生物策略表

類別	生物策略 (Strategy)
生物策略 STRATEGY	角質層基質調節組織彈性 (Cuticle matrix tunes tissue elasticity)
生物系統 LIVING SYSTEM	恐怖薊 *Cirsium horridulum* (Terrible thistle)
功能類別 FUNCTIONS	#改變材料特性 #Modify material characteristics
作用機制標題	薊屬植物的角質層透過調節組成三羥基脂肪酸化合物的水合作用程度來控制其彈性程度 (The cuticle of the thistle plant controls its degree of elasticity by regulating the degree of hydration of constituent trihydroxy fatty acids compounds.)
生物系統/作用機制示意圖	

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

植物表面的外塗層，或稱角質層 (cuticle)，可防止其脫水和被動物攝食，隨著植物的年齡也會增加植株的結構支撐。較幼嫩的植株，以及較老植株的新芽，都具有更大程度的彈性，可能是因為它們不需要支撐較多的重量，或因為它們在生長期間需要更多水合作用 (hydration)。最初，角質層的三羥基脂肪酸 (trihydroxy fatty acid) 上的羥基 (OH, hydroxyl) 具有增加組織水合作用的功能。隨著組織老化，羥基之間的交叉鏈接 (cross-linking) 增加，使它們水合作用的程度減少，產生了更大的組織剛性 (rigidity)。

The external coating, or cuticle, of plant surfaces protects from desiccation and predation, but also add to plant structural support as plants age. Younger plants, and newer growth on older plants, have a greater degree of elasticity, perhaps because they do not need to support a large mass or because they need greater hydration during growth. Initially, the OH (hydroxyl) groups of cuticle-based trihydroxy fatty acids function to increase tissue hydration. As tissues age, cross-linking between hydroxyl groups increases, making them less available for hydration leading to greater tissue rigidity.

文獻引用 (REFERENCES)

「角質層是混合了可溶性脂質、脂質聚合物和多醣類的複雜結構。除了其減少水分流失和提供保護屏障的功能外，其力學特質可能對植物生長和發育具有重要意義…我們發現花朵部分中碳水化合物與脂質的比例為 1:7，但葉表角質層的比例則為 2:1。酯化角質 (esterified cutin) 成分佔角質層約 80%，二羥基十六烷酸 (di-hydroxyhexadecanoic acid) 是角質的主要單體，不論來源為何。彈性組織的角質特徵在於其三羥基單體的含量高於剛性組織的角質。數據顯示羥基增強了角質層的親水性並形成了表皮的彈性。」(Marga et al. 2001: 841)

「彈性和剛性組織之間最顯著的差異是彈性組織的三羥基脂肪酸含量高達 4 到 8 倍。因為三羥基 C18 單體的相對含量在成熟番茄的角質層發育期間有類似的下降現象，彈性似乎與較多羥基數量有所關連。彈性組織角質層中較高含量的三羥基單體可能增加這種角質層的水合作用，並與潛在增加的交叉鏈接能力對抗，使延展性降低。」(Marga et al. 2001: 846)

「角質層的彈性取決於羥基化脂肪酸的含量。相反於更多羥基可作為形成交叉鏈接潛在鍵位的概念，羥基似乎決定了角質層的親水性並促進水分浸漬 (impregnation)。隨著角質層年齡增加、自然脫水，可能與交叉鏈接物質，主要是酚類化合物 (phenolic compound) 的增加有關，可能導致成熟角質層硬化…酚類化合物的含量與角質層剛性相關。類似於木質素 (lignin) 對細胞壁的強化，角質層也可以預期通過增加酚類化合物的交叉鏈接來獲得更大的機械強度。與角質結合的酚類化合物含量會隨著花朵組織變得富有彈性而減少。」(Marga et al. 2001: 847)

「膜的水合作用導致彈性模量降低約 35-50%並且整體增加了總延展性。這些結果表明生物聚合物 (biopolymer) 的機械特性會受到水合作用顯著影響，因此水充當了塑化劑 (plasticiser) 的角色，增加了給定應力下的延展性以及黏性組成。」(Bargel et al. 2006: 902)

“The cuticle is a complex structure of soluble lipids, lipid polymers and polysaccharides. In addition to its functions to reduce water loss and provide a protective barrier, its mechanical properties may be significant to plant growth and development... We discovered that the ratio of carbohydrates to lipids is 1:7 in floral parts but 2:1 in leaf cuticle. Esterified cutin components represented about 80% of the cuticle and di-hydroxyhexadecanoic acids were the major monomers of cutin, regardless of origin. The cutin of elastic tissues is characterized by a higher content of tri-hydroxy monomers than the cutin of rigid tissues. The data suggest that hydroxyl groups enhance the hydrophilic character of the cuticle and contribute to cuticular elasticity.” (Marga et al. 2001: 841)

“The most remarkable difference between elastic and rigid tissues was the 4- to 8-times-higher content of trihydroxy fatty acids of the elastic tissues. Because a similar decrease in the relative amount of the trihydroxy C18 monomers occurred during cuticle development in ripening tomatoes, elasticity appears to be associated with a higher number of hydroxyl groups. The higher amount of trihydroxy monomers in the cuticle of elastic tissue argues for increased hydration of such cuticle and against the potential for increased cross-linking capability, which would reduce flexibility.” (Marga et al. 2001: 846)

“[T]he elasticity of cuticle depends on the amount of hydroxylated fatty acids. Contrary to the notion that more hydroxyl groups can serve as potential sites for cross-linking, the OH groups apparently determine the hydrophilicity of the cuticle and facilitate impregnation with water. As the cuticle ages, natural dehydration, possibly in conjunction with the increase of cross-linkers, most notably phenolic compounds, may lead to the often described hardening of mature cuticle…The content of phenolics was correlated with cuticular rigidity. Similar to the strengthening of the cell wall by lignins, the cuticle can also be expected to gain mechanical strength by increased cross-linking of phenolic compounds. Cutin-bound phenolics decreased as floral tissue became more elastic.” (Marga et al. 2001: 847)

“Hydration of the membranes caused a decrease in the modulus of ~35–50% and generally increased the total extensibility. These results indicate that the mechanical properties of the biopolymer are considerably influenced by hydration and, as a consequence, water acts as a plasticiser, increasing the extensibility at a given stress as well as the viscous component.” (Bargel et al. 2006: 902)

參考文獻清單與連結 (REFERENCE LIST)

Marga, F., T. C. Pesacreta, and K. H. Hasenstein. (2009). Biochemical analysis of elastic and rigid cuticles of *Cirsium horridulum. Planta* 213: 841-848. (https://link.springer.com/article/10.1007/s004250100576)

Bargel, H., K. Koch, Z. Cerman, and C. Neinhuis. (2006). Evans Review No. 3: Structure–function relationships of the plant cuticle and cuticular waxes — a smart material? *Functional Plant Biology* 33: 893-910. (https://doi.org/10.1071/FP06139)

延伸閱讀

生物系統延伸資訊連結 (LEARN MORE ABOUT THE LIVING SYSTEM/S)

https://en.wikipedia.org/wiki/cirsium_horridulum

撰寫/翻譯/編修者與日期

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AskNature 原文連結

https://asknature.org/strategy/cuticle-matrix-tunes-tissue-elasticity/