Azospirillum: a Symbiotic Multi-Task Bacterium

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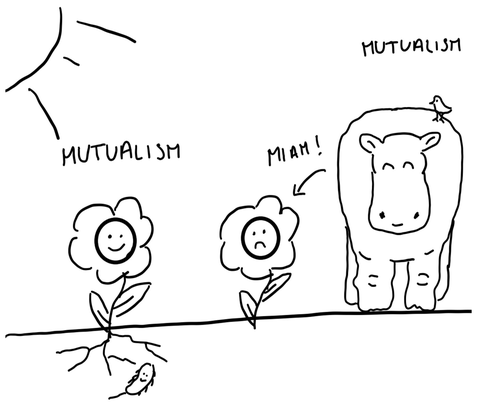
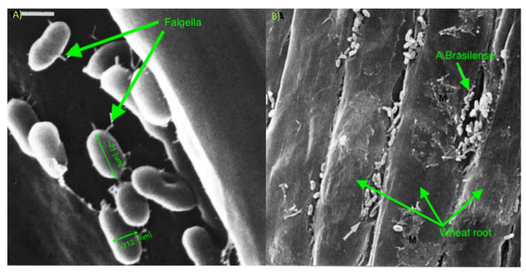
INTRODUCTION

In order to survive, living organisms have developed a range of useful functionalities and formed relationships with one another in given environments. The growth-promoting Azospirillum bacteria exhibits a **mutualistic symbiotic relationship** with plants, localizing at the roots of plants.



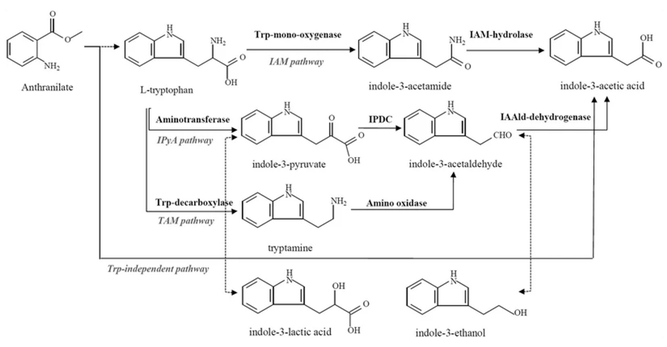
SEM of A.Brasilense in Wheat culture

(Oliveira Pinheiro, Ricardo de, Lúcia H. Boddey, Euan K. James, Janet I. Sprent, and Robert M. Boddey. "Adsorption and Anchoring of Azospirillum Strains to Roots of Wheat Seedlings.")



Around the time of the appearance of vascular plants on land (about 3 billion years ago), part of the **Rhodospirillaceae family**, to which Azospirillum belongs, transitioned to terrestrial environments. This was made possible thanks to the acquisition of genes allowing them to associate with plants in their **rhizosphere**.

PRODUCTION OF IAA (PHYTOHORMONE)



(Hypothetical pathways of IAA synthesis in Azospirillum. [3])

IAA (indole-3-acetic acid) is the most common and active **auxin**. The auxins represent a class of phytohormones that promote plant growth by cell elongation in the roots.

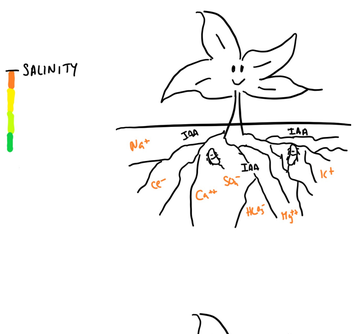
Several pathways for IAA biosynthesis by Azospirillum have been proposed:

- Three Tryptophan-dependant pathways: IAM, IPyA, TAM pathways;
- One Tryptophan-independent pathway.

The **IPDC (IPyA decarboxylase) enzyme** plays an important role in the IPyA pathway. Thus, the expression of IpdC gene coding for this enzyme is strongly related to IAA biosynthesis. Some environmental factors such as **pH**, **temperature**, **aerobic conditions**, or **nutriment stress** can influence the **ipdC gene expression** and, as a consequence, the IAA production. It is also suggested that the ipdC gene is up-regulated by IAA itself forming a positive feedback loop.

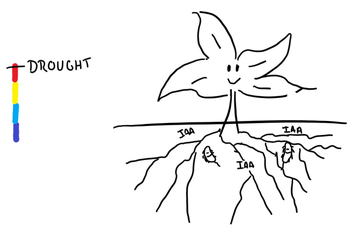
The bacterium produces more IAA in the **stationary phase** of growth. Therefore, IAA production occurs substantially to a **carbon and nitrogen stress** as in this situation, the lack of resources induces the population of Azospirillum Brasilense to reach the stationary phase (growth rate is equal to death rate).

EFFECTS OF IAA



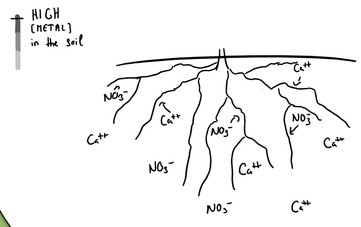
SALT

In the plant, a salinity stress can give rise to an **osmotic stress**. As the biosynthesis of phytohormones by the bacteria is generally not halted by high amounts of salt in the environment, their production of IAA reduces the salt stress in the plant by increasing the biomass of the roots. This helps the plant to come back to **ionic homeostasis**.



WATER

Under **drought conditions**, the plant suffers a water deficit stress. In this situation, the production of IAA by the bacteria enables an increase of the branching of the roots as well as an increase in their hair density. This makes the plants more prompt to capture the small amount of water in the soil.



NUTRIENTS

Soils poor in nutrients are not favorable for plant growth. Therefore, the production of IAA, **increasing the root lengths, volume and number**, enables more nutrient uptake by the plant and allows it to survive and even develop in those unfavorable conditions.

METALS

Increasing biomass, number and elongation of the roots by IAA favor the uptake of some metals. The **increased phytoextraction of copper and nitrate** can therefore be mediated through this phytohormone thanks to Azospirillum.

NITROGEN FIXATION

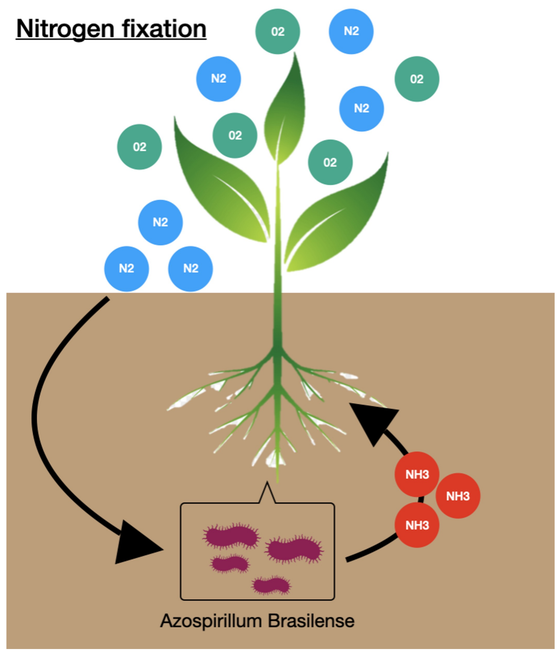
Nitrogen is one of the most important nutriments of life, as it is the principal component of amino acids, nucleic acids and other macromolecules. Due to the fact that atmospheric nitrogen molecules (N2) are highly stable, they cannot be directly assimilated by living organisms. Nitrogen has its own cycle, through which it is converted into multiple chemical forms. The conversion of nitrogen can be carried out through both biological and physical processes. Nitrogen fixation is the process through which bacteria, such as Rhizobacteria or Azobacter, convert atmospheric nitrogen (N2) into ammonia (NH3).

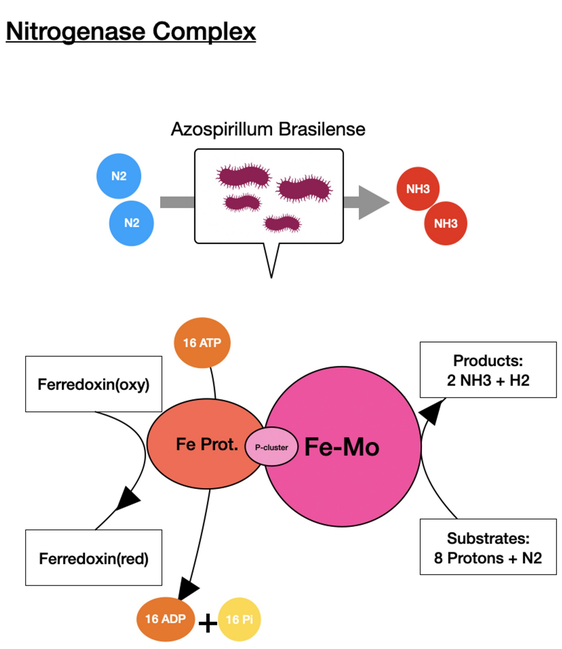
Plants require specific bacteria, like Azospirillum Barsilense, to convert this atmospheric nitrogen into nitrogen compounds that can be used in their metabolism, such as ammonia. A.Brasilense is a nitrogen fixing bacteria. It is able to convert N2 into NH3 molecules within the root nodules, even under microaerobic condition at low nitrogen levels.

NITROGENASE COMPLEX

The fixation of nitrogen occurs in A.Brasilense through the action of a **nitrogenase complex**. This complex is composed of two proteins, the **nitrogenase** (MoFe protein) which is the site of N_2 reduction and the **reductase** (Fe protein) which transfers electrons from the reducing agent (Ferredoxin) to the nitrogenase protein. The interaction between the two proteins creates the **p-cluster** that is responsible for the transfer of electrons from the reductase to the nitrogenase. All the components of this pathway alternate between their oxidized and reduced form. The mechanism through which nitrogenase complex converts N2 into NH3 requires a big amount of energy (16 ATP molecules per N2 molecule).

Nitrogen fixation is highly regulated by two external components: the **oxygen tension,** which is the partial pressure of O2 in the cell, and the **concentration of nitrogen compounds** in the soil.

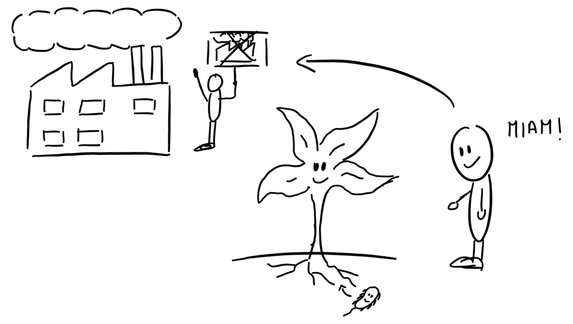




CONCLUSION

The use of the Azospirillum bacteria in agriculture can be a sustainable method for the **improvement of crop yield**, as the IAA they produce improve the plants' growth. In addition, IAA can promote **phytoextraction**, meaning that, through the incubation of plants with this bacterium, the soil can be "detoxified".

Climate change affects the soil, the availability of nutrients and water, which in turn impact the plants. The presence of plants is necessary for a large number of other organisms. With all the beneficial effects that the Azospirillum Brasilense provides, thanks to IAA amongst others, incubation of plants with this bacterium could protect them to decrease in number when under different stresses, like drought, that climate change creates.



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