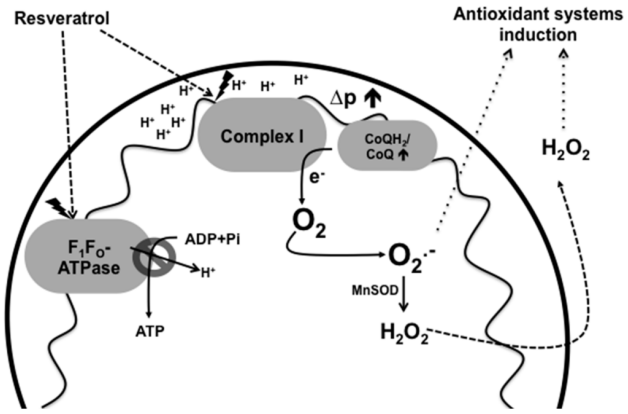
生物策略表

類別	生物策略 (Strategy)
生物策略 STRATEGY	代謝物使木材更耐用 (Metabolites Make Wood Durable)
生物系統 LIVING SYSTEM	圭亞那乳桑木（奶牛木） (*Bagassa guianensis* (Cow-wood))
功能類別 FUNCTIONS	#保護免受動物侵害 #防止真菌侵害 #防止微生物侵害 #Protect From Animals #Protect From Fungi #Protect From Microbes
作用機制標題	由於圭亞那乳桑木的組織存在一種名為二苯乙烯類（芪類）化合物的代謝物，因此增加了其耐用性。 (Tissues of the Bagassa guianensis tree increase its durability due to the presence of metabolites called stilbenoids.)
生物系統/作用機制示意圖 (確認版權、註明出處；畫質)	 圭亞那乳桑木 (https://asknature.org/strategy/metabolites-make-wood-durable/)  以白藜蘆醇為例之抗氧化示意圖 (Madrigal-Perez, & Ramos-Gomez, 2016)

作用機制摘要說明 (SUMMARY OF FUNCTIONING MECHANISMS)

木材被廣泛使用於建築和其他應用，其最主要的威脅來自真菌和昆蟲的降解作用。而部分樹木非常耐用，在先前的研究已證明，其耐用性是由於萃取物的存在。而在細胞壁的結構成分中也可能有助於抵抗生物降解。至於耐用性的增強也源自於各種化合物的協同或相加效應，例如有毒劑、疏水性化學物質和抗氧化劑。
為了解釋桑科植物的耐久性，對圭亞那乳桑木進行了植物化學研究。從心材中萃取乙酸乙酯，分離出 18 種次級代謝物，包括 6-O-甲基-moracin M、6-O-甲基-moracin N、moracin Z、moracin M、moracin N 和 moracin P 等 6 種 moracins，(-)-epialboctalol、arachidin 4、alboctalol、反式白藜蘆醇、arachidin 2、反式氧化白藜蘆醇和 artogomezianol 等 7 種二苯乙烯類化合物、3 種類黃酮（steppogenin、katuranin 和二氫桑色素）、β-谷甾醇和間苯二酚。
Schultz 表明二苯乙烯類化合物可以為 *Maclura pomifera* 的木材提供耐久性。另外該類化合物也被稱為殺真菌劑、殺白蟻劑和殺菌劑，並且還可能表現出抗氧化特性。

Wood is extensively used in construction and other applications, where it is degraded primarily by fungi and insects. However, some trees are exceptionally durable. It has previously been demonstrated that the durability of wood is due to the presence of extractives (Smith et al., 1989; Wang et al., 2005; Hsu et al., 2007); however, structural components of the cell wall may also contribute to the resistance to biodegradation (Silva et al., 2007). Enhanced durability also results from the synergetic or additive effects of various compounds, such as toxic agents, hydrophobic chemicals, and antioxidants (Suttie and Orsler, 1996; Okitani et al., 1999; Schultz and Nicholas, 2000; Schultz et al., 2007; Binbuga et al., 2008).
In order to explain the durability of the Moraceae plant family, phytochemistry of Bagassa guianensis was performed, Ethyl acetate extract was obtained from the heartwood and 18 secondary metabolites were isolated, induding 6 moracins (6-O-methyl-moracin M, 6-O-methyl-moracin N and moracin Z; previously identified: moracin M, moracin N and moracin P], 8 stilbenoids [presently identified: (-)-epialboctalol and arachidin 4; previously identified: alboctalol, trans-resveratrol, arachidin 2, trans-oxyresveratrol and artogomezianol], 3 previously identified flavonoids, steppogenin, katuranin and dihydromorin, β-sitosterol and resorcinol (Royer et al. 2010).
In addition, Schultz showed that stilbenoids provide durability to Maclura pomifera wood (Schultz et al., 1990). Stilbenes are known as fungicides, termicides and bactericides (Hart and Shrimpton, 1979; Likhitwitayawuid and Sritularak, 2001; Jayasinghe et al., 2004) and may also exhibit antioxidant properties (Dani et al., 2008; lacopini et al., 2008; Luo et al., 2005).

文獻引用 (REFERENCES)

「採用瓊脂平板技術，測定了多種(E)-4-羥基-3'-和/或 4'-取代的二苯乙烯及相關類似物對白腐真菌（Coriolus versicolor）以及褐腐真菌（Gloeophyllum trabeum 和 Poria placenta）的殺菌生物活性。針對這兩種褐腐真菌，所有具有 4'-氫的二苯乙烯以及具有 4'-氫的（還原的）聯苄化合物都比二癸基二甲基氯化銨（DDAC）具有更高的活性。利用定量構效關係（QSAR）研究發現二苯乙烯褐腐生物活性與疏水性呈線性相關。本研究的結果和對先前文獻的回顧表明，二苯乙烯植物抗毒素可以透過部分甲基化在體內進行修飾，以進一步增強其生物活性。」 （Schultz et al., 1990）

「對奧沙橙（*Maclura pomifera*）心材萃取物的分析表明，黃烷醇二氫桑色素（2.51%）和二苯乙烯氧化白藜蘆醇（2.65%）的含量比先前報告的要高得多。奧沙橙心材的高耐用性可能是由於含有大量的氧化白藜蘆醇和二氫桑色素。高含量的一種或兩種單體化合物也可以解釋刺槐和紅桑心材具有特別好的耐久性。」 （Schultz et al., 1995）

「我們先前提出高度耐用之心材中的萃取物可以透過雙重機制保護木材免受真菌定植和隨後的降解：萃取物具有一定的殺菌活性外，同時也是自由基清除劑（抗氧化劑）。」（Schultz＆Nicholas, 2000）

「從 *Artocarpus gomezianus* 的根中分離出一種新的二聚體二苯乙烯，即 artogomezianol 和 andalasin A，兩者均顯示出中等的酪胺酸酶抑制活性。」（Likhitwitayawuid＆Sritularak, 2001）

「從甲醇萃取物中的正丁醇萃取物透過抗真菌活性引導下進行分餾，得到兩種二苯乙烯衍生物(E)-4-異戊烯基-3,5,2',4'-四羥基二苯乙烯和(E)-4-(3-甲基-E-丁-1-烯基)-3,5,2',4'-四羥基二苯乙烯。在薄層層析生物自記錄法中，兩種化合物均表現出對芽枝狀枝孢菌的強抗真菌活性和對 DPPH 自由基的高自由基清除活性。」（Jayasinghe et al., 2004）

「透過使用缺乏特定抗氧化防禦系統（超氧化物歧化酶、過氧化氫酶或穀胱甘肽）的突變菌株，觀察到兩種多酚皆能提高對過氧化氫的耐受性，這與在四氯化碳條件下白藜蘆醇的存活率提高有關。耐受性的獲得與脂質過氧化的減少有關，表明白藜蘆醇和兒茶素的抗氧化特性涉及防止細胞膜氧化。」（Dani et al., 2008）

“The fungicidal bioactivity of a number of (E)-4-hydroxy-3'- and/or 4'-substituted stilbenes and related analogues was measured against the white-rot fungus *Coriolus versicolor* and the brown-rot fungi *Gloeophyllum trabeum* and *Poria placenta* using the agar plate technique…Against the two brown-rot fungi all stilbenes with a 4'-hydrogen and also a (reduced) bibenzyl compound with a 4'-hydrogen had greater activity than DDAC. A quantitative structure-activity relationship study found that stilbene brown-rot bioactivity was linearly related to hydrophobicity. The results of this study and a review of the prior literature suggests that stilbene phytoalexins may be modified in vivo by partial methylation to further enhance their bioactivity.”(Schultz et al., 1990)

“Analysis of osage orange (*Maclura pomifera*) heartwood extractives showed that two compounds were present at much higher levels than previously reported, the flavanonol dihydromorin (2.51%) and the stilbene oxyresveratrol (2.65%)…The high durability of osage orange heartwood may be due to the large amounts of oxyresveratrol and dihydromorin. High levels of one or two monomeric compounds may also explain the exceptionally good durability of black locust and red mulberry heartwood.”(Schultz et al., 1995)

“We previously proposed that extractives in highly durable heartwood may protect wood against fungal colonization and subsequent degradation by dual mechanisms: the extractives have some fungicidal activity and are also free radical scavengers (antioxidants).”(Schultz & Nicholas, 2000)

“A new dimeric stilbene, namely, artogomezianol (1), and the known compound andalasin A (2) were isolated from the roots of Artocarpus gomezianus. Both 1 and 2 showed moderate tyrosinase inhibitory activity with IC50 values of 68 and 39 μM, respectively.”(Likhitwitayawuid & Sritularak, 2001)

“Antifungal activity-guided fractionation of the n-butanol extract from the methanol extract of the stem bark of Artocarpus nobilis furnished two stilbene derivatives (E)-4-isopentenyl-3,5,2′,4′-tetrahydroxystilbene and (E)-4-(3-methyl-E-but-1-enyl)-3,5,2′,4′ -tetrahydroxystilbene. Both

compounds showed strong antifungal activity against Cladosporium cladosporioides and high radical scavenging activity towards the DPPH radical in TLC bio-autography method.” (Jayasinghe et al., 2004)

“By using mutant strains deficient in specific antioxidant defense systems (superoxide dismutases, catalase, or glutathione), it was observed that increased H2O2 tolerance produced by both polyphenols was associated with catalase, as well as the rise in survival rates caused by resveratrol under CCl4. The acquisition of tolerance was correlated with a reduction in lipid peroxidation, indicating that the antioxidant property of resveratrol and catechin involves protection against membrane oxidation.” (Dani et al., 2008)

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撰寫/翻譯/編修者與日期

王子易翻譯 (2024/03/10)；陳柏宇編修 (2024/11/30)

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