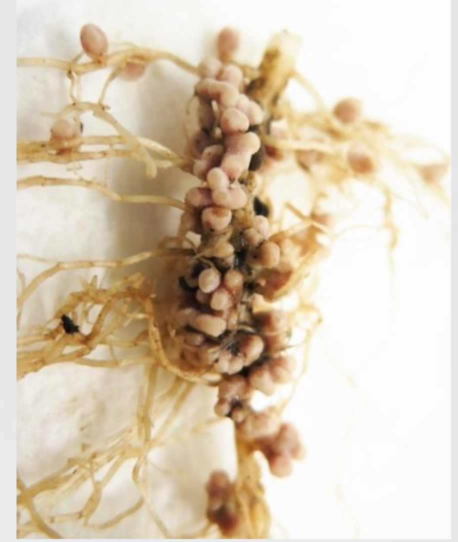


Wie beeinflusst die Leguminosen-Bakterien Interaktion die Trockenstressantwort der Pflanze?

ÖAW Workshop
Der Stickstoffkreislauf

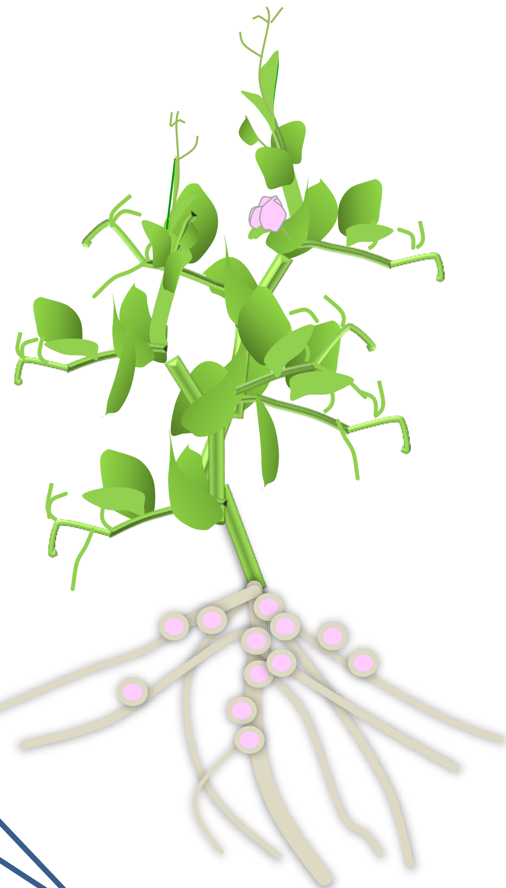
Stefanie Wienkoop
Molecular Plant Systems Interaction

INTRODUCTION

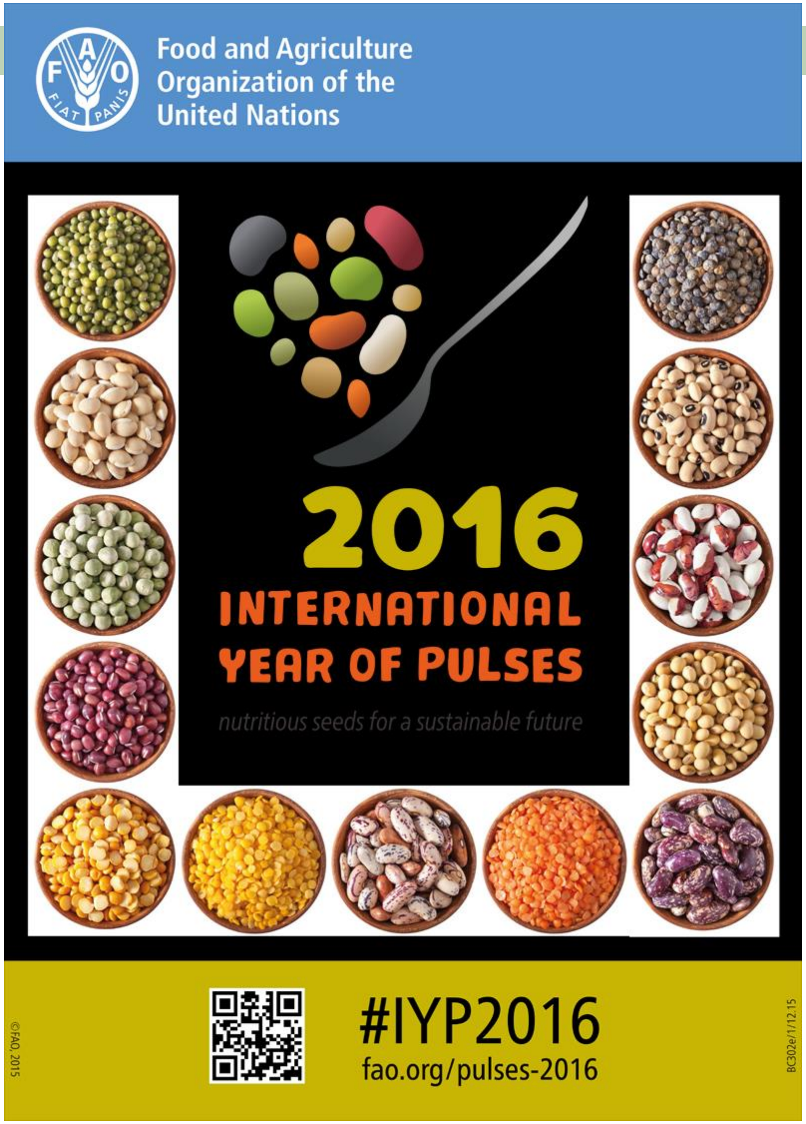
Legumes - Pulses

Hülsenfrüchtler sind die zweitwichtigste Pflanzenfamilie für die Ernährung von Mensch (70%) und Tier.

Bohnen, Erbsen, Linsen,...



Leguminosen mit symbiotischen Rhizobia



Introduction

Hülsenfrüchtler

Leguminosen

Mineral-
stoffe

Anti-
oxidantien

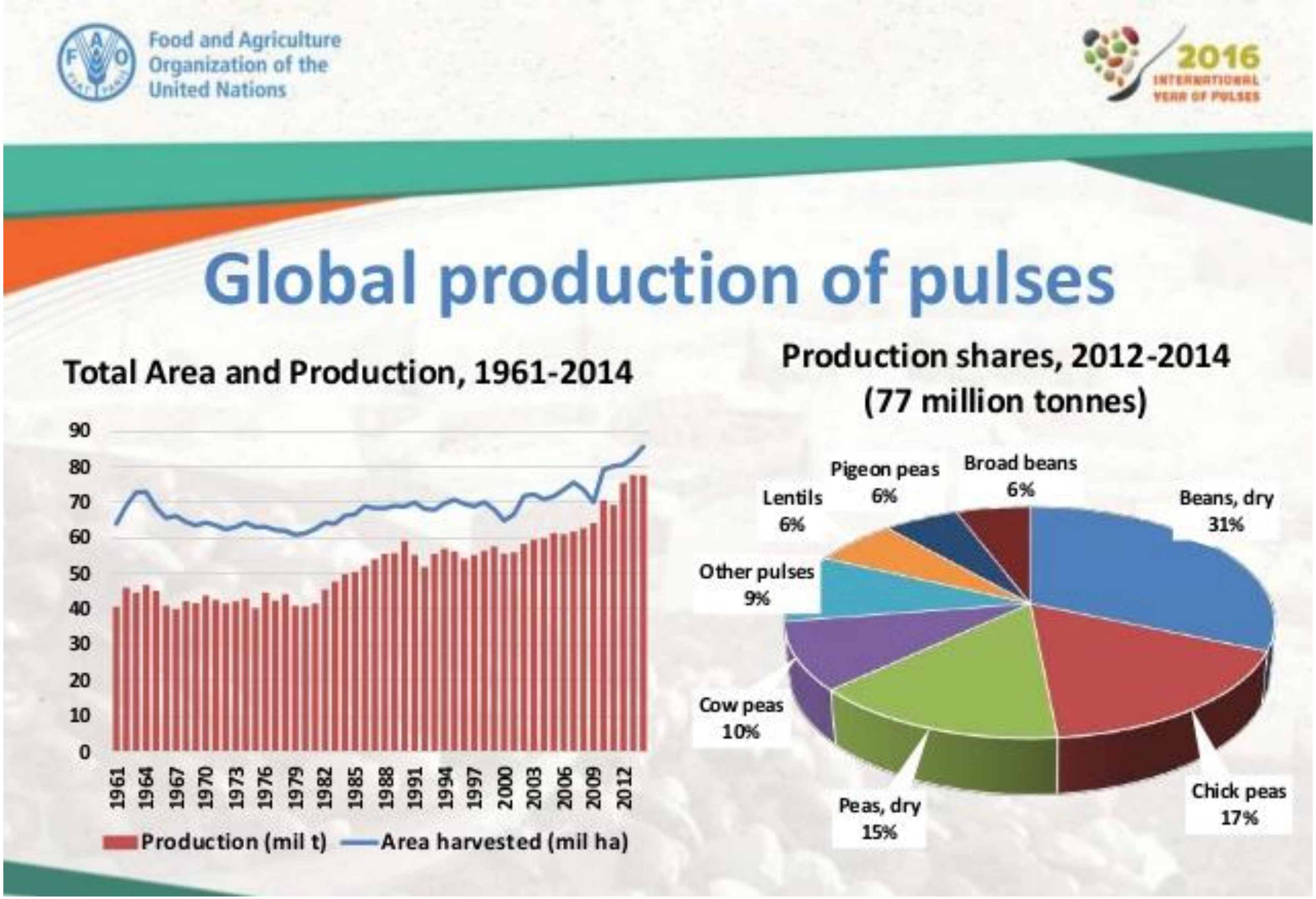
Balaststoffe

Proteine

Boden-
verbesserung

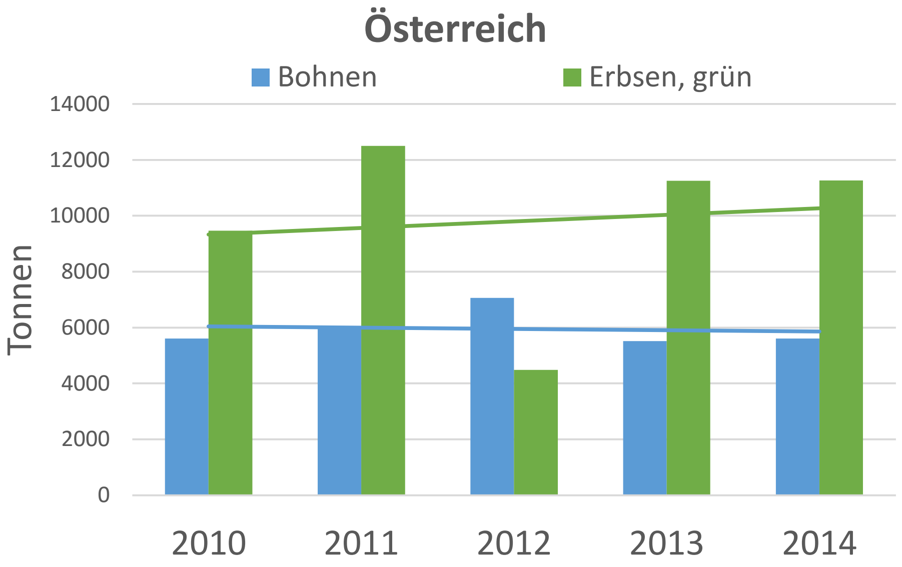
Introduction

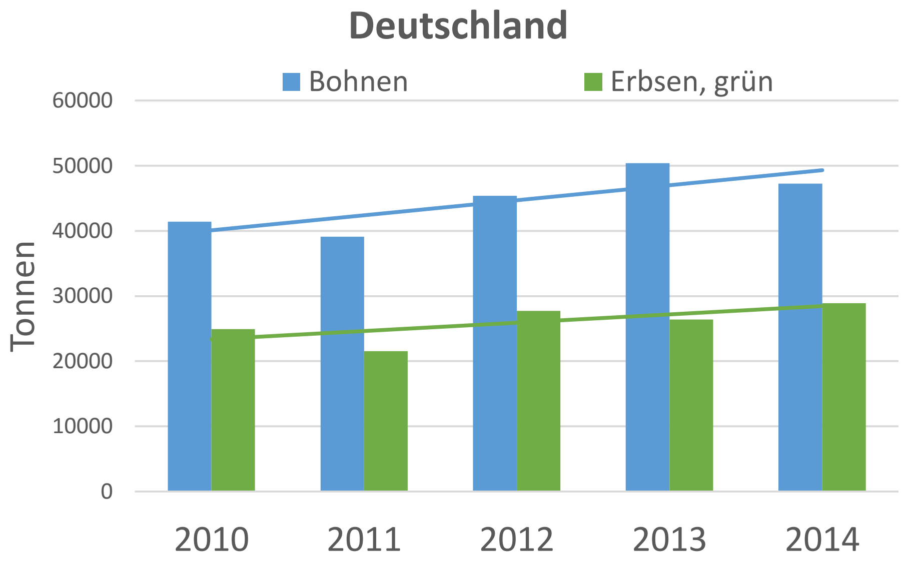
Hülsenfrüchte Produktion



Introduction

Hülsenfrüchte Produktion

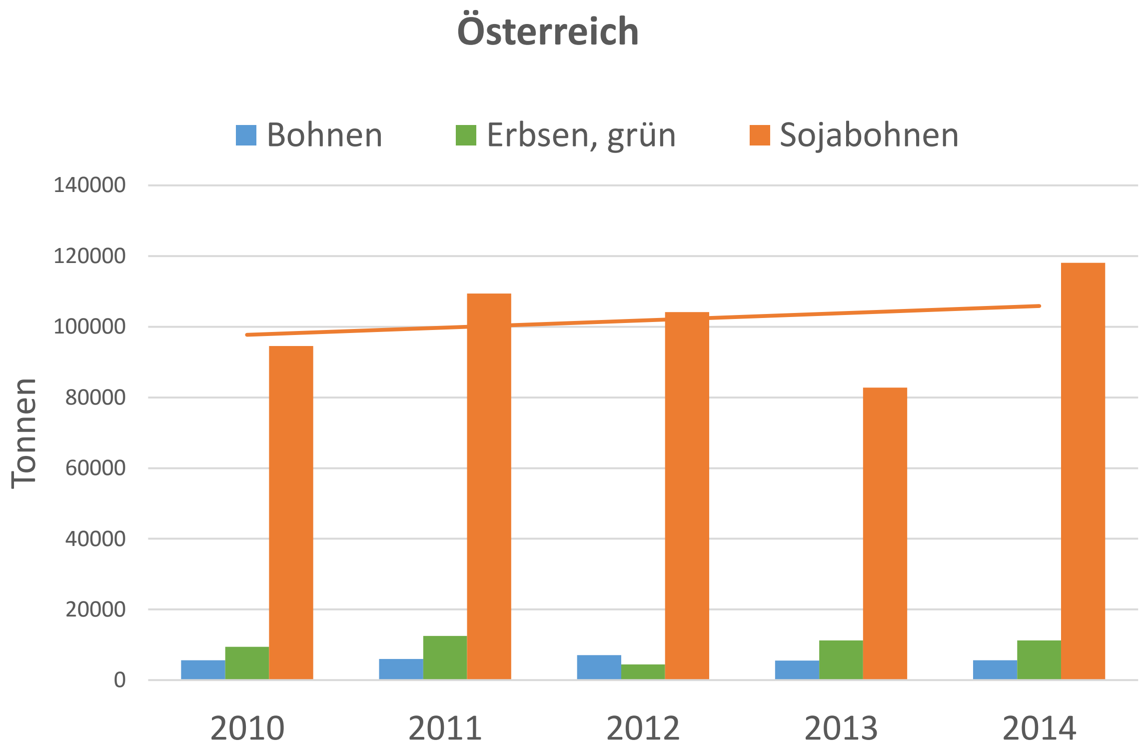




FAOSTAT

Introduction

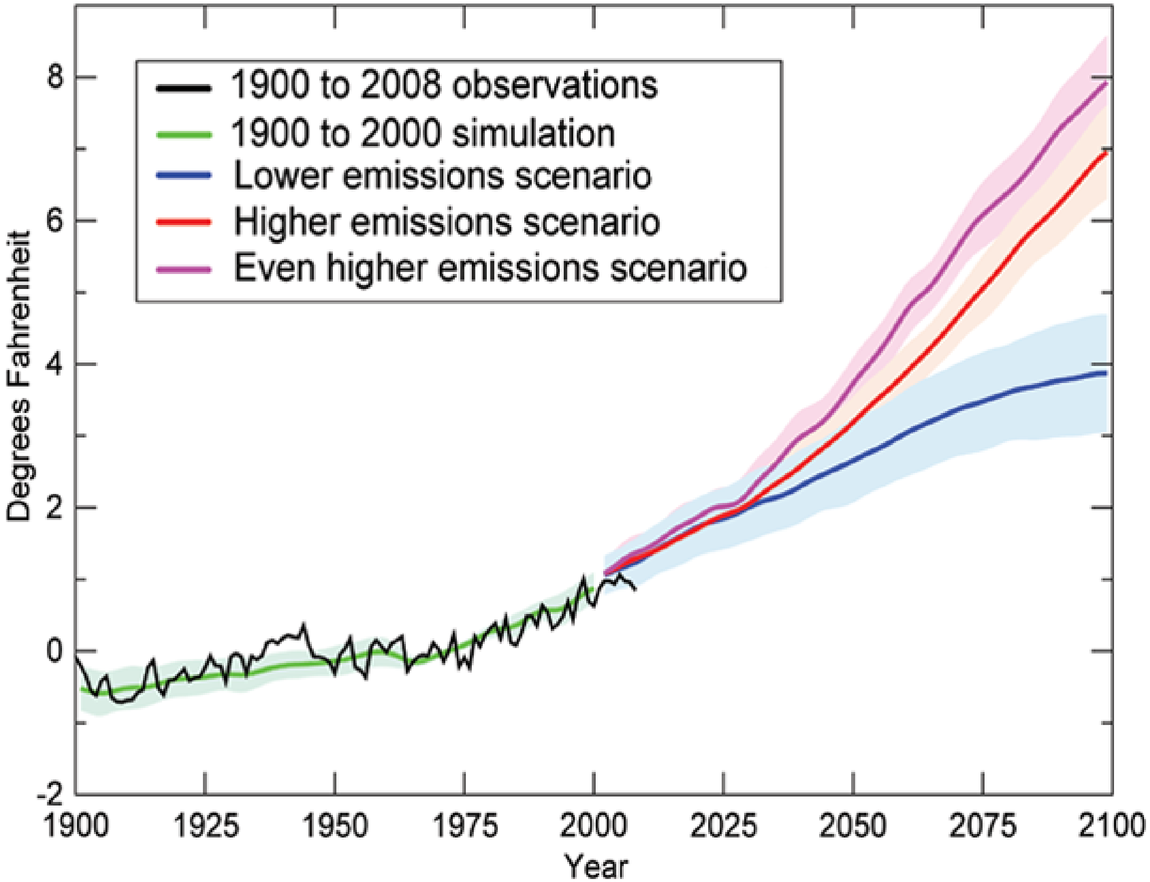
Sojabohnen Produktion



FAOSTAT

Introduction

Temperaturanstieg & Trockenstress



Smith, T. M., R. W. Reynolds, T. C. Peterson, and J. Lawrimore. "Improvements to NOAA's Historical Merged Land-Ocean Surface Temperature Analysis (1880-2006)." Journal of Climate 21, no. 10 (2008): 2283-2296.

Introduction

Temperaturanstieg & Trockenstress reduzieren Ertrag

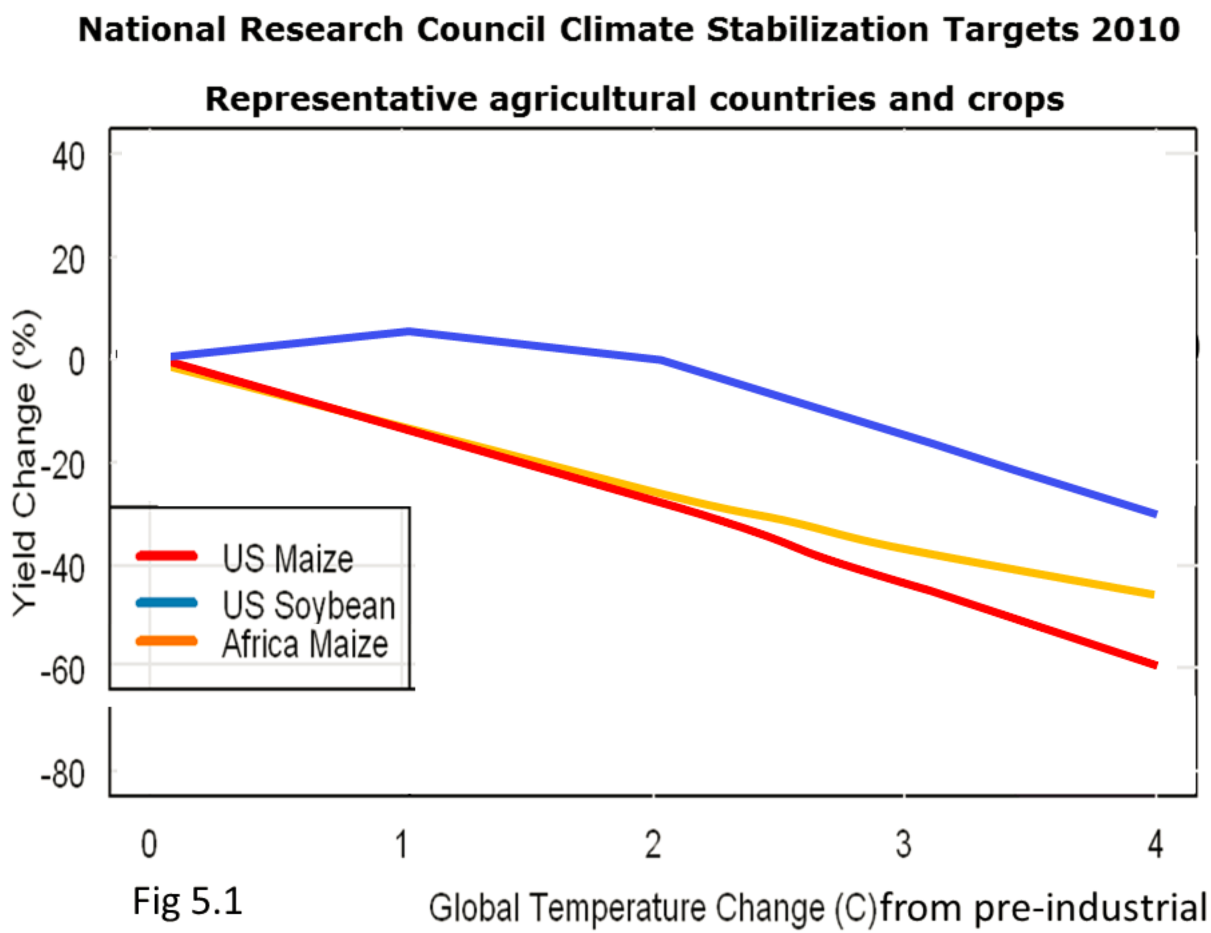
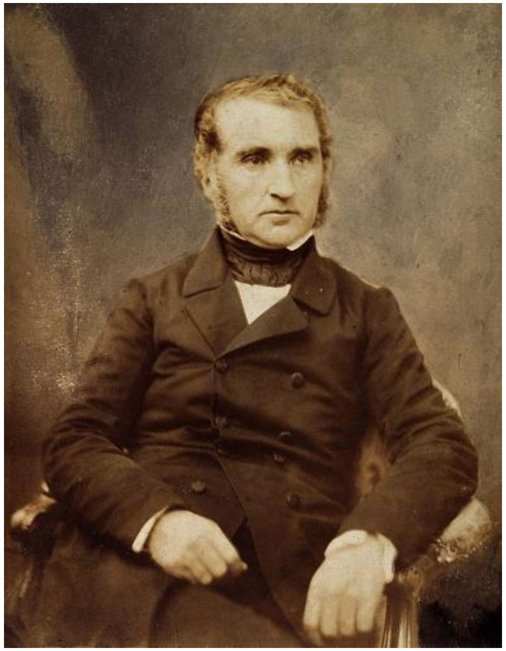


Fig 5.1

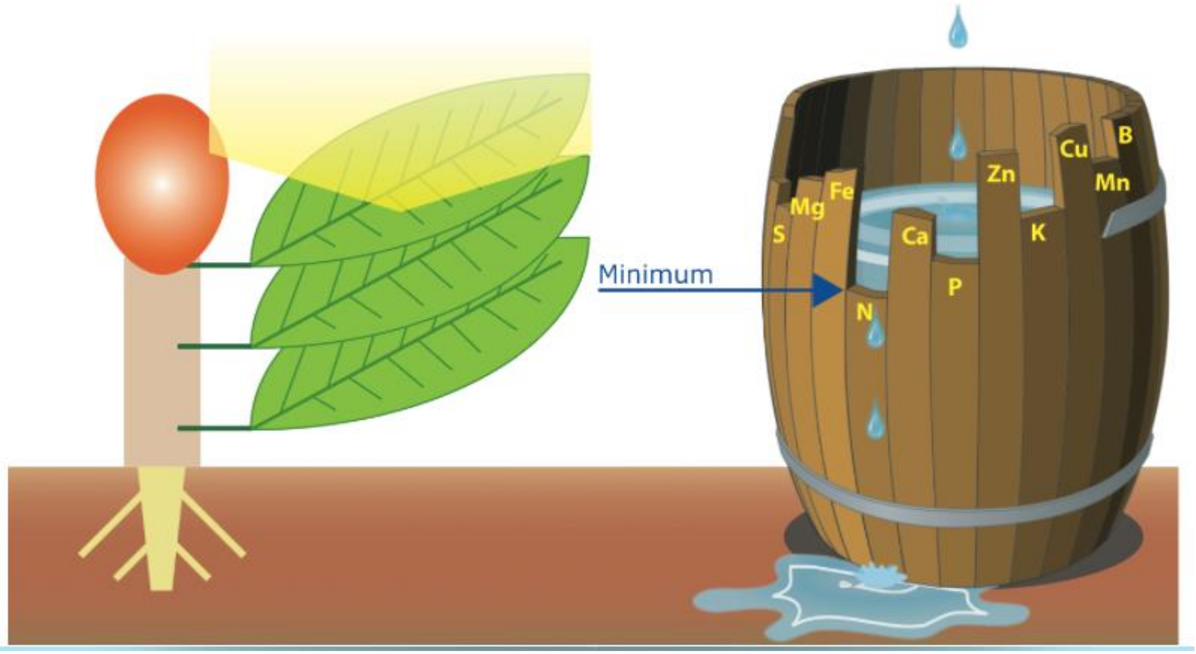
Introduction

Stickstoff

Grundlage für das Wachstum von Nutzpflanzen



Justus von Liebig
(1803–1873)

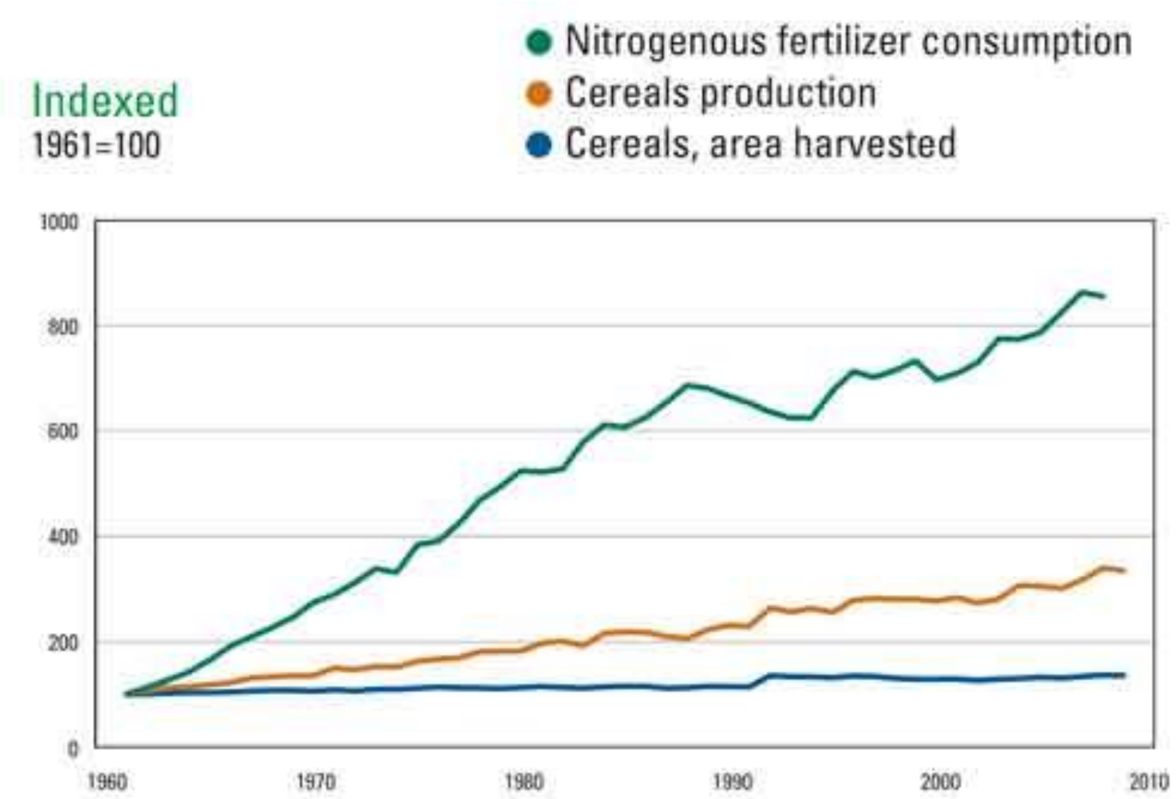


The element which is in shortest supply limits yield

Introduction

Stickstoffdüngung

United Nations Environmental Program

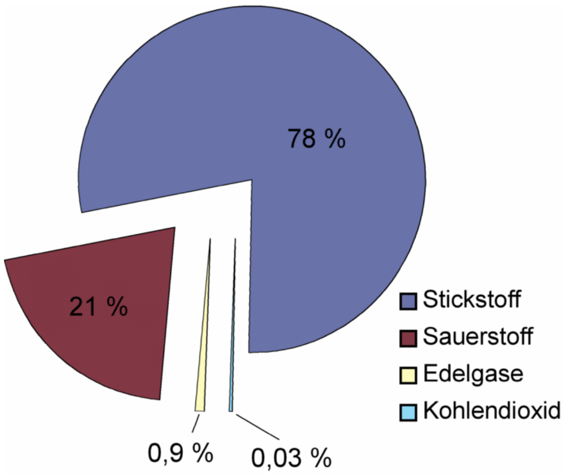


Source: UNEP 2011

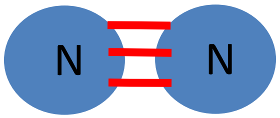
Introduction

Haber-Bosch

Atmosphäre



Stickstoff (N2)



$$N_2 + 3\,H_2 \longrightarrow 2\,NH_3$$

Die Herstellung von Ammoniak verbraucht viel Energie:

Temperatur 550°C

Druck 150 bis 250 bar

http://www.seilnacht.com/Lexikon/HaberBo.html

Symbiosis

Nitrogen Assimilation through root nodule – Rhizobia Interaction

The root nodules of *Medicago italica* inoculated with *Sinorhizobium meliloti*

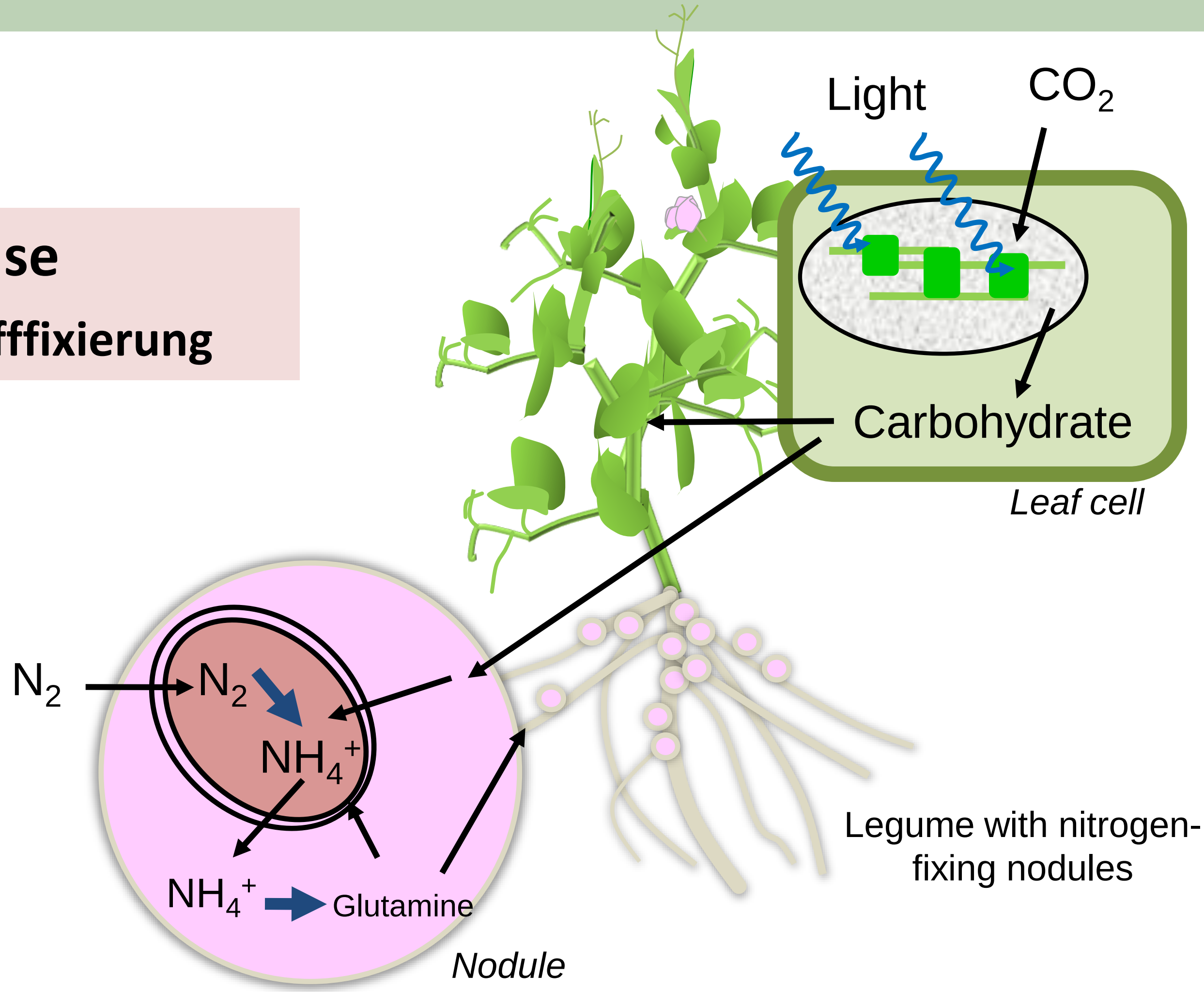
Photo credit: Ninjatacoshell

Symbiosis

Root nodule symbiosis is a mutually beneficial arrangement

Nitrogenase

Enzym zur Stickstofffixierung



Symbiosis

Symbiotische Stickstofffixierung

Die Knöllchenbildung mit Nitrogen-fixierenden Bakterien ist sehr spezifisch und nur in wenigen Pflanzenfamilien verbreitet.

Legumes with symbiotic rhizobia

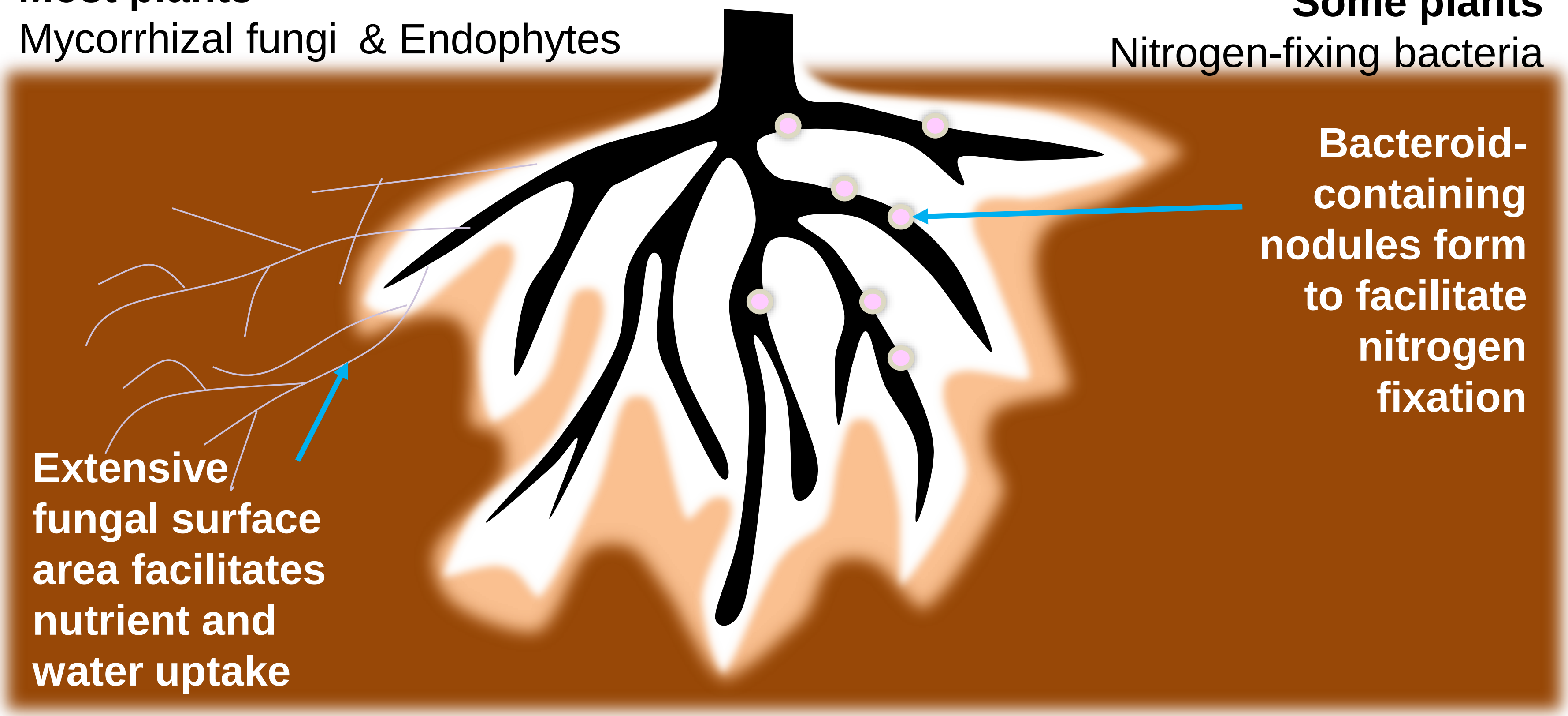
Actinorhizal plants like alder with symbiotic *Frankia* bacteria

Introduction

Mycorrhizal fungi and nitrogen-fixing bacteria are major symbionts

Most plants
Mycorrhizal fungi & Endophytes

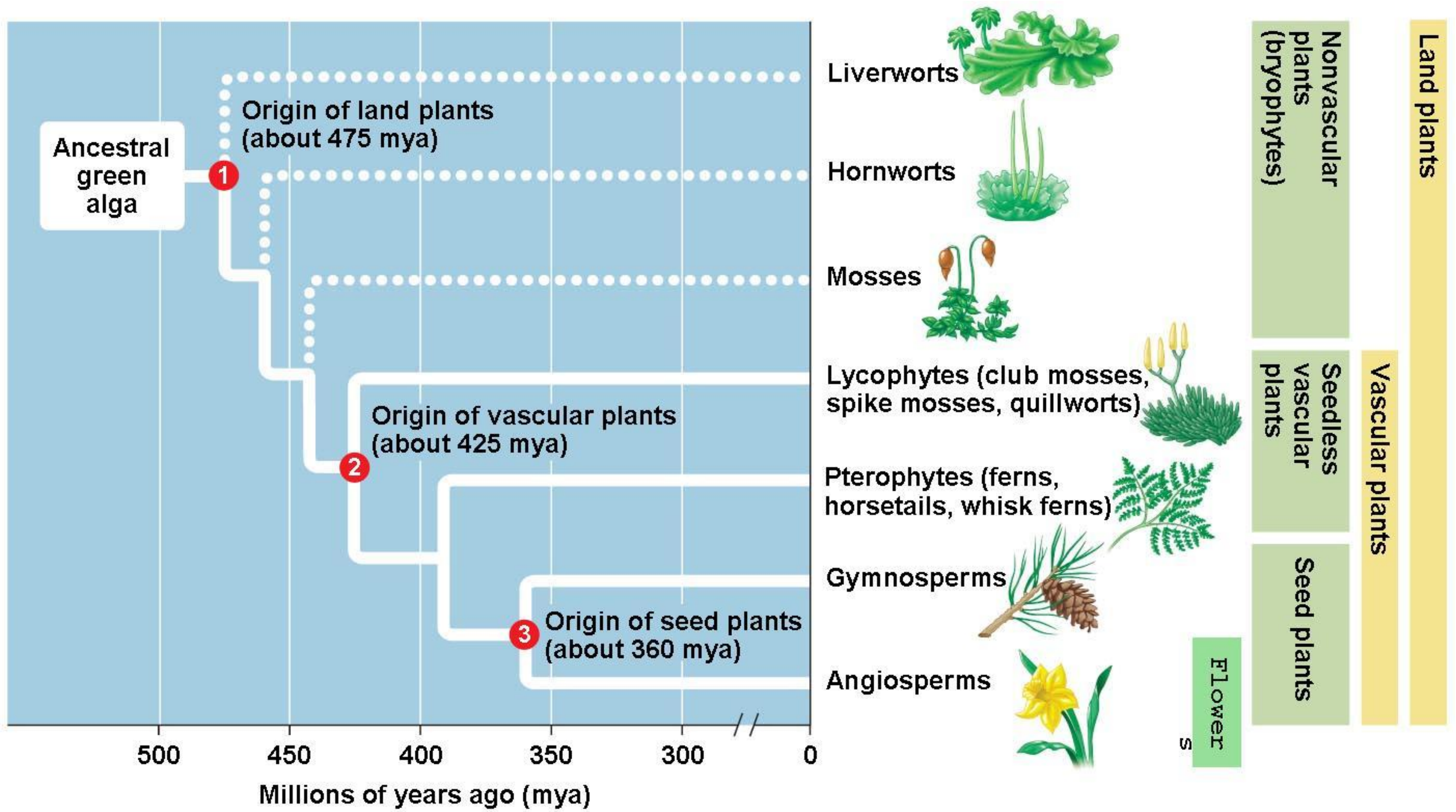
Some plants
Nitrogen-fixing bacteria



Symbiosis

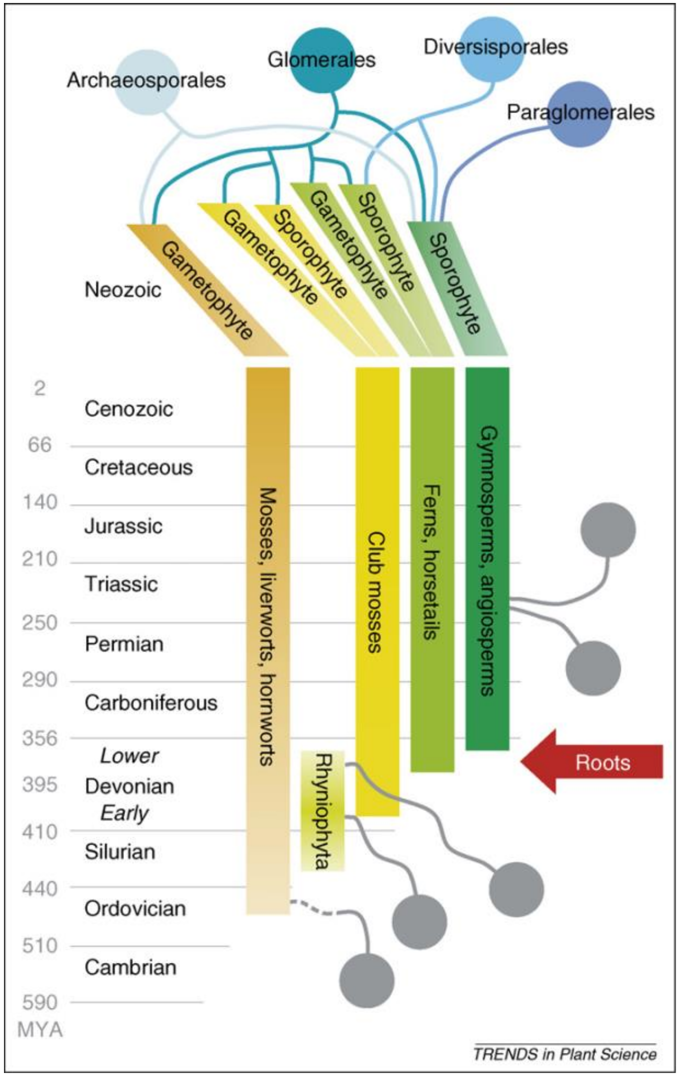
Evolution der Landpflanzen

Evidence for the appearance of the first land plants occurs in the Ordovician, around 450 million years ago, in the form of fossil spores.



Symbiosis

Why is Mycorrhizal fungi associate with ~ 80% of land plants?

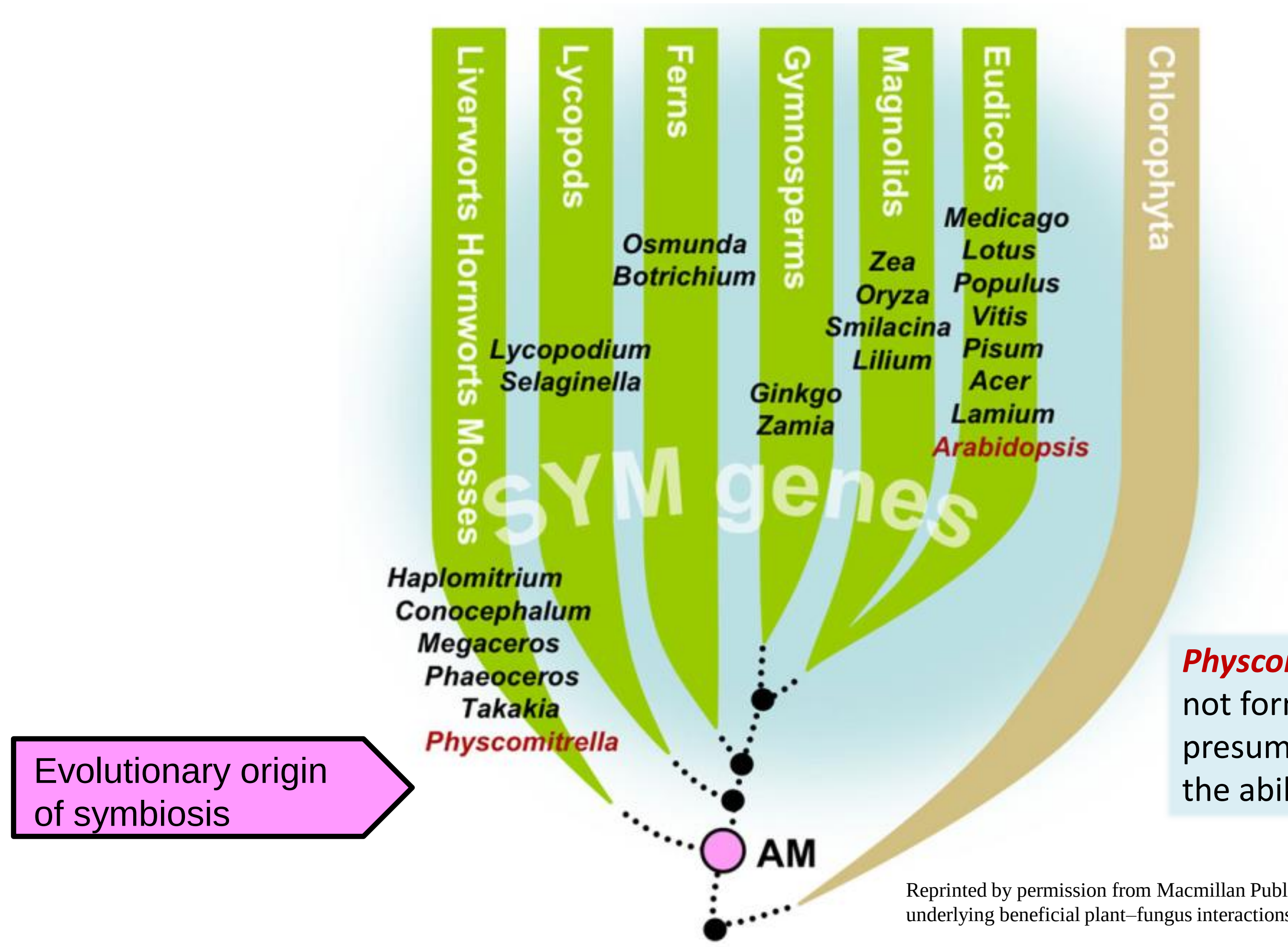


The plant – AMF symbiosis may have been **essential for plants to establish themselves in the terrestrial environment** by enhancing nutrient and water uptake, and it continues to enhance plant success.

Reprinted from Bonfante, P., and Genre, A. (2008). Plants and arbuscular mycorrhizal fungi: an evolutionary-developmental perspective. Trends Plant Sci. 13: 492-498 with permission from Elsevier.

Symbiosis

SYM genes are functionally conserved across the plant kingdom

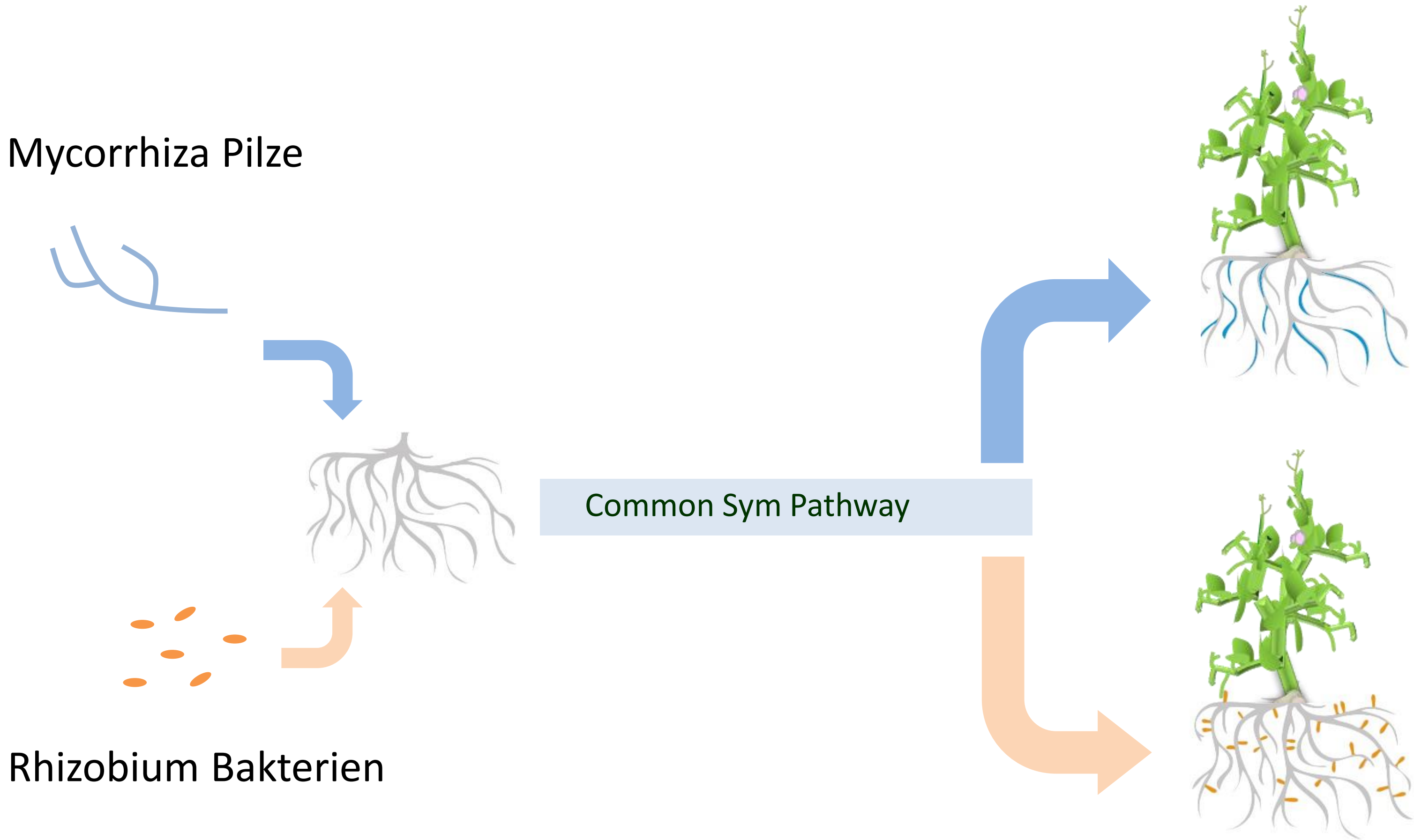


Physcomitrella and ***Arabidopsis*** do not form AM symbioses, presumably because they have lost the ability

Reprinted by permission from Macmillan Publishers Ltd. Bonfante, P., and Genre, A. (2010). Mechanisms underlying beneficial plant–fungus interactions in mycorrhizal symbiosis. Nat Commun 1: 48.

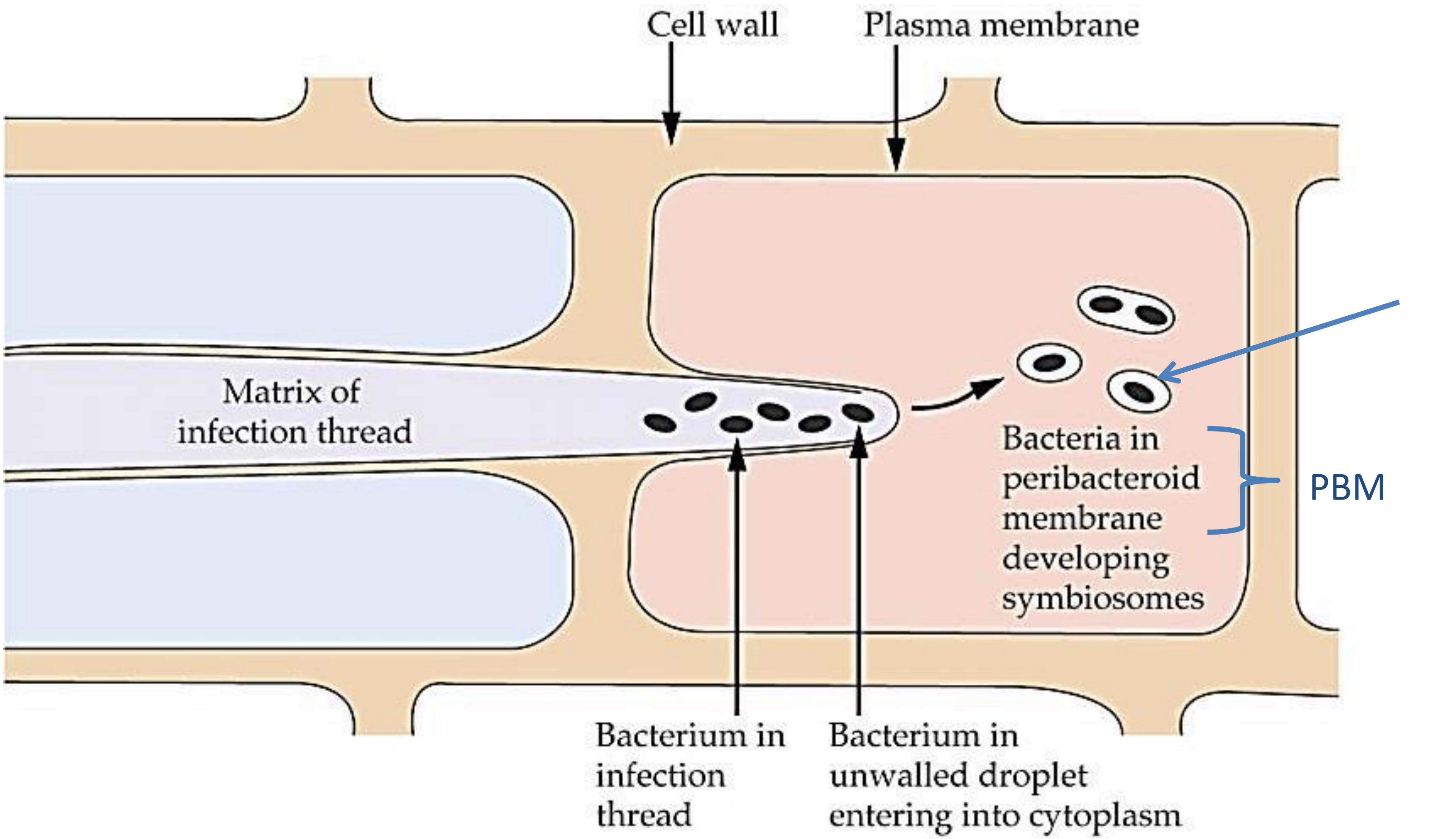
Symbiosis

Common Sym Pathway



Symbiosis

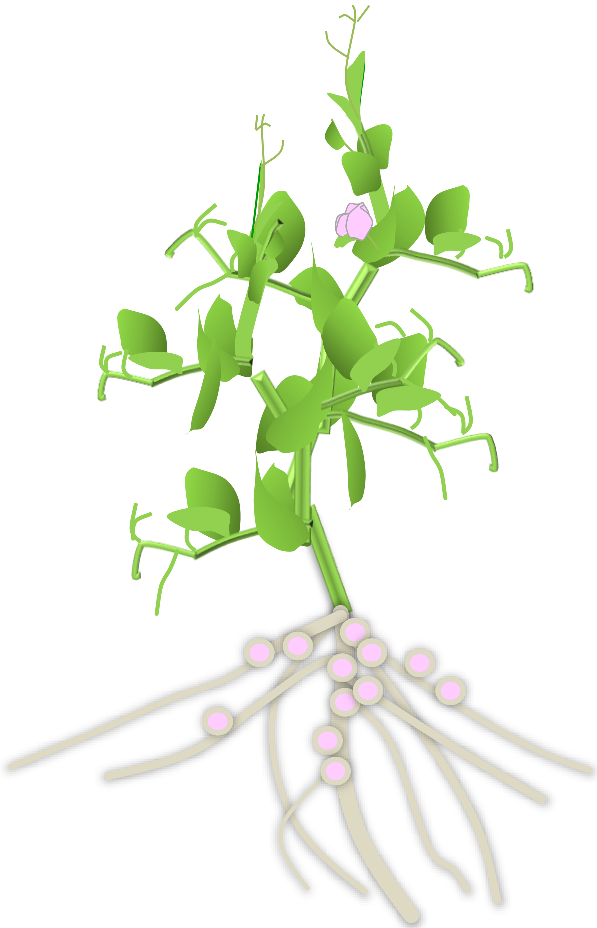
Bacteria exit the infection thread as membrane-bound symbiosomes



From: Buchanan, B.B., Gruissem, W. and Jones, R.L. (2000) Biochemistry and Molecular Biology of Plants. American Society of Plant Physiologists.

Symbiosis

Wirtskontrolle über Nodulierung



Die Pflanze:

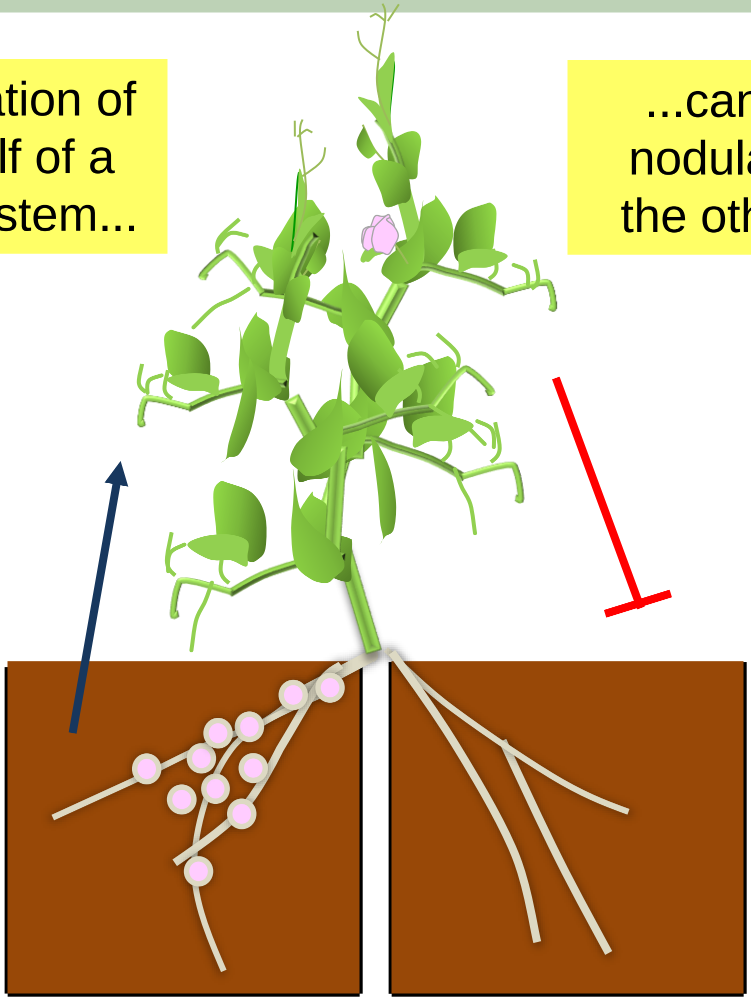
- Kontrolliert die Zahl der Knöllchen,
- Unterdrückt Entwicklung und Neubildung von Knöllchen wenn Nitrat vorhanden ist,
- Sanktioniert Knöllchen, die nicht aktiv Stickstoff fixieren.

Symbiosis

Autoregulation of nodulation (AON) balances supply and demand

Inoculation of one half of a root system...

...can inhibit nodulation in the other half



Infection with rhizobia generates a mobile signal that travels to the shoot

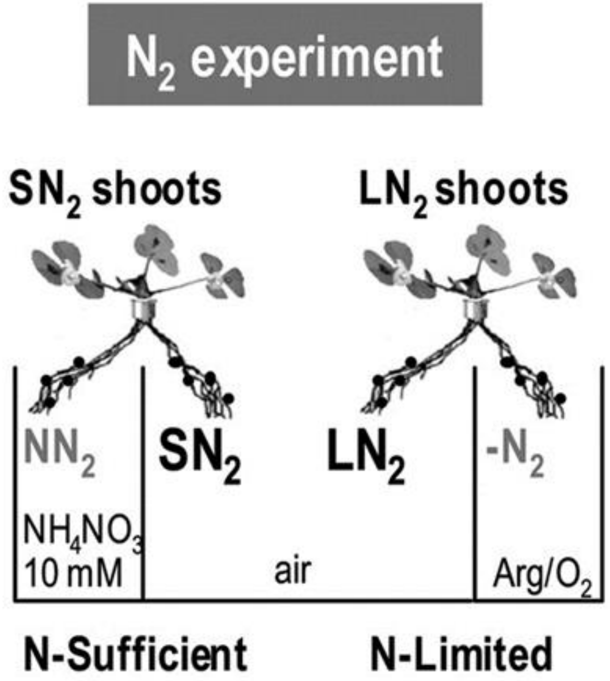
Perception of this signal generates a signal to the root to inhibit further nodulation.

This regulation adjusts nodule numbers to the plant's nitrogen demand

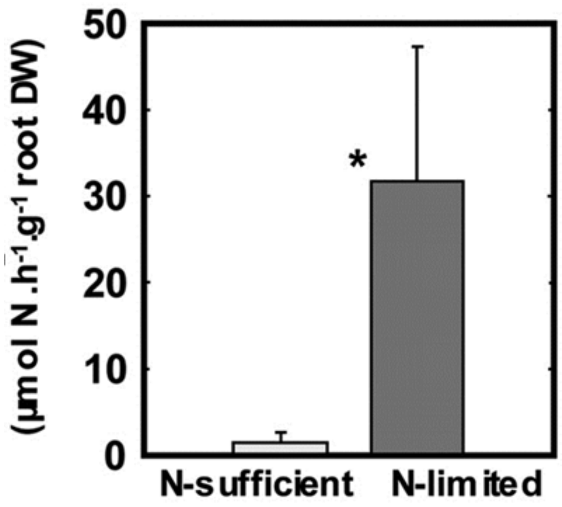
Systemische Regulation!

Symbiosis

Systemische Regulation der Stickstoff-Verfügbarkeit/Aufnahme



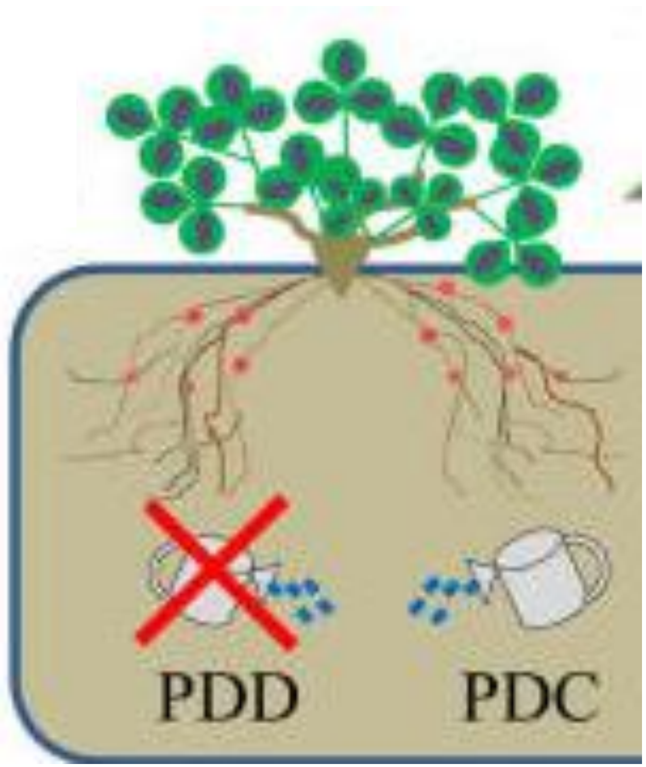
Net N-fixation



Ruffel et al. 2008, Salon et al. 2009

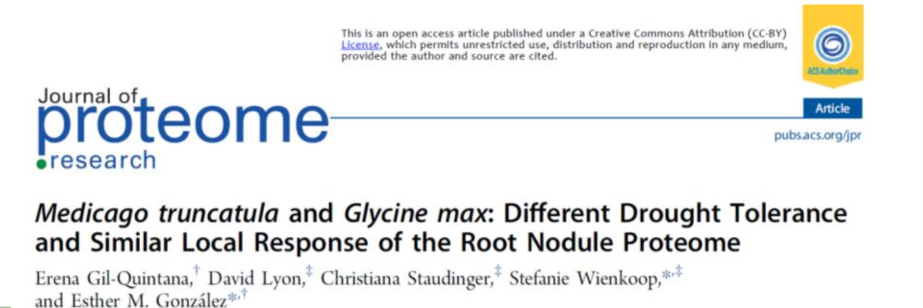
Symbiosis

Lokale Inhibition der Stickstofffixierung bei Trockenstress



Partiales Trockenstress Experiment

- N-Fixierung wird schon bei leichtem Trockenstress inhibiert
- Die Pflanze reduziert auf der Seite des Trockenstress die symbiotische Nährstoffzufuhr



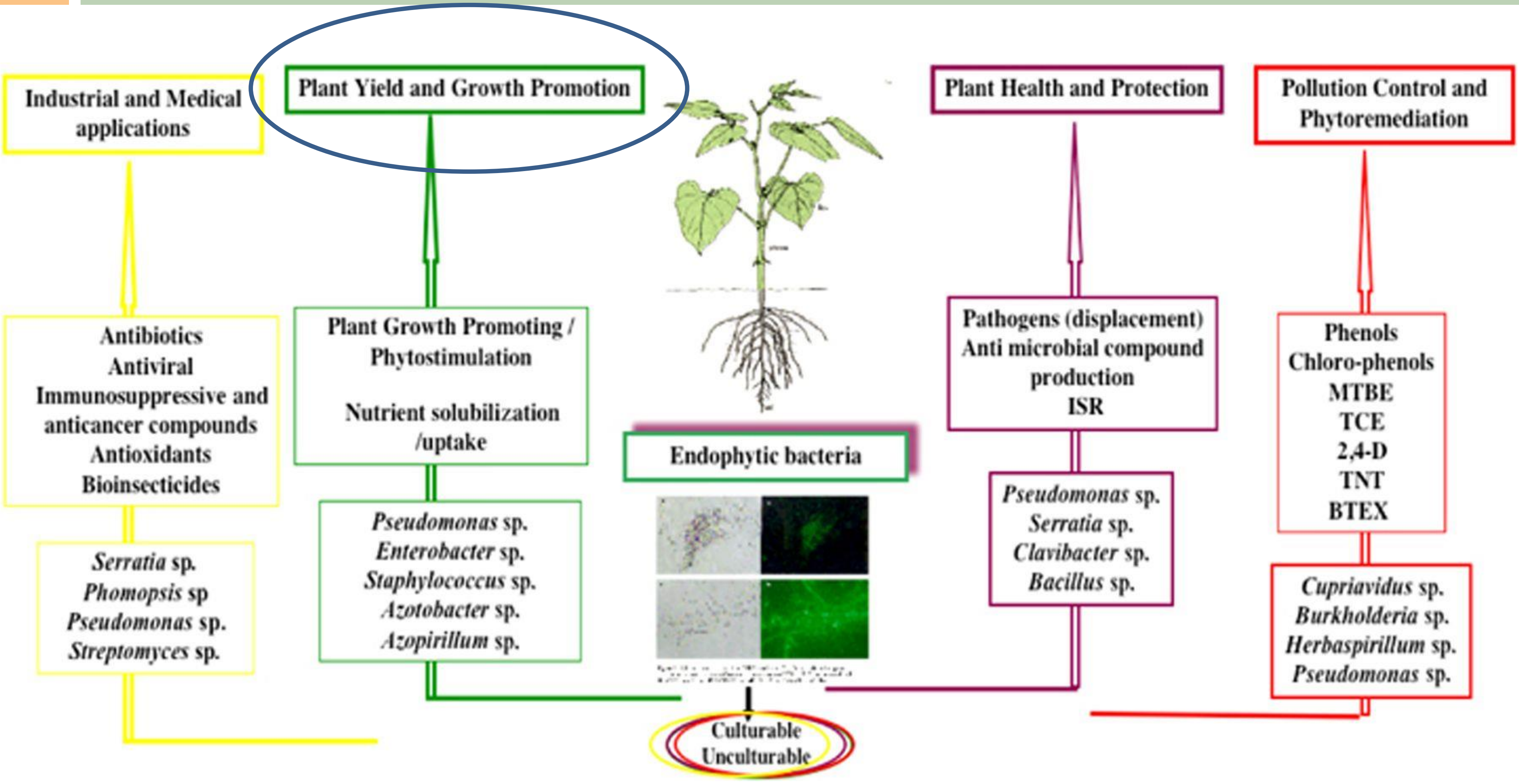
Journal of proteome research
Article
pubs.acs.org/jpr

Medicago truncatula **and** ***Glycine max*****: Different Drought Tolerance and Similar Local Response of the Root Nodule Proteome**

Erena Gil-Quintana,[†] David Lyon,[‡] Christiana Staudinger,[‡] Stefanie Wienkoop,[*,‡] and Esther M. González[*,†]

Symbiosis

Einfluss von Bodenbakterien auf die Pflanze?



Ryan et al. (2008) MiniReview_FEMS

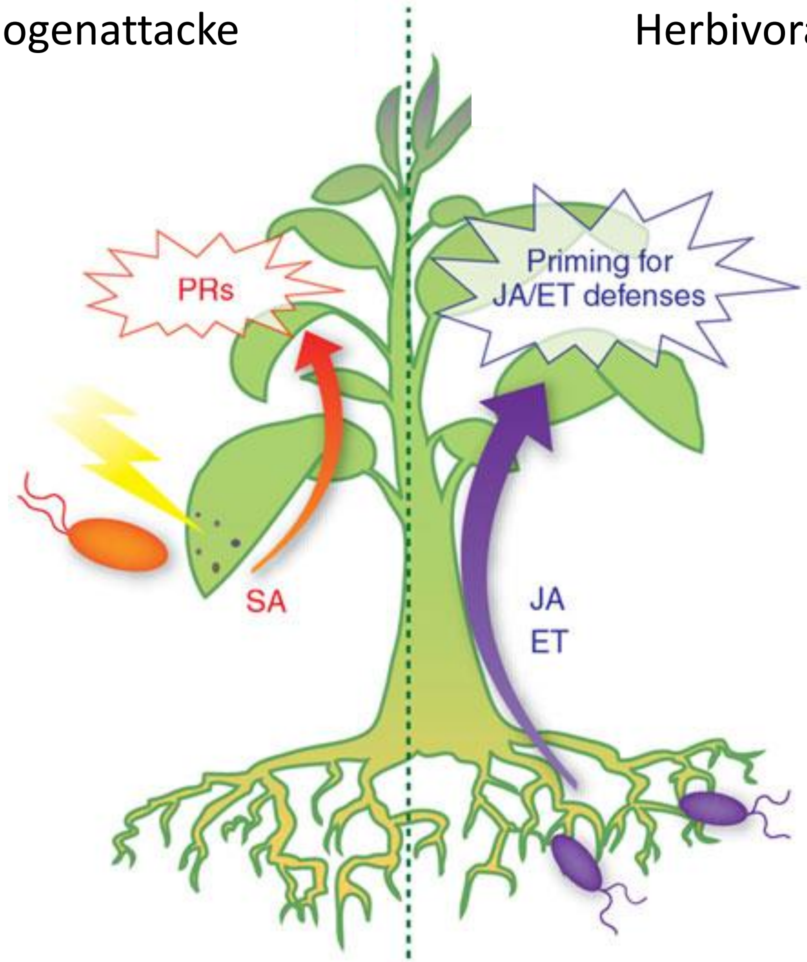
Symbiosis

Mikroben können das Immunsystem positiv beeinflussen

Pflanzen unterscheiden Freund von Feind!

Pathogenattacke

Herbivorattacke



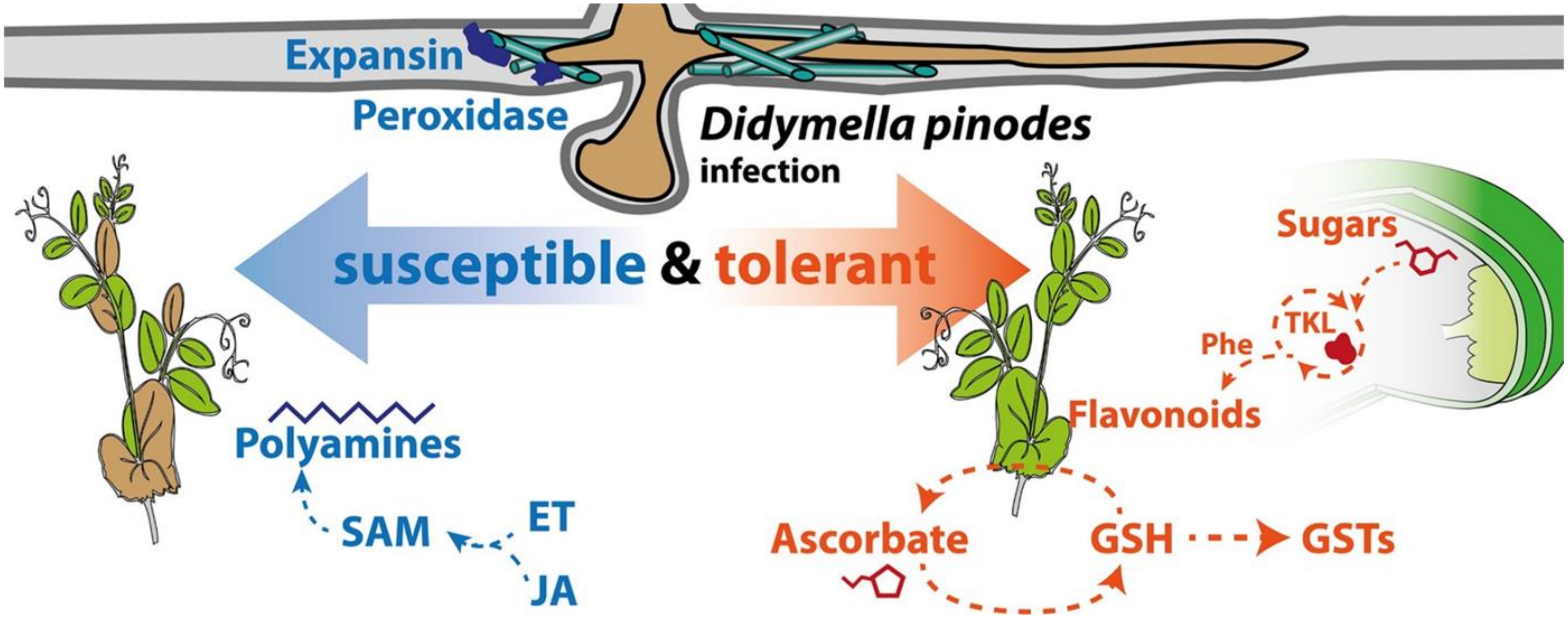
Corné M J Pieterse, Antonio Leon-Reyes, et al. Nature Chemical Biology 5, 308 – 316 (2009)

Pathogen

FWF
P24870-B22

Tripartite symbiosis formed by *Pisum sativum*, rhizobia and mycorrhiza & its effects on pathogen

Induced Systemic Resistance: Rhizobium symbiosis hampers pathogen attack



Desalign & Turetschek et al. JProt 2016
Turetschek et al JProt 2017

Pathogen

different symbiont treatments

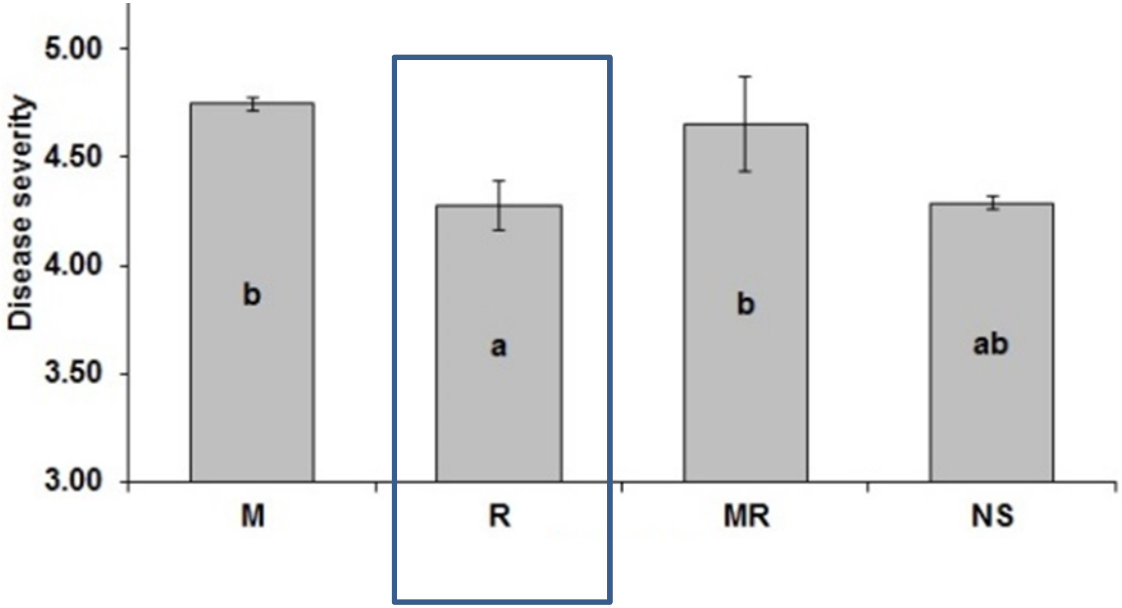
Disease Severity

necrotic lesions of leaflets

1-5 scale

1: < 25% necrotic lesions

5: dead leaf



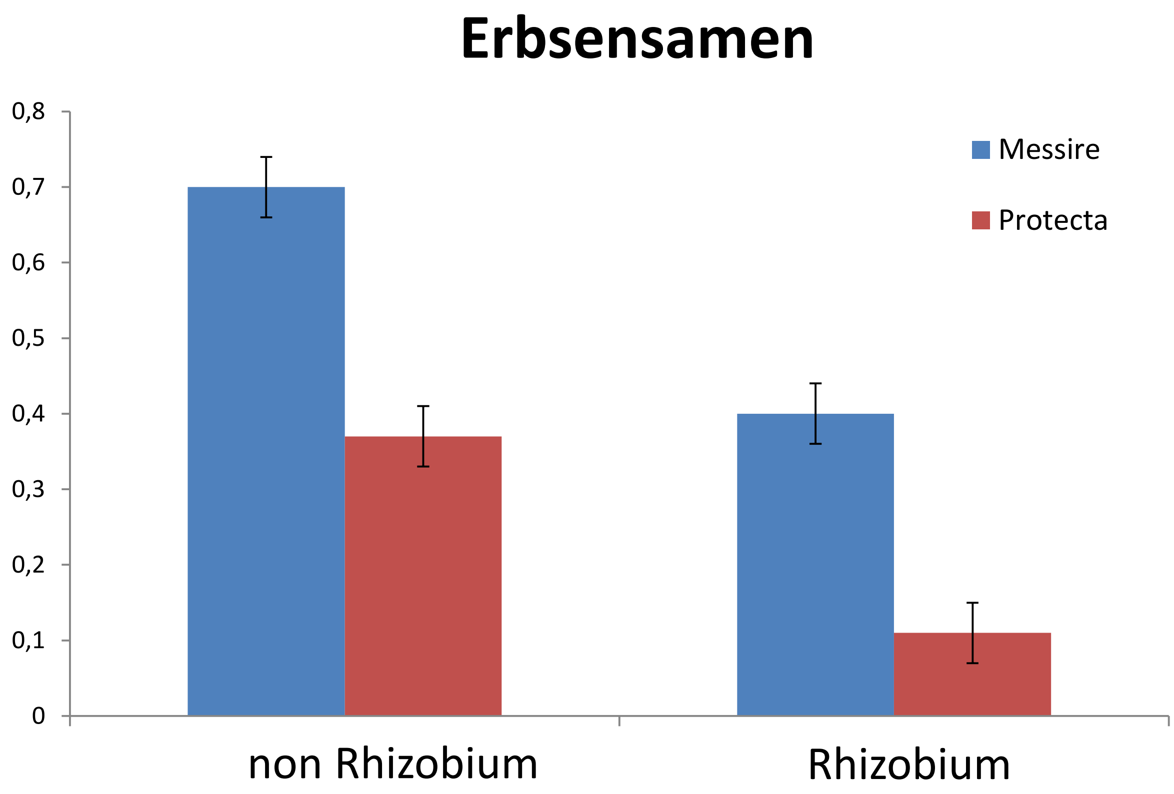
Geringster Pathogenbefall bei Rhizobien-Symbiose

Desalegn & Turetschek et al. (2016)

Pathogen

different symbiont treatments

Disease Severity
Seed Infection Level

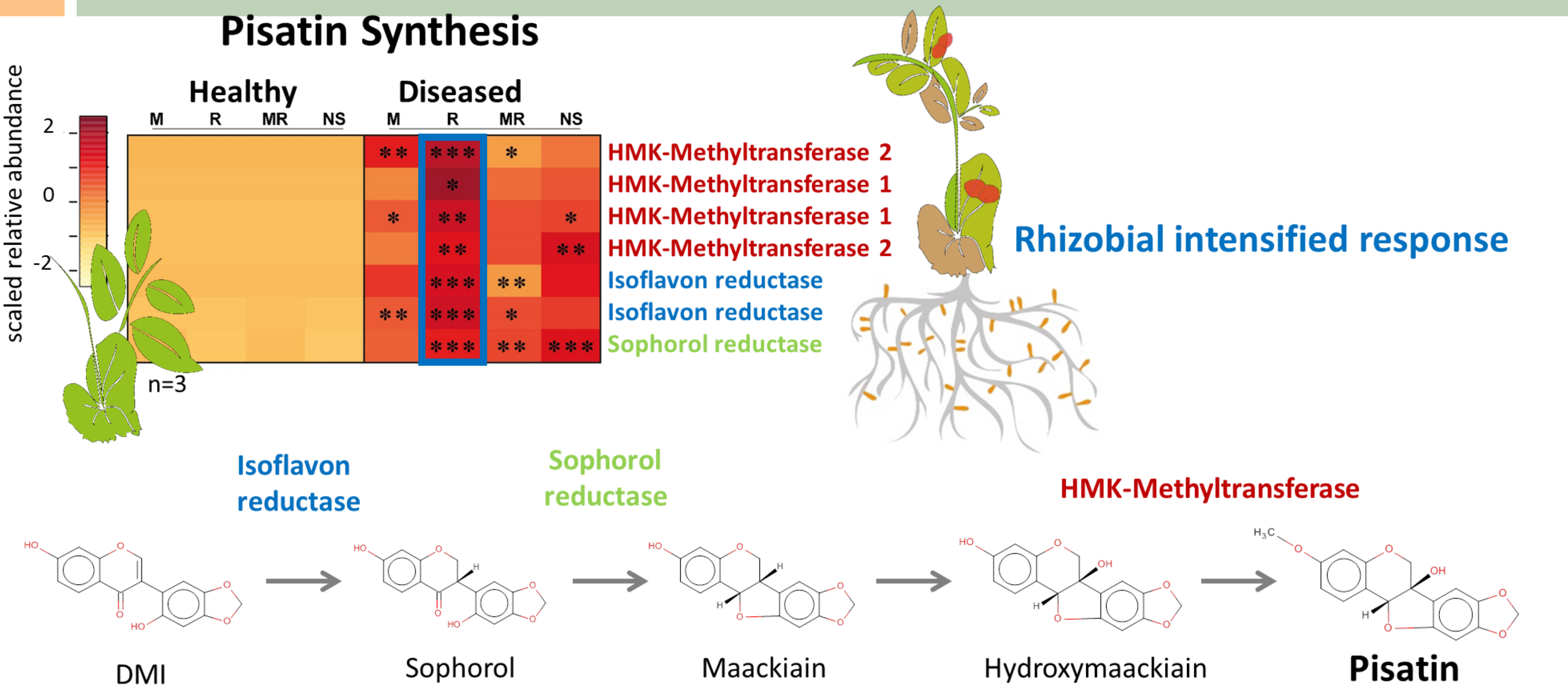


Stark verringerter Pathogenbefall durch Rhizobien-Symbiose

Ranjbar *et al.* 2017 (*submitted*)

Pathogen

Rhizobium - Einfluss auf den Metabolismus der Pflanze



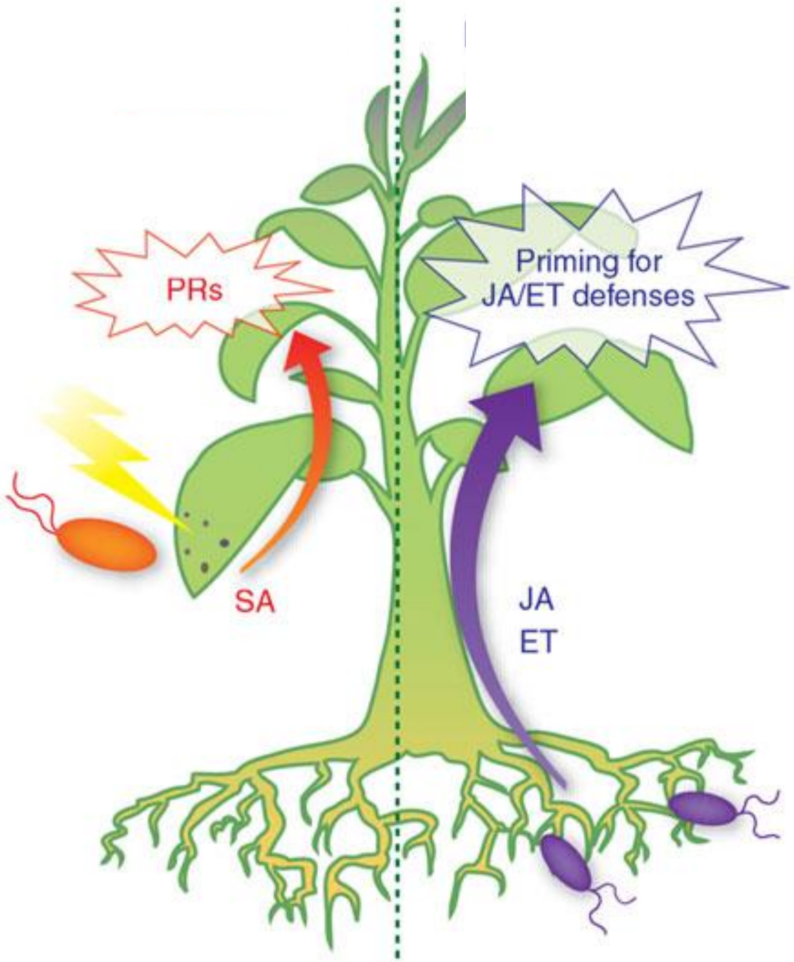
Desalegn & Turetschek et al. (2016)

Erhöhte (beschleunigte) Produktion des Abwehrstoffes PISATIN

Symbiosis

Mikroben können das Immunsystem positiv beeinflussen

Pflanzen unterscheiden Freund von Feind!



Gilt das auch für Trockenstress?

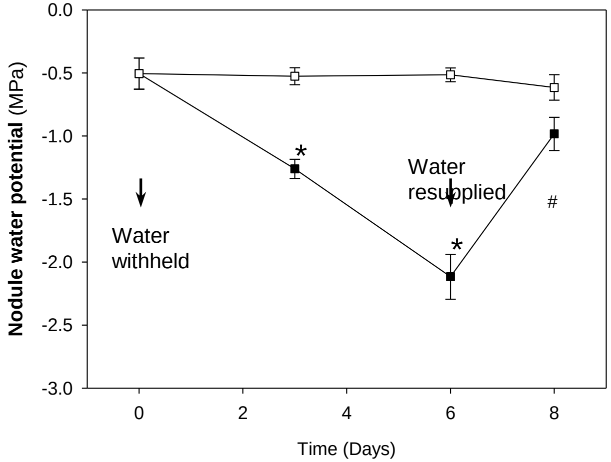
Corné M J Pieterse, Antonio Leon-Reyes, et al. Nature Chemical Biology 5, 308 – 316 (2009)

Drought

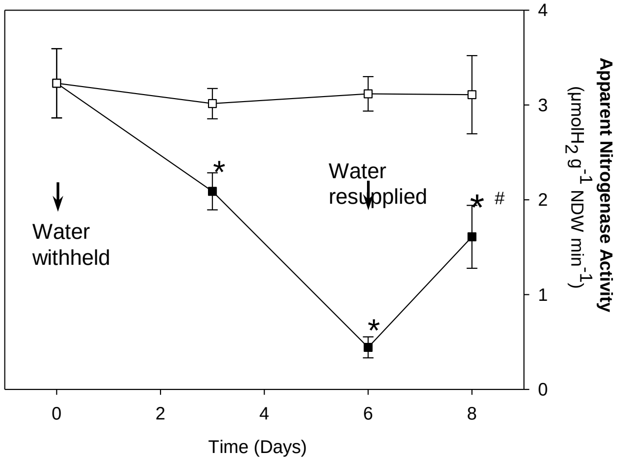
DROUGHT negatively affects N-FIXATION

Estibaliz Larrainzar

Nodule water potential



Nitrogenase activity



Sinorhizobium meliloti

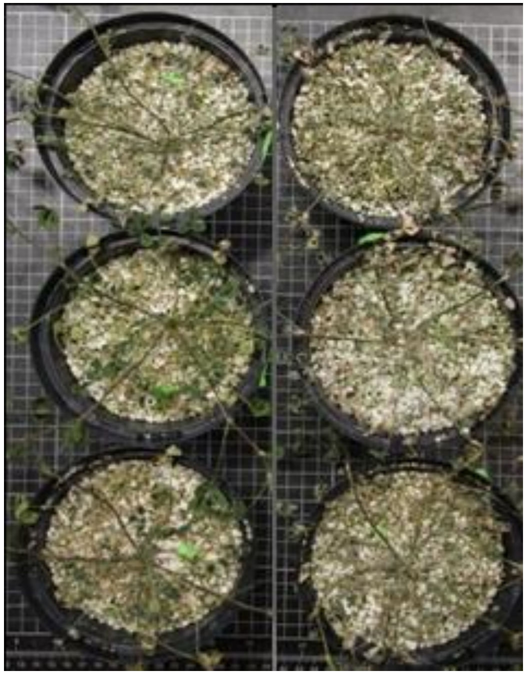
Wienkoop ***et al.*** **J Separation Science** **2006**
Larrainzar, Wienkoop *et al.* Plant Physiology **2007**
Wienkoop *et al.* JExBot **2008**
Larrainzar, Wienkoop *et al.* Molecular Plant-Microbe Interaction *2009*
Gil-Quintana *et al.* JExBot **2012**
Larrainzar, Wienkoop *et al.* Plant Cell & Environm. **2014**
Gil-Quintana *et al.* JProtRes **2015**
González *et al.* DOI10.1007/978-3-319-06212-9_2 ***2015***

In Collaboration mit
Universidad Publica de Navarra, Pamplona

Drought

Symbiose hat Einfluss auf Blätter Trockengestresster Pflanzen


Staudinger *et al.* 2016



Blätter nodulierter Pflanzen bleiben länger grün!

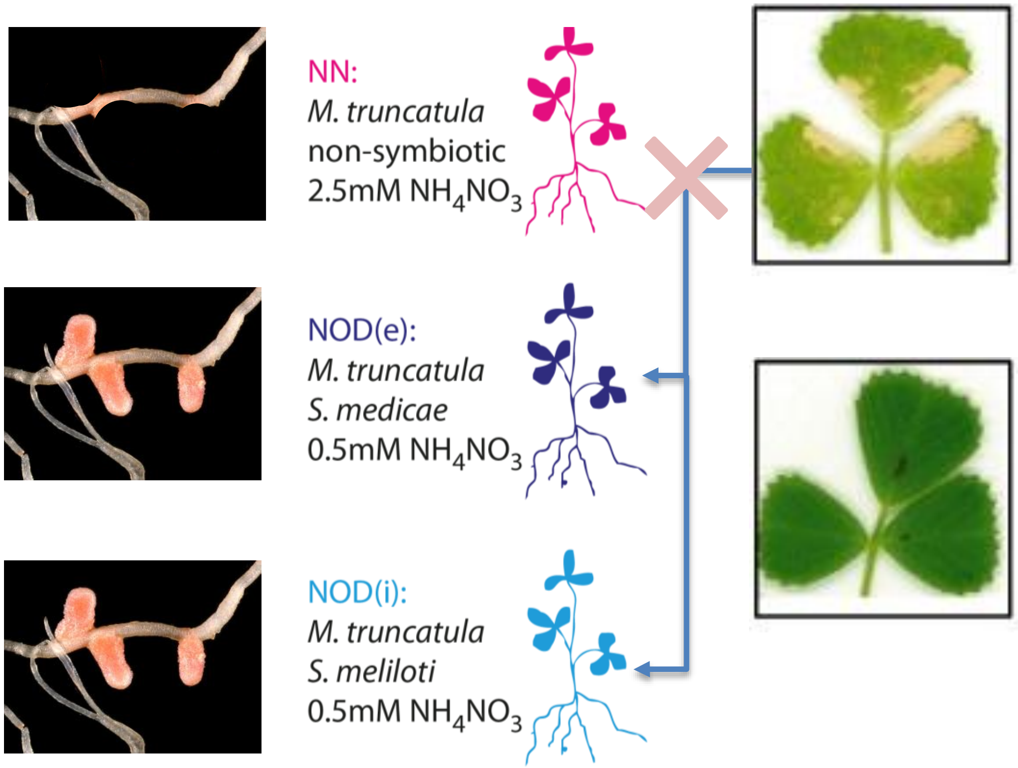
Trockenstress

Symbiose-induzierter Bleibgrün-Effekt

Drought

FWF P23441-B20

Staudinger *et al.* 2016



Christiana Staudinger

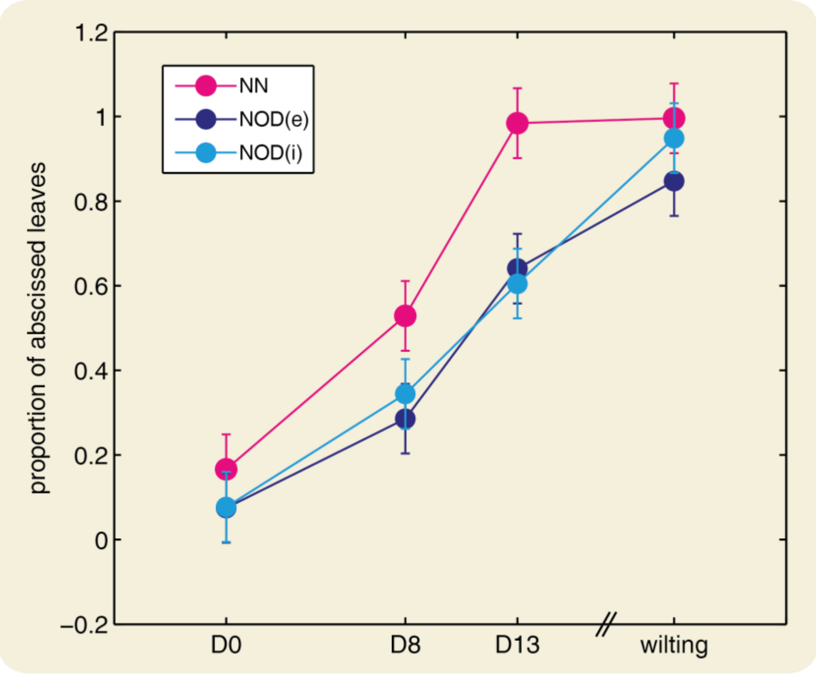
FWF Der Wissenschaftsfonds.

Project P23441-B20

Phenomics

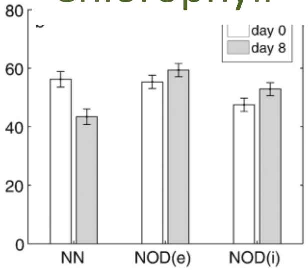
NOD plants show induced Stay-Green independent on N-fixation efficiency

Staudinger *et al.* 2016



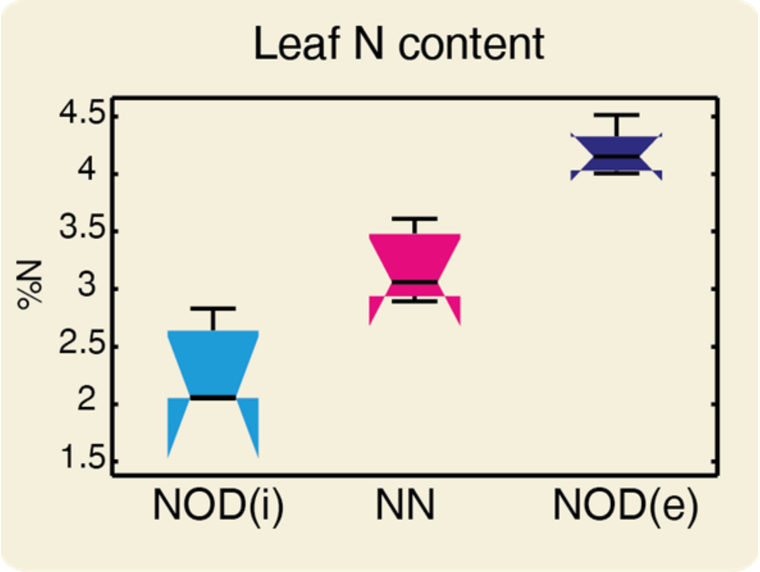
n = 7; LSD 95%

Chlorophyll



Retention of drough induced leaf senescence of NOD plants => **Rhizobia induced Stay-Green Phenotype**

Phenotype independent on leaf N content and N-fixation efficiency



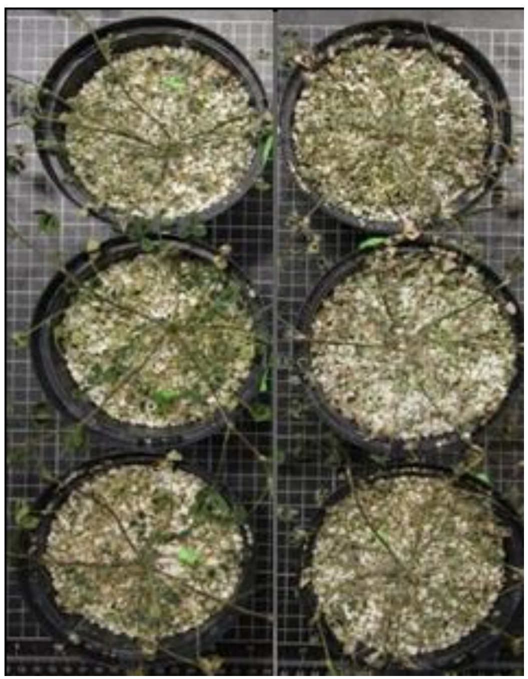
n = 3-5

Wie sieht der Symbiont-Induzierte „Stay-Green“ Effect aus?

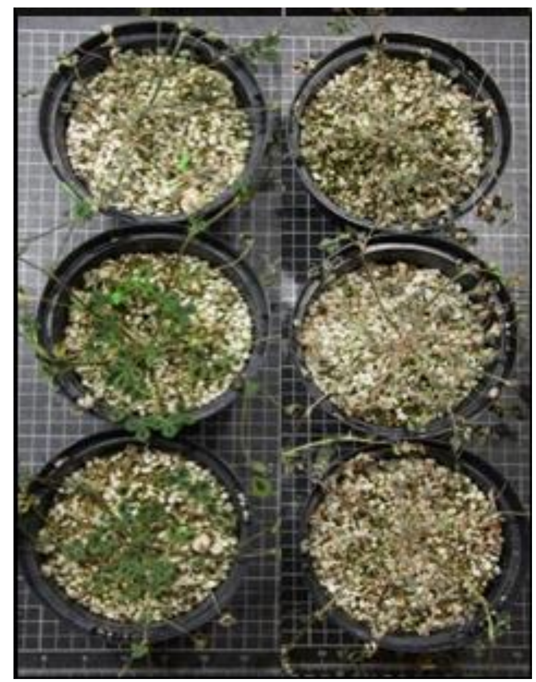
Staudinger *et al.* 2016

Drought

Rhizobieneinfluss auf Blätter Trockengestresster Pflanzen



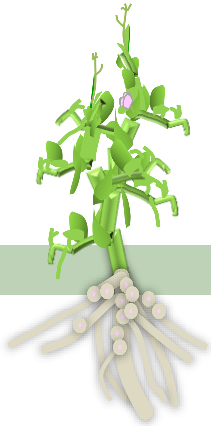
Trockenstress



Wiederbewässerung
nach Trockenstress

Staudinger *et al.* 2016

Zusammenfassung

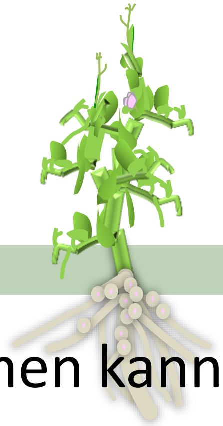


Die Rhizobium-Symbiose bewirkt:

- ein vermindertes Blattabsterben bei Trockenheit
- eine beschleunigte Wiederherstellung der Blattfunktion bei Wiederbewässerung

Ein vermindertes Blattabsterben bei Trockenheit kann den Ertragsausfall bei ansteigenden Temperaturen und den damit verbunden, häufiger auftretenden Trockenperioden reduzieren!

Fazit



- Im Zusammenwirken mit <u>geeigneten</u> Rhizobienstämmen kann bei Leguminosen auf Dünger verzichtet werden.

Weiter können bei steigenden Temperaturen und zunehmender Trockenheit die in Rhizobien-Symbiose wachsenden Leguminosen jenen unter Stickstoffdüngung überlegen sein.

- Der Stickstoff-Nutzungsgrad (SNG) ist mit dem Anbau und Verzehr von symbiotisch erzeugten Hülsenfrüchten am Höchsten.

Des Weiteren: Verbesserung der Hülsenfrucht-Qualität & Bodenverbesserung

Thanks to the Team and Collaborators!!!

APPN

Austrian Plant Phenotyping Network

COST Action 1306 PhenomenALL The quest for tolerant varieties

universität wien

MoSys

BOKU

Prof. Hans-Peter Kaul
Dr. Getinet Desalegn
Dr. Reinhard Turetschek

Green team!!
Thomas Joch
Andreas Schröfl

FWF [P24870-B22] [P23441-B20]

Der Wissenschaftsfonds.

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Sebastian Schneider

Dr. Christiana Staudinger