生物策略表

類別	生物策略 (Strategy)
生物策略 STRATEGY	葉片顏色與形狀增強冷卻效果 (Leaf color and shape enhance cooling effect)
生物系統 LIVING SYSTEM	耐陰植物 (Shade plant)
功能類別 FUNCTIONS	#保護免受光危害 #保護免受溫度危害 # Protect from light #Protect from temperature
作用機制標題	亞熱帶地區耐陰樹木的冷卻效果主要受葉片密度、葉片厚度、葉片材質及葉片顏色深淺影響 (The cooling effects of shade trees in subtropical regions are most influenced by foliage density and leaf thickness, leaf texture, and leaf color lightness)
生物系統/作用機制示意圖	

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

耐陰樹種 (shade tree) 藉由遮擋陽光並增加空氣濕度以提高散熱能力，但不是所有樹種的散熱能力都相同，有較粗糙、緊密排列及淺色葉片的樹種對於環境能提供最佳的散熱。

白天時太陽以陽光照射地球，所接觸到的物體則將之吸收。當陽光照射在樹木上，能量使葉片中的分子被激發，進而觸發光合作用且產生熱。熱能不足會造成植物生長緩慢，但過熱會導致植物中對熱敏感的分子被破壞。樹種能以產生不同反射角度之葉子，對其生長環境的日照產生適應性，換句話說即是暗色的葉片吸收較多陽光，亮色的葉片吸收較少陽光。例如，高緯度的針葉林有深色針狀葉，並可藉此吸收最大量的陽光。為避免灼傷，低緯度沙漠的仙人掌為淺色的，以反射接受到的部分陽光。

當地表暴露在陽光下時同樣也會被加熱，導致地表在白天吸熱，晚上則放熱。開曠地區因為晚上的散熱少而造成整體的升溫。葉片緊密排列的樹種可以在白天遮蔽地表，使其不被陽光加熱。遮蔽地區夜晚時會放熱，因此周遭溫度相較接收同樣日照的未受遮蔽地表涼爽。

除了一般的加熱之外，陽光的能量同樣會激發葉片中的水分子，並使之由液態轉為氣態，我們稱之為蒸散作用 (evapotranspiration)。水分子是很特別的，它可以攜帶大量的能量，卻不會將其以熱的形式釋放。在水蒸氣的狀態底下，水分子有很好的冷卻效果，因為它可以從接觸的物體上吸熱，包括樹木、地表及人體。為了使蒸散作用的冷卻效果最大化，有些樹種演化出較大表面積的葉片，以提供最大量的蒸散作用。粗糙的葉片比起光滑的樹葉有更大表面積，提供了更大的表面積供蒸散作用。這使得受高溼度環繞具有粗糙葉片的樹木有更好的散熱效果。

Shade trees provide a cooling effect by blocking sunlight and increasing air moisture, but not all trees offer equal relief from the heat. Tree species with rough, dense foliage and light colored leaves provide the greatest cooling benefits to their surroundings.

During the day, the sun warms the earth as waves of sunlight are absorbed by all that it touches. When sunlight falls on trees, the energy excites atoms in its leaves, triggering photosynthesis and creating heating. Too little heat results in very slow growth, but excess heat can be destructive to temperature sensitive molecules in the plant. Tree species are adapted to their local sunlight regime by producing leaves with varying degrees of reflectiveness; i.e., dark colored leaves absorb the most energy from sunlight, while light colored leaves reflect excess sunlight. For example, conifer forests cover high latitudes where sunlight is limited. By having dark needles, conifers are able to absorb the most energy from sunlight when it is available. In contrast, cacti receive plenty of sunlight in low latitude deserts. To prevent scorching, cacti are light colored to reflect some of the sunlight they receive.

Sunlight also heats the ground where it is exposed, causing it to collect the sun’s energy during the day and release the energy as heat at night. This results in an overall heat increase in exposed areas because nighttime cooling is minimized. Shade trees with dense foliage are able to block sunlight from reaching the ground during the day, preventing the ground from collecting energy. Because shaded areas do not release heat at night, ambient temperatures remain cooler on average than exposed areas receiving the same amount of sunlight.

In addition to general heating, the energy from sunlight also excites water molecules in leaves and transforms them from liquid to vapor, a process called evapotranspiration. Water molecules are unique because they are able to hold a great deal of energy without releasing it as heat. In the vapor state, water molecules have a pronounced cooling effect because they are able to absorb heat from objects they come in contact with, including trees, the ground, and the human body. To maximize this cooling effect, some trees are adapted to allow the greatest amount of evapotranspiration to occur by producing leaves with high surface area. Rough leaves have more surface area than smooth leaves, providing more space for evapotranspiration across the surface of the leaf to occur. This results in greater cooling benefits due to the high humidity surrounding trees with rough leaves.

文獻引用 (REFERENCES)

「近日，國立臺灣大學園藝學系的研究團隊在 HortScience 發表了一篇綜合性的研究，提供建議給亞熱帶地區的地景設計師 (landscape designer) 與都市規劃者…研究者分析了每種植物與冷卻相關的四項特徵，確定了葉片排列的影響最大，其次是葉片厚度、葉片材質、葉片顏色深淺。回歸分析 (regression analysis) 同樣顯示太陽輻射線 (solar radiation)、風速和蒸汽壓力 (vapor pressure) 對特定地點的降溫有很大的影響，可歸因於耐陰樹種或竹子。

十二個研究中的物種相較於暴露的地表能造成 0.64 到 2.52℃的降溫與 3.28-8.07℃地表溫度下降。我們的研究分析中，榔榆 *Ulmus parvifolia*、印度紫檀 *Pterocarpus indicus* 的冷卻效果是最好的，而阿勃勒 *Cassia fitula*、茄冬 *Bischofia javanica*、葫蘆竹 *Bambusa ventricosa* 效果最小。」(Science Daily 2010)

"Now, a research team from the Department of Horticulture at National Taiwan University has published a comprehensive study in HortScience that offers recommendations for landscape designers and urban planners in subtropical regions... The researchers analyzed four characteristics of each plant related to cooling effect, determining that foliage density had the greatest contribution to cooling, followed by leaf thickness, leaf texture, and leaf color lightness. Regression analysis also revealed that solar radiation, wind velocity, and vapor pressure at the site had significant effects on temperature reduction attributable to shade trees or bamboo.

Twelve species in the study provided 0.64 to 2.52ºC lower air temperature and 3.28 to 8.07ºC lower surface-soil temperature under the canopies compared with the unshaded open site. When analyzed for 'cooling effect', Chinese elm (*Ulmus parvifolia*) and Rose wood (*Pterocarpus indicus*) were the determined to be the most effective, while Golden shower tree (*Cassia fitula*), Autumn maple (*Bischofia javanica*), and Swollen bamboo (*Bambusa ventricosa*) were the least effective." (Science Daily 2010)

參考文獻清單與連結 (REFERENCE LIST)

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延伸閱讀

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

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

撰寫/翻譯/編修者與日期
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AskNature 原文連結
https://asknature.org/strategy/leaf-color-and-shape-enhance-cooling-effect/