1906, pp. 108, 111).

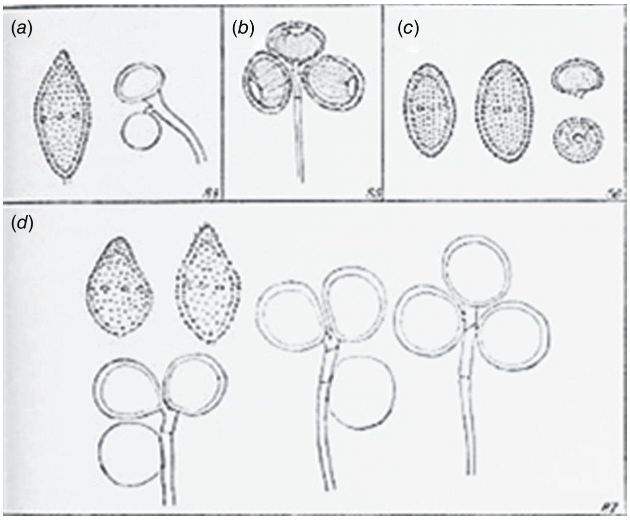

Fig. 3. (*a*) Urediniospore (left) and teliospore (right) of *U. simplex*; (*b*) teliospores of *U. tepperianum*; (*c*) urediniospores (left) and teliospores (right) of *U. notabile*; (*d*) urediniospores (upper left) and teliospores of *U. maritimum*, Sydow and Sydow (1915) figure 8, nos. 84–87.

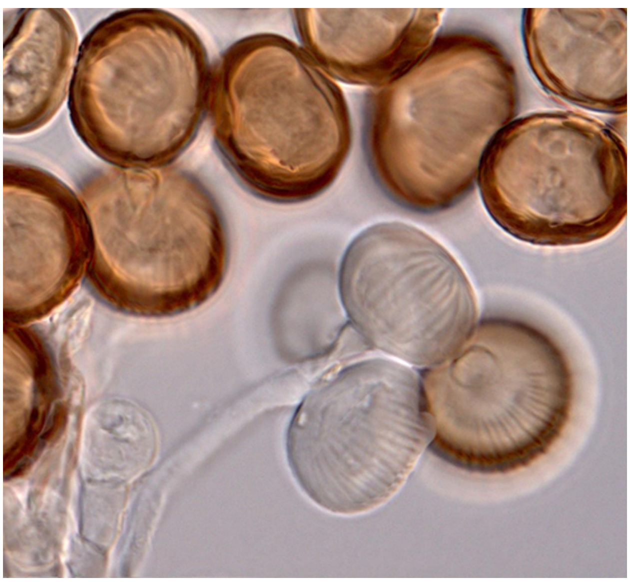

Fig. 4. Mature brown, striate teliospores and immature teliospores (bottom left) of *Uromycladium tepperianum* (BRIP 59204), photo courtesy of Chanintorn Doungsa-ard and Roger Shivas.

as potatoes' and looked like 'so many fruit' on badly affected branches.[53]

When cut through, the galls were solid and 'not the product of insects but of fungi', although insects bore into the galls and produced tunnels after the galls were formed.[54] On a branch of *A. implexa*, McAlpine found a leg-of-mutton-shaped gall weighing 3 lb (1.4 kg).[55] The other *Uromycladium* species developed sori on phyllodes and leaves. McAlpine reported that the minute spermagonia (a walled structure in which spermatia develop) of *Um. simplex* developed on leaves of *Acacia pycnantha in* 'distinct, ruddy spots' caused by *Coniothyrium pycnanthae* and other fungi, and that the hyperparasite *Darluca filum* (now *Sphaerellopsis filum*) was often found in the uredinia and telia of *Um. simplex*.[56]

Two of the early rust-gall collectors

In McAlpine's *Rusts of Australia* several collectors are listed, including his assistants at various times: Gerald Henry Robinson (1873–1961) and Charles Clifton Brittlebank (1863–1945) from Victoria; the New South Wales government consulting, and later fulltime botanist, Joseph Henry Maiden (1859–1925);[57] the New South Wales government entomologist W. W. Froggatt; Leonard R. Rodway (1953–1936)[58] honorary Tasmanian government botanist between 1896 and 1932; the Tasmanian government entomologist Arthur Mills Lea (1868–1932);[59] and Otto Tepper in South Australia.[60] Apart from Robinson and Brittlebank, all of these early collectors were either professional botanists or entomologists employed by various state governments, who could at best be described as amateur mycologists. Specimens of plant diseases collected in Australia were invariably sent to overseas mycologists, mostly in England. It was not until 1890–1, when the first professional vegetable pathologists, Daniel McAlpine, Nathan Cobb and Henry Tryon were employed by the state governments of Victoria, New South Wales and Queensland respectively, that plant disease specimens could be examined locally by competent mycologists.

In this section I focus on the lives of two of these naturalists, Otto Tepper and Charles Brittlebank. They had vastly different lives, careers and interests—Tepper was a teacher, collector of natural history and writer, with a small number

[53] McAlpine (1905, pp. 311–312, 1906, p. 111).
[54] McAlpine (1905, p. 312, 1906, p. 104).
[55] McAlpine (1906) p. 112.
[56] McAlpine (1906) p. 110.
[57] Anonymous (2021*b*).
[58] Anonymous (2017*a*).
[59] Anonymous (2017*b*).
[60] McAlpine (1906).

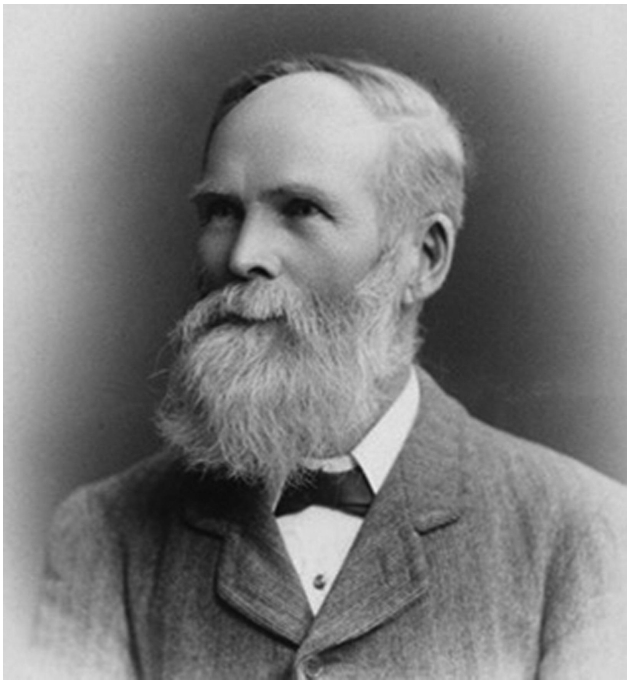

Fig. 5. Johann Gottlieb Otto Tepper (1841–1923), by unknown photographer, 1898, https://collections.slsa.sa.gov.au/resource/B+14 104/10A 316.

of mycological and plant pathology papers, while Brittlebank was a sportsman, illustrator, and later government plant pathologist in Victoria. One thing they had in common was that they were self-taught.

The remarkable Otto Tepper

Johann Gottlieb Otto Tepper (known as Otto Tepper) (Fig. 5) was born in the Prussian province of Posen (now in Poland) in 1841 and arrived in South Australia six years later when his family emigrated on religious grounds. After leaving school at the age of fourteen, he worked as a shearer and storeman before becoming a qualified public school teacher in the Barossa Valley in 1867. In 1883, he was appointed as natural history collector and later entomologist and librarian at the South Australian Museum from 1888. Tepper was a self-taught entomologist, natural history collector (mostly insects, plants and sometimes fungi, lichens, rocks and minerals) and botanical artist. He was an avid collector of natural history, displaying samples of his collections regularly at meetings of the Philosophical Society of Adelaide and the Royal Society of South Australia (RSSA), which he joined in 1878 whilst still a teacher. His services to science were recognised when he was made an Honorary Fellow of the RSSA and a Fellow of the Linnaean Society of London.[61] He is best remembered as an entomologist, most of his scientific papers being on that subject, although he published many on geology, botany, fungi and other issues such as whirlwinds,[62] trees,[63] and the deserts of the Holy Land.[64]

One of his first publications was *The Insects of South Australia—an Attempt at a Census*.[65] His private collection of insects consisted of 2655 species in 390 genera and 88 families, which was over four times the number of insects that were known at the time in that state.[66] His private natural history collection would have been a major contribution to the South Australian Museum. He also collected lichens and both macro- and microfungi in South Australia, which he sent to overseas scientists such as Saccardo, the German mycologists Heinrich Georg Winter (1848–87) and Friedrich Ludwig (1851–1918), and to Australian scientists such as Ferdinand von Mueller (1825–96) and Daniel McAlpine.[67] Among the specimens were fourteen smut fungi and fifteen rust fungi.[68] McAlpine noted that Tepper had supplied him with 'numerous, and often type specimens' from his extensive collection.[69] In 1890, Tepper described the rust fungus *Puccinia ludwigii* on *Rumex brownii* from Victoria, a still-valid name and the only one he ever described.[70]

Tepper sent McAlpine specimens of several species of *Uromycladium*, namely *U. notabile* on phyllodes of *A. notabilis* collected at Roseworthy, South Australia, in September 1889 and *U. tepperianum* on four species of *Acacia* at several localities in South Australia including Blackhills, Sandy Creek and Murray Bridge in 1889 and 1892.[71] The evidence suggests that Tepper had collected the original specimens of *Um. tepperianus* on *A. salicina* at the first two sites in 1887,[72] although at the time of this collection, the taxonomy of *A. salicina sensu lato* was

[61] Orchard (1999). Kraehenbuehl (2023).
[62] Tepper (1878) pp. 99–108.
[63] Tepper (1896).
[64] Tepper (1895) pp. 187–188.
[65] Tepper (1879) pp. 33–59.
[66] Tepper (1879) p. 34.
[67] Tepper (1885, pp. 215–216, 1889, pp. 150–153).
[68] Tepper (1889) pp. 152–153. McAlpine (1906).
[69] McAlpine (1906) p. vi. A type specimen is the specimen on which the description of an organism which fulfills the conditions of valid publication of a scientific name is based.
[70] Ludwig (1890) p. 6.
[71] McAlpine (1906) pp. 108, 111.
[72] Tepper (1889) p. 150.

confused, with *A. ligulata* referred to as *A. salicina*, and *A. salicina sensu stricto* as *A. salicina var.varians.*[73]

A more recent survey of the type localities showed that while *U. tepperianum* was common on *A. ligulata*, it was entirely absent on *A. salicina sensu stricto,* suggesting that Tepper actually collected from *A. ligulata*.[74]

As far as can be determined, Tepper published only two papers on plant pathology matters. The first was: 'The red rust: its nature, approximate causes, and probable cure'. The title suggests that there was some uncertainty about the subject amongst some scientists, particularly the identity of the rust species involved, which is reflected in several of his statements.[75] The second was on the disease 'take all' which was devastating wheat crops in Southern Australia. He mistakenly believed that the disease was caused by a deficiency of one or more elements in the soil—a 'starvation of the crop'.[76] Just over a decade later, Daniel McAlpine proved definitively that the fungus *Ophiobolus graminis* (now *Gaeumannomyces graminis*) was the causal agent of 'wheat take-all' in Australia.[77]

Tepper was also a proto-ecologist, sounding the alarm about a process we would now call desertification. In a paper and a book on trees he lamented the destruction of native vegetation, particularly trees in Australia—'what was then, and till within some 20 years, a beautiful garden in many parts, or else fair or rich fields, is now degenerated largely into real desert, yielding little or no crops, or grass, simply through rendering all equally bare of shrubs and trees'. He blamed cropping, de-pasturing, burning and then the damage caused by rabbits and locusts for that degeneration. He suggested that the forty years wandering of the Israelites may have caused the same conversion of much of the Holy Land to desert.[78]

The plant pathologist and scientific communicator Charles Clifton Brittlebank

Charles Clifton Brittlebank (Fig. 6) was born in Darley, England on 1 January 1863, his father Andrew being a gentleman of independent means through his financial investments. The family moved to Vanuatu to set up a plantation and later to Brisbane, arriving on 28 July 1875. Within two years both his father and elder brother Lewis had died from one of the fatal diseases that were circulating at the time. Ultimately, Charles and his younger brother Thomas leased a 363 acre (147 ha) property at Myrniong, near Bacchus Marsh, Victoria between 1883 and 1888 and became successful farmers.[79] That property, together with farm machinery, sheep, 'exceptionally good' horses and 'very high class' Ayrshire cattle was sold either in late 1909 or in 1910.[80]

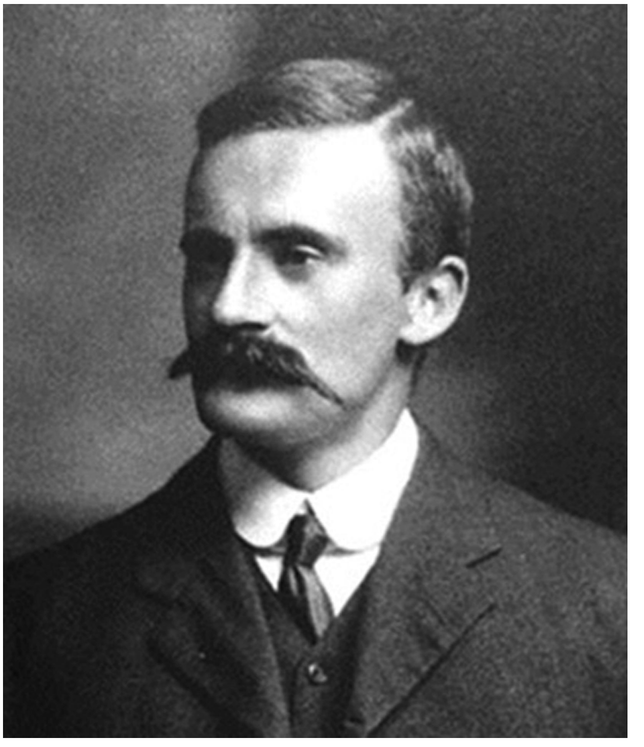

Fig. 6. Charles Clifton Brittlebank, date and photographer unknown https://www.anbg.gov.au/biography/brittlebank-charles-clifton.html, original source *Passions in Ornithology: a Century of Australian Egg Collectors* (2020) Mason & Pfitzner, Canberra.

Brittlebank was a renowned artist, producing beautiful illustrations of birds and their eggs, insects, fungi and mistletoes for Australian scientists, including the Victorian government entomologist Charles French's *A Handbook of the Destructive Insects of Victoria*, volumes 1–5,[81] and S. A. Leach's *An Australian Bird Book*.[82] In 1908, he was appointed as assistant to Daniel McAlpine, but before then he had contributed many photographic and/or hand-drawn images for McAlpine's *Fungus Diseases of Stone-Fruit in*

[73]Chapman and Maslin (1992).
[74]Doungsa-ard and others (2018).
[75]Tepper (1880) pp. 13–18.
[76]Tepper (1893).
[77]McAlpine (1904).
[78]Tepper (1878, pp. 99–100, 1895).
[79]Anonymous (1888). Hewish (2006).
[80]Anonymous (1909).
[81]French (1893, 1900, 1904, 1909).
[82]Leach (1918). McCarthy (2012).

Fig. 7. Watercolour by C. C. Brittlebank, oat, rye-grass, and barley rusts, McAlpine (1906) plate B, pp. 224–225.

Australia; The Rusts of Australia (Fig. 7); *The Smuts of Australia;* and *Handbook of Fungus Diseases of the Potato in Australia.*[83] Art, in the form of electronic images and videos, still remains an important part of plant pathology extension, by providing aids in the early diagnosis of a disease and information on aspects of biology of the pathogen, particularly its life cycle.[84] Use of these tools not only improves the knowledge of particular diseases to participants in the agricultural industry, but also fosters early intervention to reduce the impact of plant diseases.

In 1913, while Daniel McAlpine (then the Victorian government vegetable pathologist) was seconded to work on the aetiology and biology of the apple disorder known as 'bitter pit', Brittlebank was employed as McAlpine's replacement.[85] After eleven years in that position, he was appointed government biologist in charge of the science branch of the Victorian Department of Agriculture (VDA) (in 1924), but in newspapers of the time he was usually referred to as the 'government plant pathologist'. During the fifteen years of his employment in the VDA he published over twenty-four scientific papers, established a diagnostic service for Victorian farmers and delivered lectures to students. He left a lasting legacy by being the first person to describe tomato spotted wilt disease, one of the most economically important plant viral diseases in the world (see Geering article also in this issue).

Brittlebank must have been well-respected by the agricultural industry in Victoria because just a month or so before his compulsory retirement on reaching the age of 65 (31 December 1927) a deputation from three powerful Victorian grower associations met with the relevant minister, William Slater (1890–1960), to implore that Brittlebank's services be retained for another five years. The deputation claimed that his impending retirement was 'viewed with apprehension' by growers 'all over the Commonwealth'. Slater promised to put the proposal before the Victorian cabinet but warned the delegation that there might not be a favourable result.[86] Brittlebank's employment was extended initially for six months then again for another six months after pressure from the public.[87] He was replaced in mid-1929 by Dr D. B. (probably David Bonar) Adam (1901–1951) who later joined the Waite Agricultural Research Institute, Adelaide in 1934.[88]

The first radio broadcasts on plant pathology in Australia

In the years immediately following the cessation of World War 1, the wireless radio became a conduit not only for entertainment in the form of reports, music and drama, but also in the delivery of scientific knowledge. Radio broadcasting was officially established in Australia in September

[83]McAlpine (1902, 1906, 1910, 1911).
[84]Dowling and Schnabel (2020).
[85]Anonymous (2023*b*).
[86]Anonymous (1927).
[87]Anonymous (1928*a*, 1928*b*).
[88]Anonymous (1934*a*).

1923 under the control of the then Office of the Post Master General,[89] but radio broadcasts did not begin until November 1923 in Sydney and in the following year in Melbourne and Perth.[90] The physicist Thomas Howell Laby (1880–1946) was the visionary and driving force behind the development of science communication in Australia,[91] and with his encouragement scientists from different disciplines began to use the radio to extend information to the general public as early as June 1924.[92]

As far as is known, Brittlebank was the first Australian plant pathologist to embrace the radio as an extension tool. In September and October 1926, he presented three talks on 'Plant diseases', 'Disease control in the flower garden' and 'The thrip pest', to the audience of Melbourne station 3LO.[93] There is no evidence that D. B. Adam followed Brittlebank's radio foray, but Stanislaus Fish (1903?–81), who was the assistant plant pathologist at the time of Adam's appointment in Victoria and later plant pathologist after Adam left for Adelaide in 1934, did deliver radio talks on plant pathology matters.[94]

The species of *Uromycladium* in Australia

In March 2023, the website Index Fungorum (www.indexfungorum.org) listed 28 valid species of *Uromycladium*, 17 of which produce galls.[95] McAlpine listed and discussed seven species of *Uromycladium* in his *Smuts of Australia*, and up until the early 1970s just three new species of *Uromycladium* were described, namely *Um. acaciae* (originally as *Uromyces acaciae*) in 1914, *Um. cubense* (now *Diabole cubensis*), and *Um. fusisporum* (originally as *Uromyces fusisporus*) in 1971, all based on differences in morphology.[96] In 1915, Sydow & Sydow synonymised McAlpine's *Uromycladium bisporum* with *Um. acaciae*, and in 2010 the German mycologist Reinhard Berndt described *Um. narracoortense* on three species of *Acacia* from Australia.[97]

In 2015, Chanintorn Doungsa-ard submitted a PhD thesis to the University of Queensland titled 'The diversity and coevolution of gall rusts (Uromycladium) on Australian *Acacia* species'.[98] She combined morphology and molecular analyses using the internal transcribed spacer (ITS), large subunit (LSU), and small subunit (SSU) regions and the cytochrome *c* oxidase subunit 3 (CO3) in the mitochondrial genome to undertake her investigations.[99] As a result, sixteen new species of *Uromycladium* causing galls on *Acacia* in Australia were identified and later described, all producing three teliospores at the apex of each pedicel.[100] Another species, *Um. woodii*, was described from specimens collected on *Paraserianthes lophantha* (Cape Leeuwin wattle, Fabaceae) in the southwest of Western Australia.[101] Doungsa-ard and her colleagues had found that the rust fungus traditionally called '*Um. tepperianus*' was, in fact, a cryptic species complex of morphologically indistinguishable fungi, which could only identified by DNA sequencing, and to a lesser extent by host species.[102]

The molecular studies also revealed that all the species of *Uromycladium* identified up to, and including, 2015 clustered in a discrete clade, separate from the other families of the Pucciniales, which Doungsa-ard proposed to be called the family Uromycladiaceae Doungsa-ard, McTaggart & R.G. Shivas, with *Uromycladium simplex* as the type species.[103] However, this new taxon was not validly described according to the *International Code of Nomenclature for Algae, Fungi and Plants* 2018, and has been superseded by the family name Uromycladiaceae P. Zhao & L. Cai, with *Um. simplex* as the type species.[104]

The species of *Uromycladium* outside Australia

Two new *Uromycladium* species have been identified from countries other than Australia. The first, *Um. falcatariae* (originally as *falcatarium*), was found on *Paraserianthes*

[89] Johnson (1988) p. 12
[90] Bowen (2017) p. 93.
[91] Bowen (2017) p. 93.
[92] Bowen (2017) p. 94.
[93] Anonymous (1926*b*, 1926*c*, 1926*d*).
[94] Anonymous (1934*b*).
[95] Wood (2023).
[96] Sydow and Sydow (1915) p. 195. Arthur (1922) p. 194. Savile (1971) p. 1091.
[97] Berndt (2010) p. 300.
[98] Doungsa-ard (2016). Prior to the development of molecular technology, the morphology of a fungal plant pathogen, such as a rust, was the major taxonomic criterion for describing a new species. DNA sequencing has led to a better understanding of the genetic relatedness of organisms, and has revealed a plethora of previously cryptic taxa.
[99] Doungsa-ard and others (2015, 2018).
[100] Doungsa-ard and others (2018) pp. 224–235.
[101] Doungsa-ard and others (2018) pp. 235–236.
[102] Doungsa-ard and others (2018) p. 236.
[103] Doungsa-ard and others (2015) p. 239.
[104] Zhao and others (2021) p. 51.

falcataria (as named, now *Falcataria falcata* but also previously known as *Falcataria moluccana*) in the Philippines and Timor Leste,[105] and the second, *Um. yunnanense*, was described on *Acacia yunnanensis* (now *Senegalia yunnanensis*) from Yunnan province, China.[106] Because of their limited distribution, it is probable that these two new species are native to their respective countries of discovery.

Although native to Australia, Papua New Guinea, New Caledonia and parts of Indonesia, species of *Uromycladium* have also been recorded in New Zealand, South Africa, and Malaysia.[107] It is uncertain how the pathogens were introduced into these latter countries. Nevertheless, *Uromycladium* infection has had a profound effect on some of its hosts. In New Zealand, *Um. murphyi* has impacted tannin production and the ornamental use of *Acacia decurrens*, and in parts of southeast Asia, *Um. falcatariae* has seriously damaged *Falcataria moluccana* (as named, now *F. falcata*), a tree used for a variety of purposes including sources of shade in coffee plantations.[108]

South Africa

In South Africa, different species of *Uromycladium* have been both destructive and useful. In some regions, *Uromycladium acaciae* is a major disease in commercial plantations of *Acacia mearnsii*, causing malformation and matting of the leaves and stunting of the plant. This pathogen, originally identified as *Um. alpinum*, was first recorded in South Africa in the 1980s.[109] It was most likely introduced on the bodies of the insect *Melanterius maculatus,* that was introduced as a biological control agent against *Acacia* species.[110] On the contrary, *Uromycladium morrisii* (called *Um. tepperanum* at the time of introduction) and *U. woodii* were deliberately introduced into South Africa for the biological control of *Acacia saligna* and *Paraserianthes lophantha,*respectively, which are noxious weeds in this country.[111]

New Zealand

Until 1998, six (unnamed) species of *Uromycladium*, some of which produce large galls, had been recorded in New Zealand, and may have been introduced on plant material,[112] although there was no evidence to prove that possibility. Currently, *Uromycladium murphyi* (as *Uromycladium notabile* in the literature) causes significant damage to trees of *Acacia decurrens* that are grown for tannin production and as an ornamental plant.[113] *Uromycladium paradoxae* attacks the weed *Acacia paradoxa* which was introduced into New Zealand as an ornamental plant in 1911.[114]

In a paper on *Uromycladium* the Australian botanist and mycologist Norman (Alan) Burges (1911–2002) stated that 'the introduction of *A. decurrens* into South Africa and New Zealand led to the spread of *Uromycladium tepperanum*' (as written).[115] He noted that he had collected specimens of the widespread '*Um. tepperanum'* on species of *Acacia* 1932–3, but provided no compelling evidence for his statement regarding South Africa.

Conclusion

The Merriam-Webster dictionary defines the word 'quintessential' as being a 'perfectly typical or representative of a particular kind of person or thing'.[116] There are over 1100 species of *Acacia* in Australia, most of which are endemic, and most species of *Uromycladium* are likewise endemic to Australia. Both *Acacia* and *Uromycladium* are very common in Australia, with over 849 000 and 803 occurrences, respectively, recorded in the Atlas of Living Australia.[117] In addition, there has been a long association between *Uromycladium* and *Acacia* in Australia. The mean age of the most recent ancestor of *Uromycladium* has been estimated as 16.7 million years ago,[118] while the earliest fossil record of *Acacia* in Australia was from the Miocene epoch (23–5.3 million years ago).[119]

The wattle is a well-loved part of the indigenous Australian flora. It is in the coat of arms of Australia and

[105] Doungsa-ard and others (2015, pp. 28–29, 2018, p. 225).
[106] Zhao and others (2021) p. 52.
[107] Wood (2023).
[108] Wood (2023).
[109] Fraser and othersand others (2021).
[110] Wood (2023).
[111] Wood (2012). Wood (2023).
[112] McKenzie (1998) p. 239.
[113] Wood (2023).
[114] Anonymous (2023*b*, 2023*c*).
[115] Burges (1934) p. 213.
[116] https://www.merriam-webster.com/dictionary/quintessential
[117] https://bie.ala.org.au/
[118] McTaggart and others (2016) p. 1153.
[119] Barlow (1981) p. 59.

the Golden Wattle (*Acacia pycnantha*) is the official floral emblem. There is a wattle flag and an official wattle day (but unfortunately not a holiday), and this group of plants has featured prominently in Australia's literature. Who can deny the beauty of wattle trees in flower? There can be little argument that the galls of *Uromycladium* species that infect wattles (*Acacia* species) can be called a quintessential Australian plant disease.

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