

Ganoderma – Jekyll and Hyde mushrooms

Ganoderma fungi play important roles in breaking down dead wood and returning nutrients to the soil, but some species attack and kill living trees while others have strong reputations for medicinal properties

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Basidiomes of *Ganoderma boninense* fruiting at the base of an oil palm infected by basal stem rot (BSR)

Ganoderma mushrooms are well-known in East Asia because of their popular use in traditional East Asian medicine under names such as *ling zhi* (Chinese) or *reishi* (Japanese). *Ling zhi* actually consists of several closely-related species of *Ganoderma* such as *Ganoderma lucidum*, *G. tsugae* and *G. sichuanense*.

Among plant pathologists, agronomists, and plantation managers, however, *Ganoderma* is more well-known as a plant pathogen, causing root and stem rots and mortality of a wide range of economically important trees and perennial crops. These include oil palm, rubber, coconut, tea, cocoa, pepper, betelnut, peaches and pears, guarana, grapevines and forest trees such as *Acacia*, *Albizia*, *Populus* and *Macadamia* as well

as various wild and ornamental palm species and urban trees.

In the forest, *Ganoderma*, like other wood-decay fungi, play an ecologically important role in the decomposition and delignification of dead woody plants.

The actual number of species of *Ganoderma* found worldwide is not yet known with certainty; some reports mention 80 species while others put the number at around 300. The Index Fungorum database (www.indexfungorum.org) which is maintained at the Royal Botanic Gardens Kew in the United Kingdom currently lists 403 names (which does not equate to number of species) while Mycobank (www.mycobank.org), the



Oil palms infected by BSR: typical symptoms include wilting of fronds (centre) and falling over of infected palms (left).

International Mycological Association's database maintained at the Centraalbureau voor Schimmelcultures (CBS) Fungal Biodiversity Centre in the Netherlands lists 354 associated records. More than 20 species of *Ganoderma* have been recorded in Malaysia (Lee *et al.*, 2012) but the true number will not be known until the taxonomy of *Ganoderma* is properly sorted out and a full inventory of all the fungi in Malaysia is made.

Uncertainties in the identification and naming of *Ganoderma* species have been largely due to the great variability in macroscopic and microscopic characters of the fruiting bodies or basidiocarps (i.e. the mushrooms) as well as to the differing viewpoints among the many mycologists and collectors who have studied the genus as plant pathogens or as medicinal herbs. However, with the application of new molecular methods and



Basidiome of *Ganoderma philippii* growing on an old forest tree stump left over after logging.



Basidiomes of *Ganoderma philippii* fruiting on the stems of dead *Acacia mangium* trees

the rapid expansion of molecular databases for a broad array of fungi, it is likely that significant progress will be made with *Ganoderma* taxonomy in the near future.

Notwithstanding the still uncertain state of many *Ganoderma* species, what is clear is that the species of plant pathogenic *Ganoderma* are quite different from the species used in traditional and herbal medicine. Those used in traditional medicine belong to the morphologically highly variable *G. lucidum* complex while the plant pathogenic species consist of several other distinctly different *Ganoderma* species, such as *G. boninense*, *G. chaliceum* and *G. philippii*. The variable morphological features of the *G. lucidum* complex, such as the size, colour and shape of fruit bodies, is believed to be caused by different environmental conditions during development.



Symptoms of red root-rot disease in an *Acacia mangium* plantation. Note the dead tree in the centre surrounded by trees with sparse crowns and yellowing foliage of reduced size.



A large patch of second rotation *Acacia mangium* trees in Indonesia killed by red root-rot disease. (Photo: Caroline Mohammed)

Pathogenic *Ganoderma*

The most well-known plant pathogenic *Ganoderma* species in South-East Asia are *G. boninense* and *G. philippii*. *Ganoderma boninense* is the cause of oil palm basal stem rot, commonly referred to as BSR, which is the most destructive disease of oil palm in Malaysia and Indonesia. The fungus has also been recorded causing BSR in Angola, Cameroon,



Acacia mangium roots with the reddish brown 'skin' of fungal mycelia characteristic of red root-rot

Colombia, Ghana, Honduras, Nigeria, Papua New Guinea, Principe, Republic of Congo, San Tome, Tanzania, Zambia, Zimbabwe and Thailand (Ariffin *et al.*, 2000). The fungus can infect palms as early as 12 to 24 months after planting with increased incidence on 4 to 5 year-old palms, particularly in replanted areas or areas under-planted with coconut palms (Ariffin *et al.*, 2000). In Malaysia, BSR incidence of over 50% has been recorded in palms aged between 20 and 25 years and up to 85% in coastal estates (Chung, 2011). In Indonesia, disease incidence of up to 87% has been reported in palms over 16 years old (Viridiana *et al.*, 2012). As indicated by its name 'basal stem rot', the bases of palm stems infected by *G. boninense* become rotten resulting in the infected palm toppling over. Oil palms have a long productive life of up to over 25 years and because the disease affects productive young palms, it can cause significant economic losses. In fields with between 31%

to 67% increase in BSR incidence, yields were reduced by between 26% and 46% (Singh, 1991). Many measures have been tested and practiced for the management of BSR, such as soil mounding, sanitation, tree surgery, isolation trenches, chemical treatment, ploughing and harrowing, biological control, planting legume cover crops, planting disease resistant material and fertiliser inputs, with no one method being able to effectively control the disease. At the present time, sanitation measures, especially at replanting is seen as the single most important measure in BSR management (Chung, 2011).

Ganoderma philippii (syn. *G. pseudoferreum*) has been reported from many different hosts as well as from dead stumps and trunks in the forest but is most well-known as the cause of red root-rot disease in rubber (*Hevea brasiliensis*) and of the popular fast-growing exotic forest plantation species, *Acacia mangium*. In rubber,

red root-rot disease is not as serious as white root-rot disease caused by *Rigidoporus microporus*. However, red root-rot is a major disease causing significant tree mortality in acacia plantations and is also an emerging threat in *Eucalyptus* plantations in Malaysia and Indonesia.

Exotic acacias and eucalypts planted on short rotations of 5 – 7 years are highly popular in South-East Asia for pulpwood production. Presently there are an estimated 7 million ha of acacia and eucalypt plantations in South-East Asia with more than 3 million ha in Indonesia alone. Red root-rot disease is the most serious disease of short pulpwood rotations of *A. mangium* plantations in Malaysia and Indonesia and trees as young as six months of age are known to have been killed by the disease. Studies in Indonesia have shown that major tree mortality can reach up to 50% in some areas within less than 20 years of establishing the first rotation because of disease build-up in woody debris left behind after harvest. The fungus is a facultative parasite and in the absence of living roots can live on dead woody debris. The disease is mainly spread by contact of live roots with diseased roots and/or infected woody debris. In some Indonesian plantations which have been seriously infested by red root-rot disease, *A. mangium* has had to be replaced by other fast-growing species such as *Eucalyptus* hybrids and *E. pellita*. However, there is now evidence that these replacement species are also susceptible to the disease and other alternative species or strategies may be needed. Presently there are no methods that can effectively control the disease. Research is actively being conducted in Indonesia, both by local scientists and through international collaborative projects, in search of



Ganoderma chalceum growing from base of *Casuarina equisetifolia* with root disease.



Wild *G. lucidum* (www.ganodermatown.com/Wild-Ganoderma-lucidum.html)

effective means for management and control of the disease.

Medicinal *Ganoderma*

The popularity of *ling zhi* which is composed of several species of *Ganoderma* has recently extended from the East to the West. In the East *ling zhi* (靈芝 in Chinese) or *reishi* (in Japanese) has long been recognised and well respected as a powerful medicinal mushroom for over 2000



(www.museumsyndicate.com/artist.php?artist=1016)



(www.vanderven.com/655-Boxwood-Ruyi-scepter-the-form-Lingzhi-Fungus-DesktopDefault.aspx?tabid=6&tabind...)

Ling zhi as a symbol of longevity and power as shown in a royal painting entitled “The Pine, Hawk, and Glossy Ganoderma” by Giuseppe Castiglione commissioned by Emperor Qianlong of the Qing Dynasty, and Ruyi scepter in the form of a ling zhi fungus

years. Its name in Chinese means “spiritual herb”. According to an ancient dictionary, *Yupian* 玉篇 (Jade Page Dictionary), compiled in 534 AD, *zhi* 芝 refers to the *Ganoderma* species (especially *G. lucidum*), which is thought to symbolize good fortune (Lu, 2013). Thus, it is also called *ruicao* 瑞草 which in Chinese means auspicious plant (with *rui* 瑞 meaning "auspicious; felicitous omen" and *cao* 草 "plant; herb"). *Ling zhi* is also associated with health and healing, happiness, long life and even immortality. *Ling zhi* was further immortalized as the ultimate healing

substance and spiritual herb of China in the classic Chinese folk tale, "The White Snake", wherein a mystical heroine in the form of a white snake that could change into a human female, stole a magical *ling zhi* plant from the gods to save the life of her human lover. This is a story known by virtually every person of Chinese descent. Taoism has helped to further immortalize and elevate it to celestial status. Its depiction as a symbol of divinity, longevity and good fortune can be seen in art and artefacts, in paintings, embroideries, buildings, and



Cultivated *Ganoderma tsugae*



Cultivated *Ganoderma lucidum*



Antler or deer horn shaped reishi
(www.hokkaido-reishi.net/)



Natural *Ganoderma lucidum*
(www.ireishi.com)

sculptures of the gods and immortals throughout the Chinese dynasties. Even the traditional sceptre of emperors of China, called a "*Ru Yi*" 如意 or "as desired", was stylised in the form of *ling zhi*.

Ling zhi is documented in several ancient Chinese texts. It was first mentioned in Sheng-nong's Herbal Classic 神農本草經 (*Sheng Nong Ben Cao Jing*) written in the Eastern Han Dynasty (25-220 AD). Later, a renowned Ming

Dynasty physician scholar, Li Shi Zhen, gave a more detailed description of the efficacy and medicinal uses of *ling zhi* and related species in the Compendium of Materia Medica 本草綱目 (*Ben Cao Gang Mu*) in the 16th century. *Ling zhi* (*G. lucidum* and *G. sinense*) is currently listed in the Pharmacopoeia of People's Republic of China (Part I). In nature, it was very rare and only found in remote high mountain forests. Therefore, only the rich and powerful could afford to enjoy it. Two important monographs on

the cultivation of *Ganoderma* exist in the Taoist literature *Daozang* 道藏 (Taoist Patrology), namely, *Zhong zhicao fa* 種芝草法 (Methods of Cultivating Zhi) and *Taishang lingbao zhicaopin* 太上靈寶芝草品 (A Treatise of Zhi of the Supreme Numinous Treasure) (Lu 2013).

Ling zhi has over the centuries been claimed to have health enhancing effects and numerous other health benefits with little to no side effects in long term use. It has been portrayed as a panacea for maladies such as heart problems, low blood pressure, high blood pressure, cholesterol, HIV, cancer, diabetes, asthma, insomnia, rheumatism, paralysis, fatigue, hepatitis (A, B, and C), sterility, psoriasis, epilepsy, alcoholism, and the list goes on. Although many of these claims are exaggerated and unsubstantiated, a number of studies have documented a range of positive medicinal effects.

Three major physiologically active constituents in *G. lucidum* are polysaccharides, peptidoglycans and triterpenes (Boh *et al.*, 2007 and Zhou *et al.*, 2007 in Wachtel-Galor *et al.*, 2011). The polysaccharides and peptidoglycans are found in all parts of the fruiting bodies, mycelium and spores. Of these, polysaccharides (β -glucans) have been shown to exhibit a broad range of bioactivities, including immuno-stimulating, anti-inflammatory, hypoglycaemic, anti-ulcer, and anti-tumourigenic effects. *Ganoderma lucidum* is clearly rich in triterpenes, and it is this class of compounds that gives the mushroom its bitter taste. The triterpenes, ganoderic acids A and B, have also been shown to help alleviate common allergies by inhibiting the chemical mediators of inflammation, including histamine release (Wong, 2003). The bioactive



Whole dried mushroom of *G. lucidum* sold in Malaysia

proteins such as the immunomodulatory protein LZ-8 and other peptides from *ling zhi* exhibit hepatoprotective and antioxidant activities (Wachtel-Galor *et al.*, 2011; Lin *et al.*, 2014).

A review of the scientific literature reveals that some of the traditional medicinal claims can now be validated, particularly the antioxidant and anti-inflammatory properties. Antioxidants reduce oxidative stress due to free radicals. Inflammation is part of the complex biological response of our body tissues to harmful stimuli such as bacteria, viruses, damaged cells, or irritants. It is a protective response involving immune cells, blood vessels, and molecular mediators to eliminate the initial cause of cell injury, clear out necrotic cells and tissues, and to initiate tissue repair. Atherosclerosis, allergies, cancer, asthma, and rheumatoid arthritis are some of the more well-known inflammatory disorders. The antioxidant and anti-inflammatory properties of *G. lucidum* indirectly help to alleviate these conditions but more studies are needed to determine the actual mechanism associated with these disorders. Consumption of antioxidant-rich plants may help prevent cancer and other chronic diseases (Benzie & Wachtel-Galor, 2009). Antioxidants protect cells from



Whole *Ganoderma lucidum*
(www.hokkaido-reishi.net/)



Ganoderma capsule
(www.alohamedicinals.com/reishi-compare.htm)



Ganoderma lucidum slices
(www.mikei.com/en/products.html)



Soap
(www.dxnusa.com)



Facial care products
(www.dxnusa.com)



Broken *Ganoderma* spores
(www.ireishi.com)



Ganoderma tea
(www.online-ganoderma.com/quick_order_form.asp)



Ganoderma coffee
(uk.dxneurope.eu)

oxidative damage, which is likely to decrease risk of mutations and carcinogenesis. They also protect immune cells, allowing them to maintain immune surveillance and response.

Ling zhi is gaining credence as an example of an "adaptogen" – to help the body adapt to various stresses that may be caused by temperature, trauma, sleep deprivation, exposure to toxins, radiation, infection, or psychological problems. It is also gaining acceptance for use as an adjunct in combating the unpleasant side effects associated with radiation and chemotherapy for cancer treatment (Wong, 2003).

Today, *ling zhi* (mainly *G. lucidum*, *G. sinensis* and *G. tsugae*) is cultivated in many countries including China, Japan, Korea, Taiwan, Malaysia and the United States. In Malaysia, *ling zhi* (mainly *G. lucidum*) is cultivated in Kedah and Sabah with the strain most likely originating from China or Taiwan. The cultivated materials are mainly for the preparation of *ling zhi* products by the company that owns the farm. Where insufficient, additional quantities are presumably imported from China or other producer countries. There is an increasing popularity of *ling zhi* products worldwide with global consumption estimated at several thousand tonnes (Wachtel-Galor *et al.*, 2011). The commercially available products that incorporate *G. lucidum* as an active ingredient are available as food supplements. These include whole fruiting bodies, slices, powders, spores, extracts and isolated constituents in various formulations, which are marketed in the form of capsules, beverages (e.g. *ling zhi* coffee and tea), creams, hair tonics, soups, and syrups. As the



Ling zhi coffee and tea (www.manta.com)

fungal polysaccharides responsible for immunostimulation or modulation are water soluble, the best way to consume these beneficial molecules is via the traditional method of boiling *ling zhi* in water and drinking the resulting concoction.

With its growing popularity and demand, more in-depth studies are required on its many reputed positive health benefits. Reliable experimental and clinical data from well-designed human trials are needed to complement the great wealth of anecdotal evidence. Meanwhile, people will continue to consume *ling zhi* products for health.

In conclusion, the fungus *Ganoderma* consists of numerous species with different 'faces' or roles, hence the Jekyll and Hyde reference in the title. While a few species are highly prized for their medicinal value, others are plant pathogens and many others are saprophytes playing important roles in the decomposition of woody material and nutrient cycling. This reminds us of the importance of fungal taxonomy in the correct identification of any mushroom in determining its role in a given ecosystem.

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