生物策略表

類別	生物策略 (Strategy)
生物策略 STRATEGY	萬壽菊的檸檬烯驅除粉虱 (Limonene from marigolds repels whiteflies)
生物系統 LIVING SYSTEM	萬壽菊 *Tagetes patula*、番茄 *Solanum lycopersicum* (Marigold, tomato)
功能類別 FUNCTIONS	#生物性控制族群、蟲害、病害 #生態系統中合作 #不同物種之間合作/競爭 #維持生物多樣性 #保護免受動物危害 #Biological control of populations, pests, diseases #Cooperate within an ecosystem #Cooperate/compete between different species #Maintain biodiversity #Protect from animals
作用機制標題	萬壽菊花朵散發檸檬烯，能透過驅除粉虱來保護番茄 (Marigold flowers emit limonene, which protects tomatoes by repelling whiteflies.)
生物系統/作用機制示意圖	 

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

單一作物栽培 (monoculture)，即只耕種單一種類農作物，在農業產業中是十分普遍的做法。在單一作物栽培中，並不會有生物多樣性 (biodiversity)。這是一個問題，因為單一栽培的作物提供了充足的食物給以其為食的害蟲，而這些害蟲能夠容易地在植株之間繁殖及移動。為了阻止害蟲生長，農場人員經常使用會對大自然造成破壞的殺蟲劑。人工合成殺蟲劑是典型的化學物，能殺死其它植物或害蟲，也連同了有益的生物，例如蜜蜂和土壤微生物。

健康的生態系統通常有大量多樣的物種。一個含有多種植物、動物及微生物物種的地區，就是一個有高度生物多樣性的地方。生活在該地區的物種可以互相提供重要的服務 (services)。害蟲控制 (pest control) 就是一個植物提供給另一種植物的服務例子。在農業中，伴植 (companion planting)，或是在同一田地中至少種植兩種作物，可以作為幫助控制害蟲的一個方式。

一個伴植的例子就是將番茄與萬壽菊 (marigold) 一起種植。在一片只有番茄生長的田地，粉虱 (whitefly) 是一種會破壞作物的常見害蟲。在很久以前農夫會透過在番茄植株旁邊種植萬壽菊來解決這個問題。他們相信這樣做可以保護番茄免受粉虱侵襲。最近，科

學家證實了當番茄與萬壽菊一起種植時，粉虱的族群會變小。他們鑑定出檸檬烯 (limonene)，一種在萬壽菊中找到的化學物質，就是驅除粉虱的成分。檸檬烯屬於一群稱為揮發性植物化合物 (volatile plant compound, VPCs) 的化學物質。植物釋放揮發性植物化合物來傳遞訊息給其它植物，或是吸引或驅除昆蟲。昆蟲的觸角 (antennae) 或是其它感覺器官能偵測到揮發性植物化合物，就像人類的鼻子能察覺很多化學性化合物。揮發性植物化合物能從植物中分離出來。分離出物質之後能以噴灑或是散發的形式來驅除害蟲。然而，在番茄的例子中，直接種植萬壽菊比起使用分離出來的檸檬烯揮發性植物化合物，能提供更多的益處。這亦能增加生物多樣性以及提供花蜜給蜜蜂。

在大自然中，不同植物會釋放不同的揮發性植物化合物。總括來說，這些植物能驅除不同的昆蟲物種，並提供一個安全的方法來控制害蟲。這表示精心混合的植物可能可以驅除所有種類的害蟲。科學家除了害蟲控制之外還有更多可以向大自然系統學習的地方。這些知識有望指導科學家朝向有效而安全的害蟲控制方式發現，並可能減少或消除對人工製造殺蟲劑的需求。

Monoculture, the practice of planting only one crop, is commonly used in the agriculture industry. In monocultures, there is no biodiversity. This is an issue because a monoculture crop provides an abundant supply of food to a pest that favors it, and the pest can easily reproduce and travel between plants. In order to suppress pests, agriculturalists often use pesticides that damage the environment. Man-made pesticides are typically chemicals that kill other plants or pests along with beneficial organisms, such as bees and soil microbes.

Healthy ecosystems usually have a large variety of species. An area that consists of many plant, animal, and microbe species is an area with high biodiversity. Species living in that area can provide important services to each other. Pest control is an example of a service a plant can provide to another plant. In agriculture, companion planting, or planting at least two crops in the same field, can be used as a way to help control pests.

An example of companion planting is planting tomatoes with marigolds. In a field where only tomatoes are grown, whiteflies are a common pest that can destroy the crop. Long ago farmers solved this problem by planting marigolds next to tomato plants. They believed that doing so protected the tomato plants from whiteflies. Recently, scientists confirmed that whitefly populations were smaller when tomatoes were planted with marigold flowers. They've identified that limonene, a chemical substance found in marigolds, is the substance that repels whiteflies. Limonene belongs to a group of chemical substances called volatile plant compounds (VPCs). VPCs are emitted by plants to send signals to other plants or to attract or repel insects. An insect's antennae or other sensory organs detect the VPCs, just as a human nose detects many chemical compounds. VPCs can be isolated from a plant. The isolated substances can then be sprayed or emitted to repel pests. However, in the case of tomatoes, planting marigolds directly can provide more benefits than using the isolated limonene VPC. It also increases

biodiversity and provides nectar for bees.

In nature, distinct VPCs are emitted by different plants. Together, these plants can repel different insect species and provide a safe method for pest control. This suggests that a careful mix of plantings could repel all sorts of pests. Scientists have much more to learn from natural systems regarding methods of pest control. Those lessons should guide scientists towards effective and safe pest control and could reduce or eliminate the need for man-made pesticides.

文獻引用 (REFERENCES)

「我們的研究顯示了將萬壽菊與短蔓種 (short vine) 番茄伴植持續一整個生長季，會減緩粉虱族群的發展。在粉虱已經顯著建立族群之後，引進萬壽菊到未受保護的番茄之中，將會有較小的效果。使用檸檬烯噴霧器放置於番茄植株旁亦有很有潛力。有人認為這種混植番茄與伴生作物的方法，有機會幫助建立「輔助抗性」 (associational resistance)，能抵抗很多主要危害番茄的無脊椎害蟲。這種混合種植方式，如果是由可食用或觀賞性植物所組成，將會在經濟上有可行性，能夠減少對於額外化學性及生物性防治的需求，以及如果在戶外使用，可能產生植物多樣性 (plant-diverse) 的農業生態系統 (agro-ecosystems)，能更有效地為野生無脊椎生物提供庇護。」(Conboy et al. 2019: 1-2)

「這顯示了萬壽菊具驅散性的揮發性有機化合物 [volatile organic compounds, VOCs，又稱揮發性植物化合物] 很可能就是在間作萬壽菊與番茄中，粉虱出現減少的原因。」 (Conboy et al. 2019: 5)

「運用針對草食性 (herbivorous) 昆蟲物種的氣味景觀 (odorscapes) 作為殺蟲劑替代品使用於植物保護，已經有重大的實際成果…透過引入其他自然釋放不同種類揮發性植物化合物的植物物種來改變氣味景觀，亦能減少殺蟲劑造成的破壞。」(Conchou et al. 2019: 13-14)

「我們的發現證實了植物可能導致草食生物 (herbivore) 的族群被抑制，不只是透過降低平均品質，也透過在營養層面的異質性 (heterogeneity)…一個關鍵的影響是農業系統可能會遭遇到草食生物的大爆發，因為景觀簡單化 (landscape simplification)、植物物種多樣性減少以及作物育種使變異減少，這些都人為地降低了植物異質性，使草食生物的數量增加。在農業系統中增加植物營養的異質性，可能是通向可持續性昆蟲害蟲控制關鍵的一步。植物營養異質性可透過種植較多品種的作物來增加，透過在作物品種中增加基因多樣性，或透過育種，使該品種植物受昆蟲害蟲攻擊的部分增加營養構成或導入營養變化。」(Wetzel et al. 2016: 427)

“Our work indicates that companion planting short vine tomatoes with French marigolds throughout the growing season will slow development of whitefly populations. Introducing marigolds to unprotected tomatoes after significant whitefly build- up will be less effective. The use of limonene dispensers placed near to tomato plants also shows promise. It is argued that

this work supports the possibility of the development of a mixture of tomato companion plants that infer 'associational resistance' against many major invertebrate pests of tomato. Such a mixture, if comprising edible or ornamental plants, would be economically viable, would reduce the need for additional chemical and biological control, and, if used outdoors, would generate plant-diverse agro-ecosystems that are better able to harbour invertebrate wildlife." (Conboy et al. 2019: 1-2)

"This indicates that repellent volatile organic compounds [aka volatile organic compounds from plant origin, or VPCs] from marigold are the probable cause of the reduction in whitefly performance on tomato intercropped with marigold (Fig 1)." (Conboy et al. 2019: 5)

"Manipulating the odorscapes of herbivorous pest species has already important practical implications in plant protection as an alternative to pesticides… Modifying the odorscape by introducing other plant species that naturally release different VPCs can also reduce the damage caused by pest insects." (Conchou et al. 2019: 13-14)

"Our findings indicate that plants may contribute to the suppression of herbivore populations, not only through low average quality but also through heterogeneity in nutrient levels… A key implication is that agroecosystems may experience outbreaks of herbivores because herbivore performance is increased by artificially low plant heterogeneity owing to landscape simplification, reduced plant species diversity and crops that are bred to minimize variation. Increasing heterogeneity in plant nutrients in agroecosystems may be a key step towards the sustainable control of insect pests. Plant nutrient heterogeneity could be increased by planting greater numbers of crop varieties, by increasing genetic diversity within crop varieties, or by breeding varieties with increased constitutive or induced nutrient variance within the parts of the plant that are attacked by insect pests." (Wetzel et al. 2016: 427)

參考文獻清單與連結 (REFERENCE LIST)

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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/tagetes_patula https://www.onezoom.org/life/@tagetes_patula https://eol.org/pages/52374879
撰寫/翻譯/編修者與日期
譚國鎏翻譯 (2021/03/22)；黃盟元編修 (2021/03/22)
AskNature 原文連結
https://asknature.org/strategy/limonene-from-marigolds-repels-whiteflies/