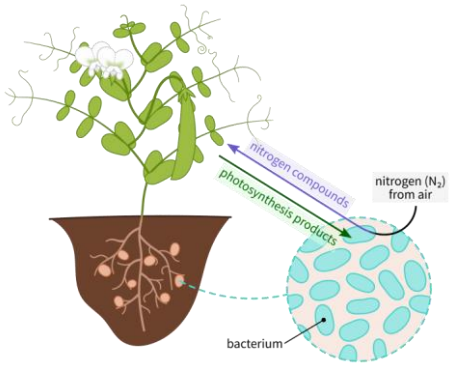
生物策略表

類別	生物策略 (Strategy)
生物策略 STRATEGY	互利共生增強對污染物的分解 (Mutualism enhances pollutant breakdown)
生物系統 LIVING SYSTEM	根瘤菌屬 *Rhizobium* (Rhizobacteria)
功能類別 FUNCTIONS	#化學性分解有機化合物 #不同物種之間合作/競爭 #Chemically break down organic compounds #Cooperate/Compete between different species
作用機制標題	植物和細菌透過互利共生關係分解土壤中的有機化合物 (Plants and bacteria break down organic compounds in the soil through a mutualistic relationship.)
生物系統/作用機制示意圖	  

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

介紹

植物由多個部位所組成，土壤之上有莖幹、葉片，以及花朵，而葉片會在那進行光合作用 (photosynthesize)。土壤之下的根部以及一些共生夥伴亦同樣重要。根部幫助固定植株並從土壤中吸收水分和養分。根系亦支持著多種細菌，包括生活在植物細胞內與生活在細胞之間的細菌。另一大類則為根圈細菌 (rhizobacteria)，牠們生活在植物的根際 (rhizosphere) 之中。

策略

根圈細菌與植物合作並幫助對方生存，稱為互利共生關係 (mutualistic relationship)。植物提供細菌生存空間並透過根系提供養分。作為回報，細菌將土壤中的天然化學物質，例如氮 (nitrogen)，轉換成更有用的化合物，例如氨 (ammonia)，硝酸鹽類 (nitrates) 和亞硝酸鹽類 (nitrites)。有些細菌所產生的化學物可以增加根系大小與表面積，因此與土壤有較多接觸。這增加了水分與養分的吸收，使植物更加強壯。

要滿足植物的所有需求，需要很多種的根圈細菌群落 (community)。而根系周圍的土壤有許多細菌。一公克的土壤樣本裡約有一億到一兆個細菌（一公克約等於一張美金紙鈔的重量）。

根圈細菌亦可以幫助分解土壤中的污染物並降低其毒性，使植物保持健康。科學家對於植物與它們的細菌夥伴如何清除種為碳氫化合物 (hydrocarbons) 的特定工業污染物十分有興趣。碳氫化合物是由碳元素和氫元素所組成的化合物。它們來自石油 (oil) 和天然氣 (natural gas)，以及塑膠、橡膠、溶劑和其它產品的製造過程，最終會以污染物形成存在於土壤中。研究人員嘗試將植物栽培於受到碳氫化合物所污染的地區，他們亦嘗試將根圈細菌加入土壤中。他們發現植物與根圈細菌能共同合作，其分解碳氫化合物分子的能力相較於植物或細菌單獨作用更為顯著。

潛力

碳氫化合物廢棄物會使人生病和減少植物的生長，因此找到能移除或分解這些污染物的方法十分重要。利用傳統方法例如掩埋 (digging) 和焚化 (incineration) 來分解碳氫化合物的價格非常昂貴，因此利用早已在植物和根圈細菌間存在的互利共生關係，或許能幫助我們發展出更符合經濟效益的方法來減少土壤污染。

Introduction

Plants are made up of different parts. The stems, leaves, and any flowers sit above the soil where the leaves photosynthesize. Below the soil surface the plants' roots and some important partners are also working hard. The roots help anchor the plants and take in water and nutrients from the soil. The roots also support a large variety of bacteria, including ones that live inside plants' cells and others that live in the spaces in between the cells. Another group of bacteria called rhizobacteria live outside the plant nestled among the roots. This area is known as the rhizosphere.

The Strategy

Rhizobacteria and plants work together to help each other survive. This is called a mutualistic relationship. The plant gives the bacteria a place to live and provides them with nutrients through its roots. In return, bacteria take natural chemicals in the soil such as nitrogen and turn them into more useful kinds of chemicals such as ammonia, nitrates, and nitrites. Some chemicals the bacteria produce increase the size and surface area of roots so they have more contact with the soil. This increases nutrient and water uptake, making the plant stronger.

It takes a diverse community of rhizobacteria to meet all of the plant's needs. And there are lots of bacteria in the soil near a plant's roots. 100 million to 1 trillion bacteria can be living in a 1-gram sample of soil (1 gram is about the weight of a U.S. dollar bill).

Rhizobacteria can also help break down soil pollutants and make them less toxic so the plants stay healthy. Scientists are interested in how plants and their bacteria partners get rid of a specific industrial pollutant called hydrocarbons. Hydrocarbons are chemical compounds made

up of carbon and hydrogen. They end up in the soil as pollutants from oil and natural gas and the manufacturing of plastics, rubber, solvents, and other products. Researchers have tried growing plants by themselves in areas polluted with hydrocarbons, and they've also tried putting rhizobacteria in the soil by themselves. What they've found is that when they allow the rhizobacteria and the plants to work together, they are better at breaking down the hydrocarbon molecules than either one working alone.

The Potential

Hydrocarbon waste can make people sick and decrease plant growth, so finding a way to remove or break down these pollutants is important. Using conventional methods such as digging or incineration to break down hydrocarbons is very expensive, so taking advantage of the mutual relationship that already exists between plants and rhizobacteria could help us develop more economical methods of reducing ground pollution.

文獻引用 (REFERENCES)

植物會與多種在根際生活的細菌有相互作用。這些細菌被根分泌物 (root exudate)吸引到根部表面…這種所謂的根際效應 (rhizosphere effect) 比起周圍的土壤，能在根系附近維持多達 100 倍的細菌細胞密度…這種植物-細菌相互作用可以是有害的，例如植物病原體 (phytopathogen)，也可以是有益的，如根圈細菌能促進植物生長並使其對植物逆境具有抗性…根圈細菌能透過保護寄主植物 (host plant) 抵抗害蟲 (pest) 和病菌而間接地促進植物生長。這種保護作用可以是基於直接的抗生作用 (antibiosis) 或是養分競爭，但亦可以是誘導系統性抗病 (induced systemic resistance, ISR) 所導致。從證據中推測與植物合作的細菌已經演化出代謝植物衍生 (plant-derived) 芳香族化合物 (aromatic compound) 的能力。苯并噁嗪類 (Benzoxazinoids, BXs) 例如 2,4-dihydroxy-7-methoxy-2H-1,4-benzoxazin-3(4H)-one (DIMBOA)，是帶有苯甲酸 (bnzoic acid) 部分 (moiety) 的雜環芳香族 (heteroaromatic) 代謝物…它們在植物防禦地面上的害蟲和病原菌中起作用。BXs 通常在植物相對早期和易受害 (vulnerable) 的生長階段中產生。」(Neal et al. 2012: 1)

Plants interact with a wide range of rhizosphere-colonising bacteria. These are attracted to root surfaces by chemical components in root exudates…This so-called rhizosphere effect supports bacterial cell densities in the root vicinity up to 100-fold greater than in surrounding soil…the plant-microbe interaction can range from deleterious, in the case of phytopathogens, to beneficial, where rhizobacteria can promote plant growth and resistance to plant stress…rhizobacteria can promote growth indirectly by protecting the host plant against pests and diseases. This protection can be based on direct antibiosis or competition for nutrients, but can also result from induced systemic resistance (ISR). Evidence suggests that plant-associating bacteria have evolved the ability to metabolise plant-derived aromatic compounds…Benzoxazinoids (BXs), such as 2,4-dihydroxy-7-methoxy-2H- 1,4-benzoxazin-3(4H)-one (DIMBOA), are heteroaromatic metabolites with benzoic acid moieties…their role in plant defence against above-ground pests and pathogens. BXs are typically produced during relatively early, vulnerable plant growth stages." (Neal et al. 2012: 1)

參考文獻清單與連結 (REFERENCE LIST)

Neal, A. L., S. Ahmad, R. Gordon-Weeks, and J. Ton. (2012). Benzoxazinoids in root exudates of maize attract *Pseudomonas putida* to the rhizosphere. *PLoS One* 7: e35498. (https://doi.org/10.1371/journal.pone.0035498)

延伸閱讀:

AskNature Team. (18 June, 2020). How Clownfish Avoid Sea Anemone Stings. *AskNature*. (2020). Retrieved 18 April 2021, from: https://asknature.org/strategy/intricate-relationship-allows-the-other-to-flourish/

Ritter, S. (3 November, 2020). Underground Network Distributes Resources. *AskNature*. Retrieved 16 April 2021, from: https://asknature.org/strategy/fungal-network-distributes-resources/

AskNature Team. (18 June, 2020). Mycorrhizal Fungi Distribute Water Between Plants. *AskNature*. Retrieved 18 April 2021, from: https://asknature.org/strategy/mycorrhizal-fungi-distribute-water-between-plants/

AskNature Team. (14 February, 2019). Symbiosis Enables Growth in Salty Soil. *AskNature*. Retrieved 18 April 2021, from: https://asknature.org/strategy/symbiosis-enables-growth-in-salty-soil/

AskNature Team. (23 March, 2020). Roots Recruit Symbiotic Soil Bacteria. *AskNature*. (2020). Retrieved 18 April 2021, from: https://asknature.org/strategy/roots-recruit-symbiotic-soil-bacteria/

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https://asknature.org/system/bacteria?post-type=Biological%20Strategies

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