Universitat Autònoma de Barcelona

Review on

GENETIC PERSPECTIVES ON SYMBIOTIC MECHANISMS OF ENDOPHYTIC BACTERIA

INTRODUCTION

Plant associated bacteria can be epiphytes if they infect and colonize the host surfaces, forming external structures, or endophytes if they colonize the plant **internally.**

Endophytes live inside their hosts without causing any harm, and the exchange of products benefits both partners.
The plant provides **nutrients** and a stable habitat with **less competitors** than the soil, while bacteria provide **nutrients**, and **defence.**[1]

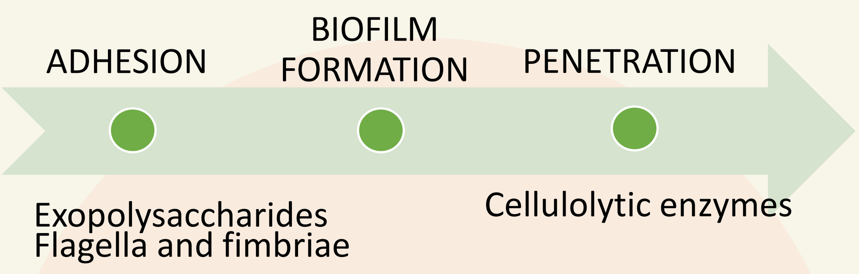
In all mutualisms, a fluid genetic dialogue must be held by both partners in order to work in synchrony. To shed light in the physiological processes that the bacteria induce to their hosts, modern -omic approaches are being made for the global study of genes and biochemical adaptations for the mutualistic lifestyle. [2]

Methods & Objective

Bibliographic search from PubMed data base for reviews and classical articles with the keywords: *endophytic bacteria, seed bacteria, endophytic genes*

To acquire a general view of the **genetic components of the plant-endophytic bacteria mutualism.**

GENETIC MECHANISMS



miRNAs[3]

- Pathogenic bacteria: promote defence and detoxification pathways
- Mutualistic bacteria: turn off defence pathways to allow proliferation

⚠ Stop the over-proliferation of endophytes

ENDOSYMBIONT EVOLUTION

A set of "endophytic genes" could be associated with host colonization. But many of them were also found in pathogens.

Transport	Polymer degradation	Secretion	Transcriptional regulators	Detoxification
for nutrient obtention	for cell wall degradation	of effectors into the host	for biofilm formation and adhesion	for surviving ROS response

Table 1. Mechanisms endophytic orthologue genes are involved in. ***Predicted by Ali et al, 2014 after a genome comparison analysis.***

Same machinery for infection, a separate set of genes allows mutualism/pathogenicity.

PLANT-BENEFICIAL ENDOPHYTE GENES[5]

1. GROWTH PROMOTION

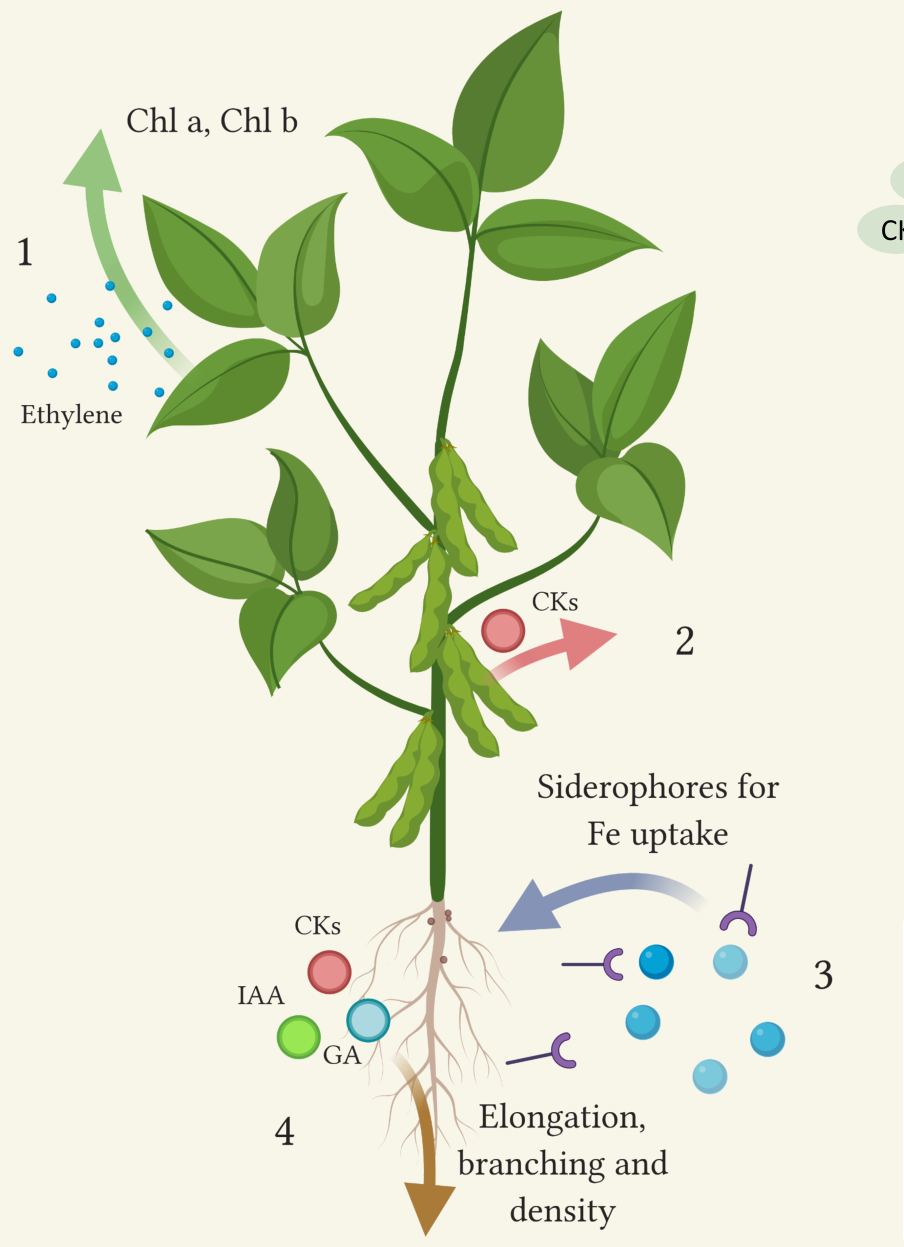


Fig. 1. Bacterial mechanisms for plant growth promotion. *(1) Ethylene increases chlorophyll levels, (2) Cytokinines (CKs) promote germination, (3) phosphorous and nitrogen fixation, plus iron uptake via siderophores, (4) root elongation via indole-3-acetic acid (IAA), CKs and gibberellins (GA).*

2. DEFENCE

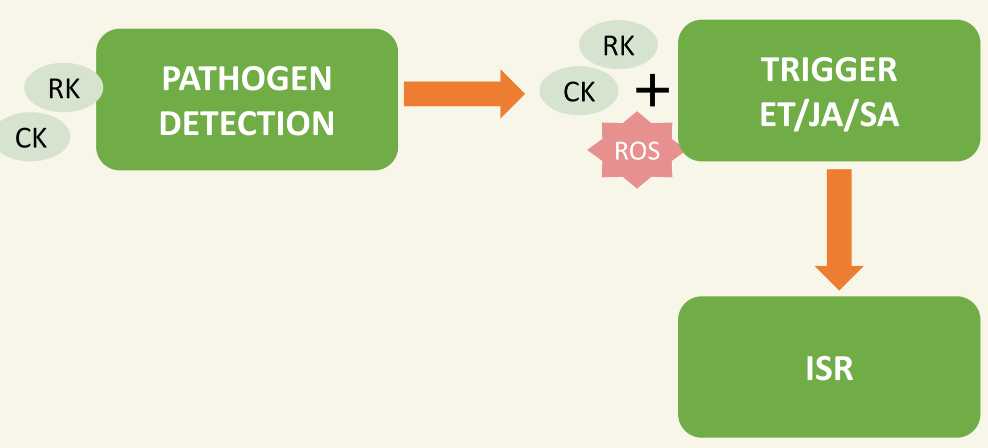


Fig. 2. Enforcement of the plant immune system. *receptor kinases (RK) and cytoplasmic kinases (CK), along with ROS trigger the ethylene/jasmonic acid/salicylic acid (ET/JA/SA) pathway, involved in the induced systemic response (ISR).*

LIPOPEPTIDES	VOCs	TOUGH LEAVES

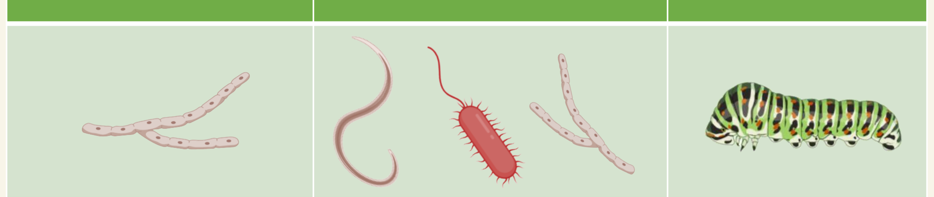


Table 2. Pathogen. Attack. *Lipopeptides cause leakage in hyphal membranes, volatile organic compounds (VOCs) are broad-spectrum antimicrobials and tougher leaves dissuade herbivory.*

3. STRESS ENDURANCE

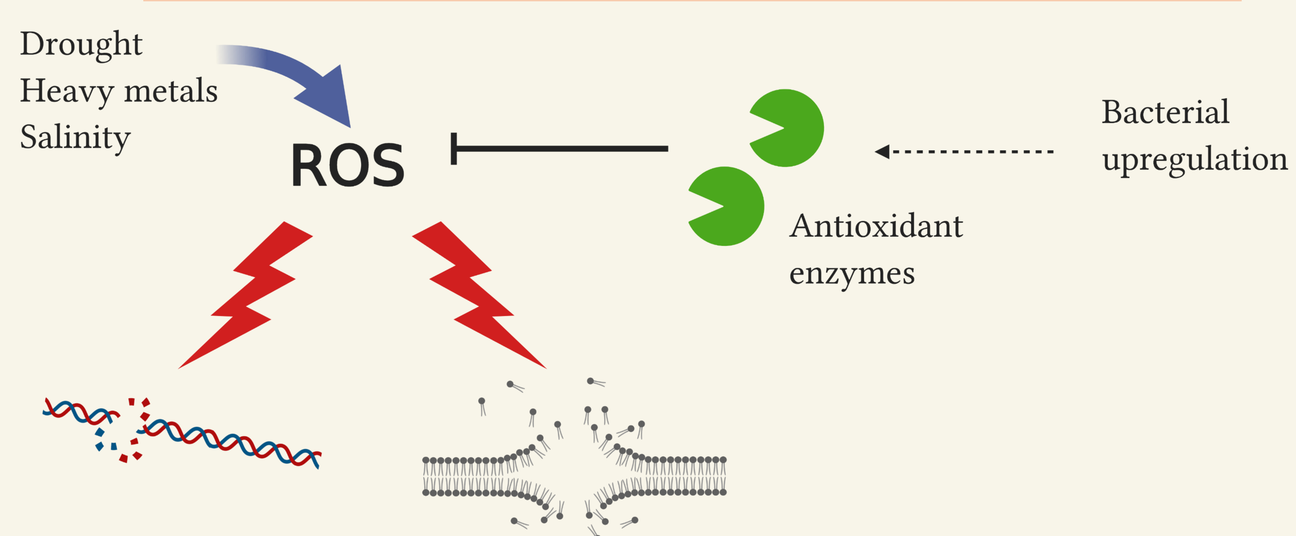


Fig. 3. Modulation of the redox status of the plant reduces oxidative damage. *Stress triggers plant cells to form ROS products that damage tissues. Endophytic bacteria upregulate the transcription of ROS-degrading genes.*

SEED ASSOCIATED BACTERIA

Bacteria help **gemination**, and give support to the seedling (crucial phases in the plant's life-cycle). Therefore, they impact on plant **ecology**, **health** and **productivity**.

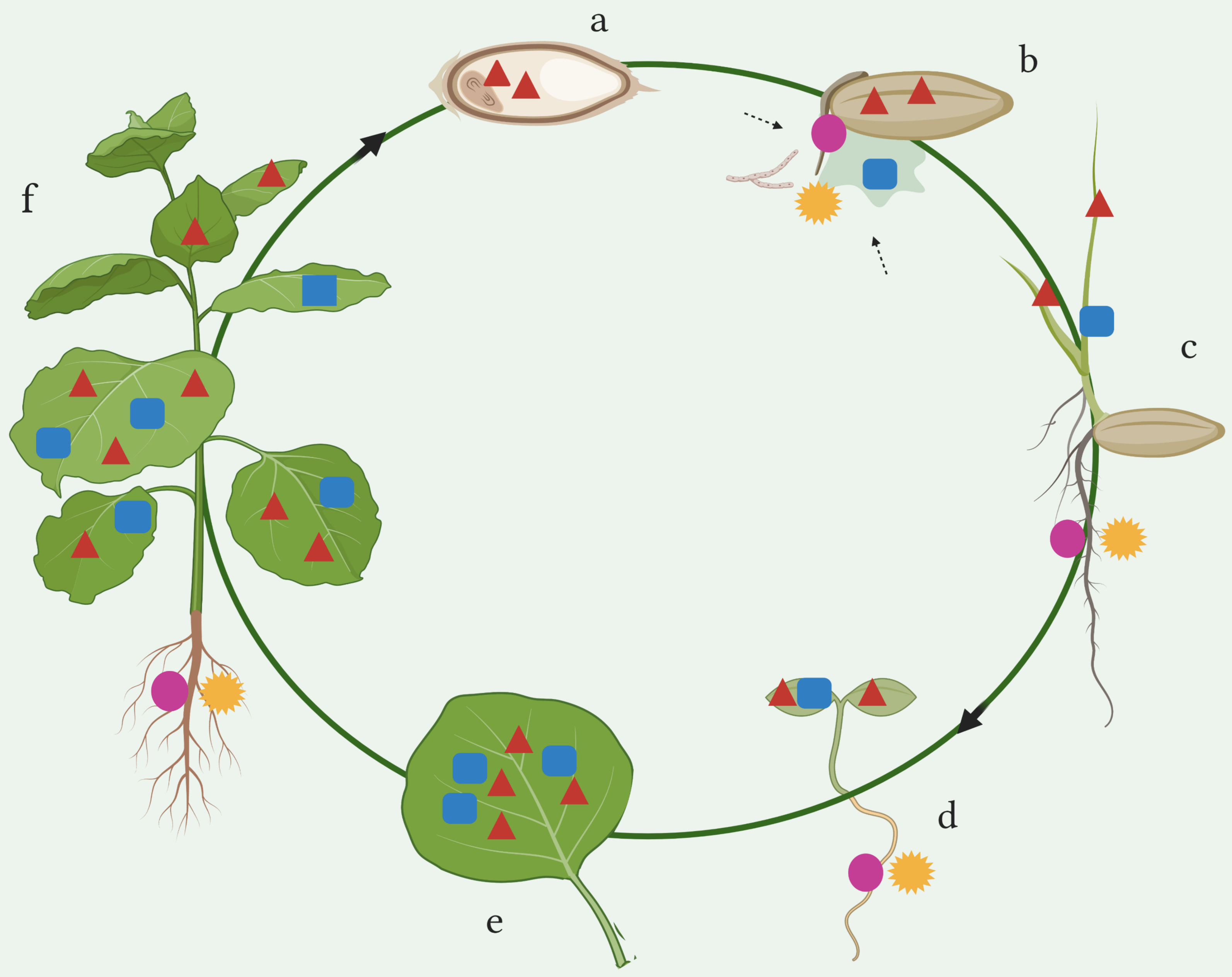


Fig. 4. Based on Kandel et al, 2017. Bacterial colonization cycle of the host. Different shapes refer to different bacterial populations. *(a) Propagation via seeds. (b) Soil bacteria attraction with root mucilage. (c) Soil bacteria colonize roots and some became endophytic. (d) Inherited and alien endophytes colonize new tissues. (e) Endophytes reach leaves and flowers. (f) The whole plant is colonized and some of the flower endophytes colonize the seeds.*

Vertical Transmission And Evolutive Implications

Endophytes originated from free-soil living bacteria. New genetic mechanisms have evolved and continue to do so.

The vertical transmission should select against pathogenicity and favour mutualism as endosymbionts depend on their host for survival and reproduction. This translates into a **coadaptation** while forming a **holobiont**, where chromosomal, chloroplast and microbial DNA are transmitted to the next generation.[7]

CONCLUSIONS

A plant's nuclear DNA solely cannot determine its fitness, as changes in the microbiome would create new holobionts, and therefore, modulate its behaviour. When studying a vegetal organism, **nuclear, chloroplast and bacterial/fungal genetic material** must be taken into account.

APPLICATIONS
Endophytes in agriculture can alleviate the stress posed by the expansion of arid soils due to the climate change, and have shown the capacity of mitigating other stresses. They also promote germination.

DOMESTICATION
Selecting the most productive individuals may have inadvertently promote the endophytes that where most beneficial to the host. Lost variability on domesticated species could also be analysed, and possible inoculation of endophytes from ancient varieties could be beneficial in agriculture.

REFERENCES

1) Chimwamurombe et al. (2016). Isolation and characterization of culturable seed-associated bacterial endophytes from gnotobiotically grown Marama bean seedlings. **(2)** Truyens et al. (2015). Bacterial seed endophytes: genera, vertical transmission and interaction with plants: Bacterial seed endophytes. **(3)** Plett et al. (2018). Know your enemy, embrace your friend: using omics to understand how plants respond differently to pathogenic and mutualistic microorganisms. **(4)** Ali et al. (2014). A bioinformatics approach to the determination of genes involved in endophytic behavior in Burkholderia spp. **(5)** White et al. (2019). Review: Endophytic microbes and their potential applications in crop management. **(6)** Kandel et al. (2017). Bacterial Endophyte Colonization and Distribution within Plants. **(7)** Mitter et al. (2017). A New Approach to Modify Plant Microbiomes and Traits by Introducing Beneficial Bacteria at Flowering into Progeny Seeds.