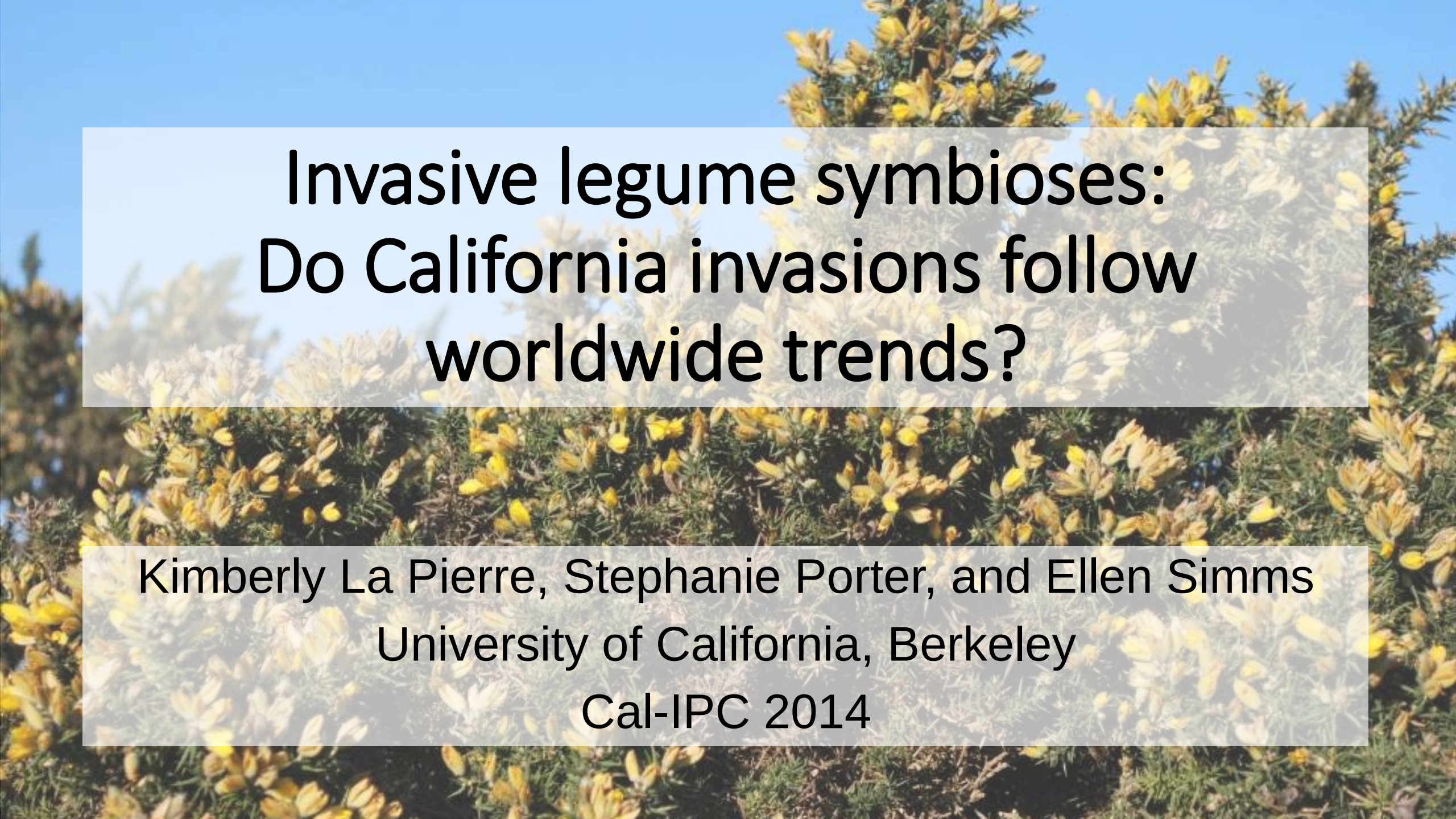

Invasive legume symbioses: Do California invasions follow worldwide trends?

Kimberly La Pierre, Stephanie Porter, and Ellen Simms
University of California, Berkeley

Cal-IPC 2014

How do species interactions influence invasion success?

Mutualism and Invasion Theory

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- Mutualists enter into symbiotic, mutually beneficial relationships

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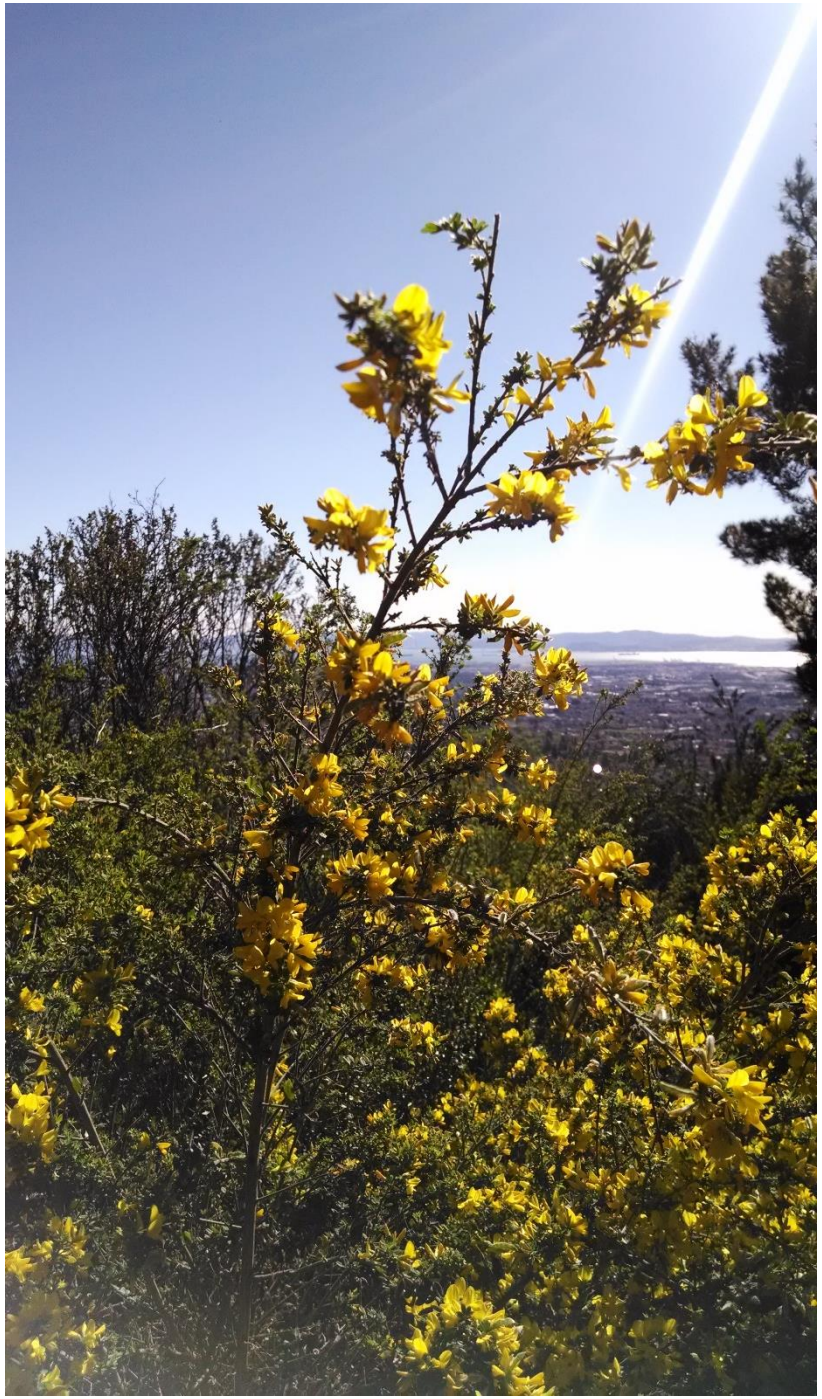
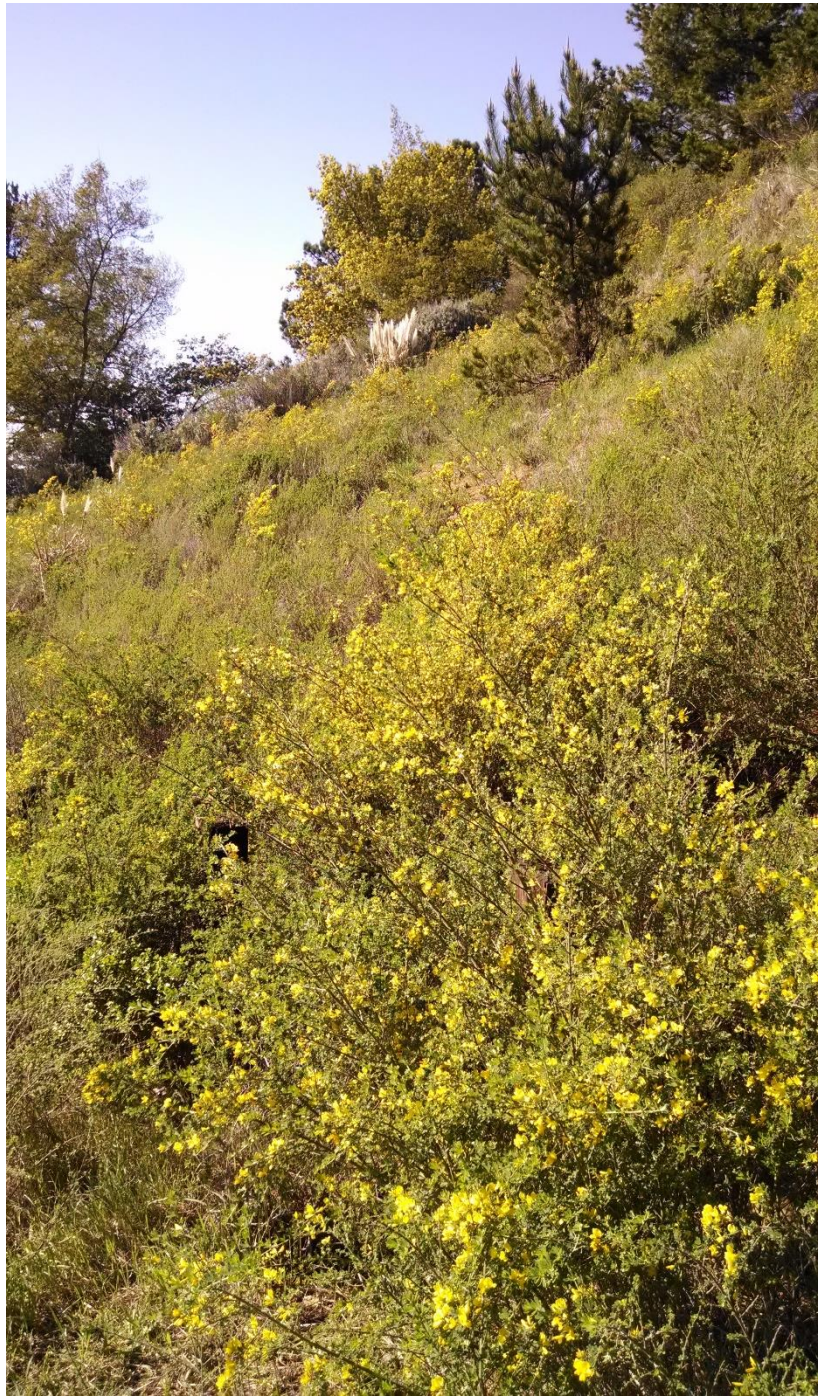
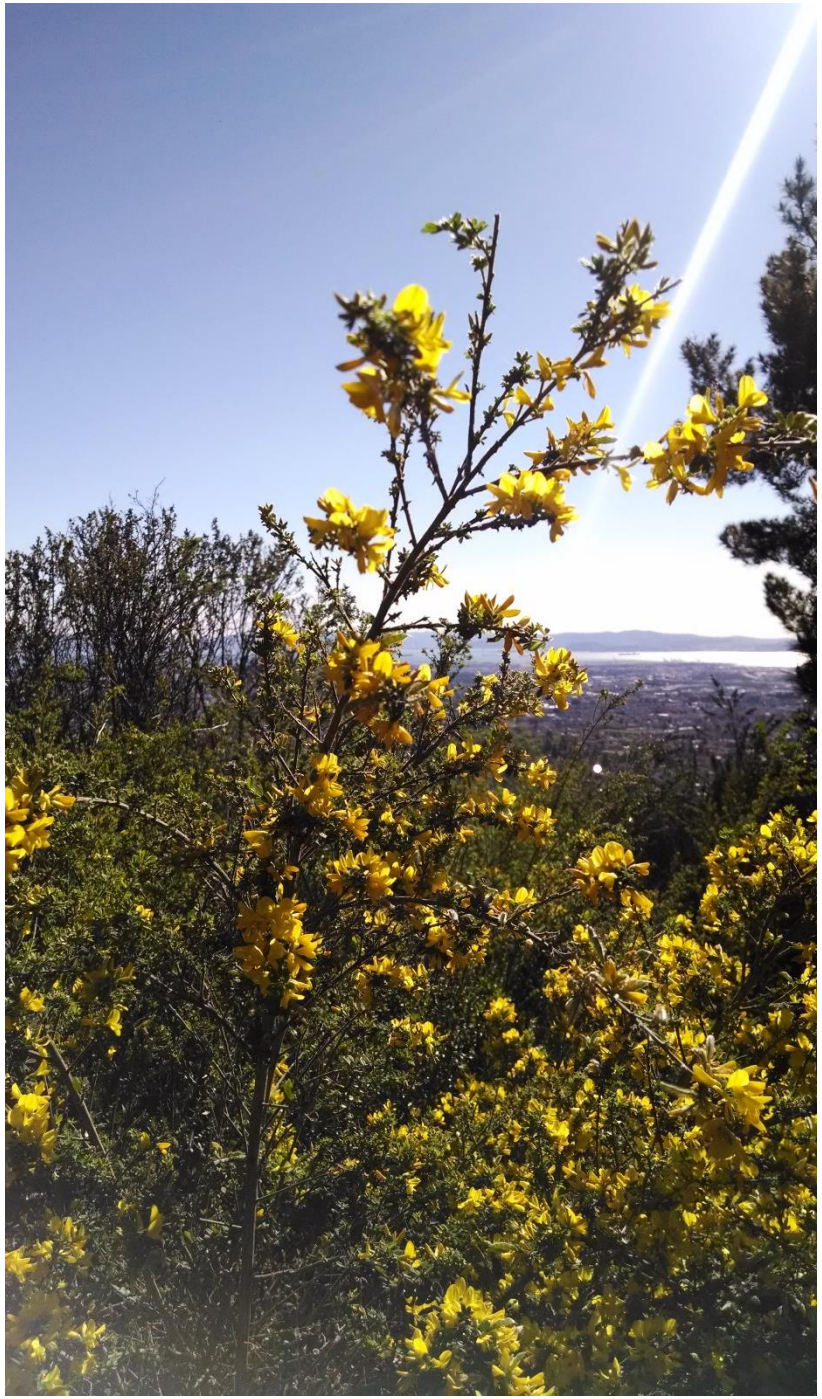
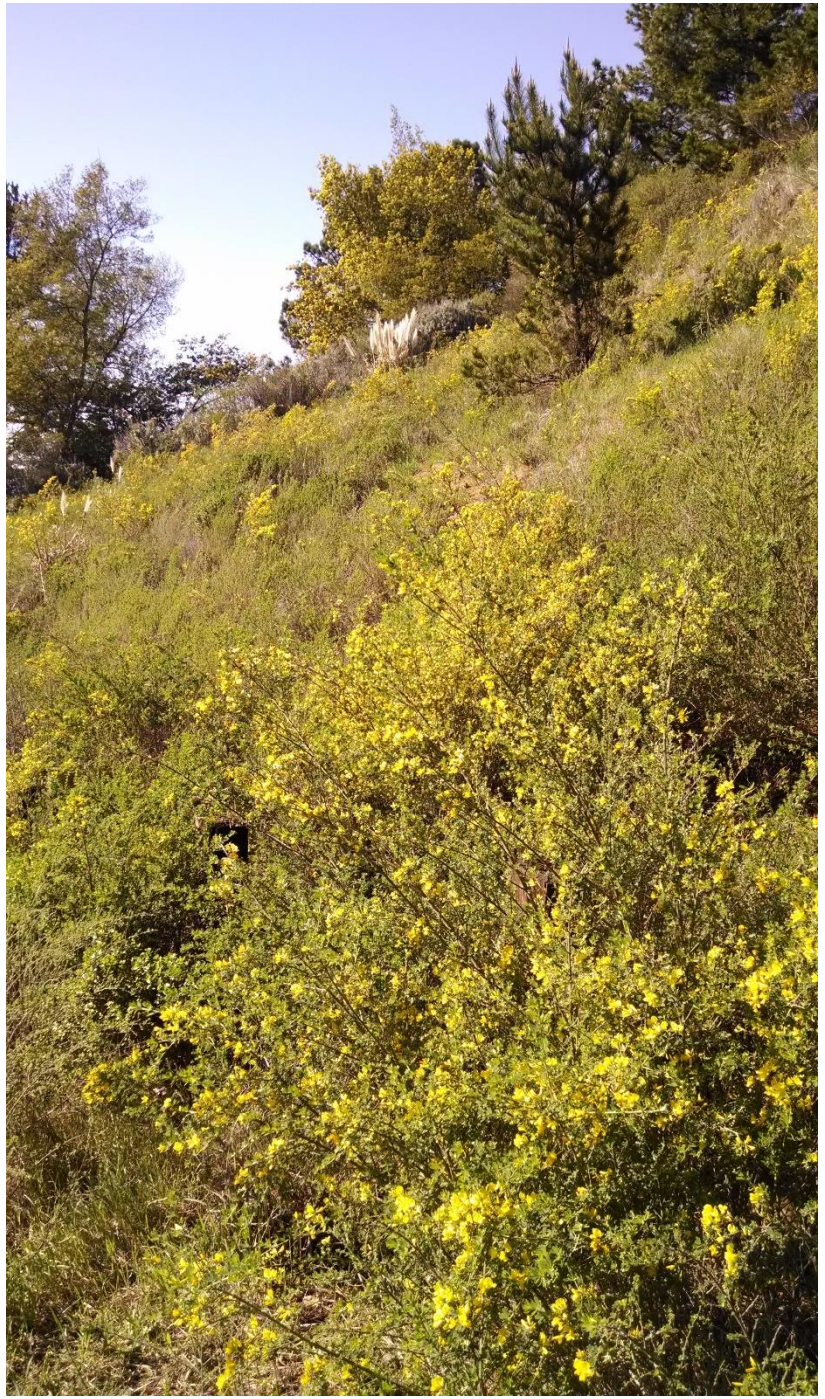
- Lack of symbionts may be a barrier to invasion





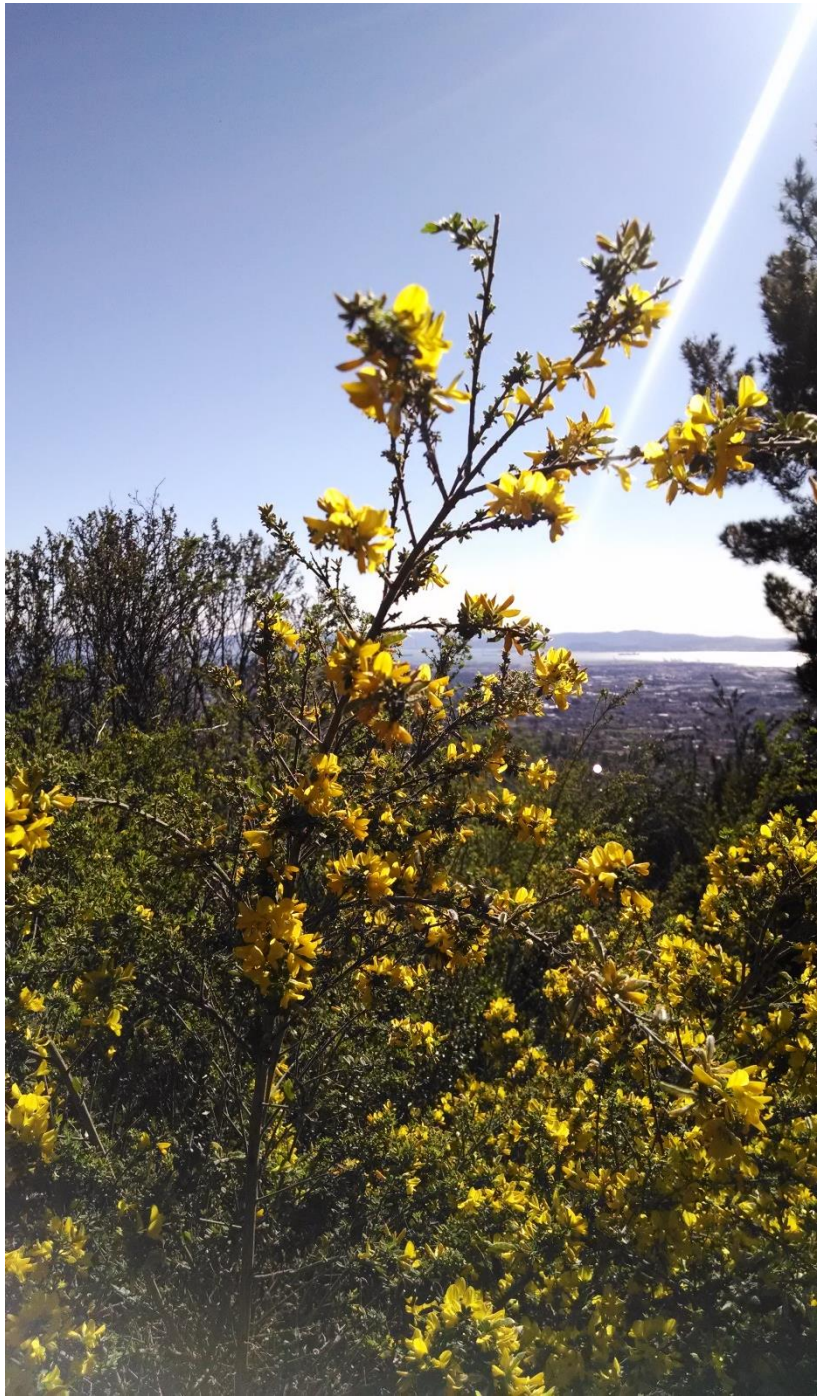
Legumes as a model system

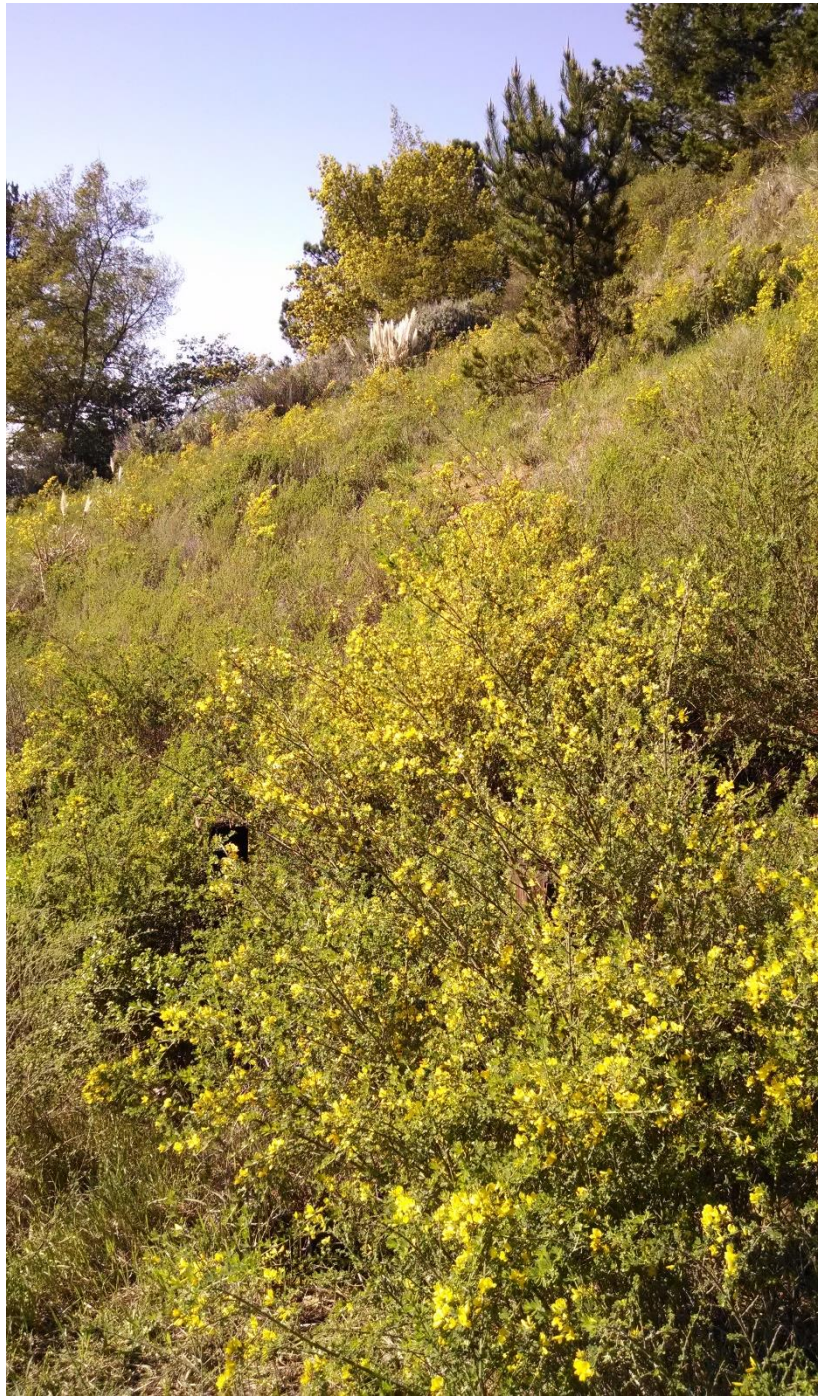




Legumes as a model system

- Pea family





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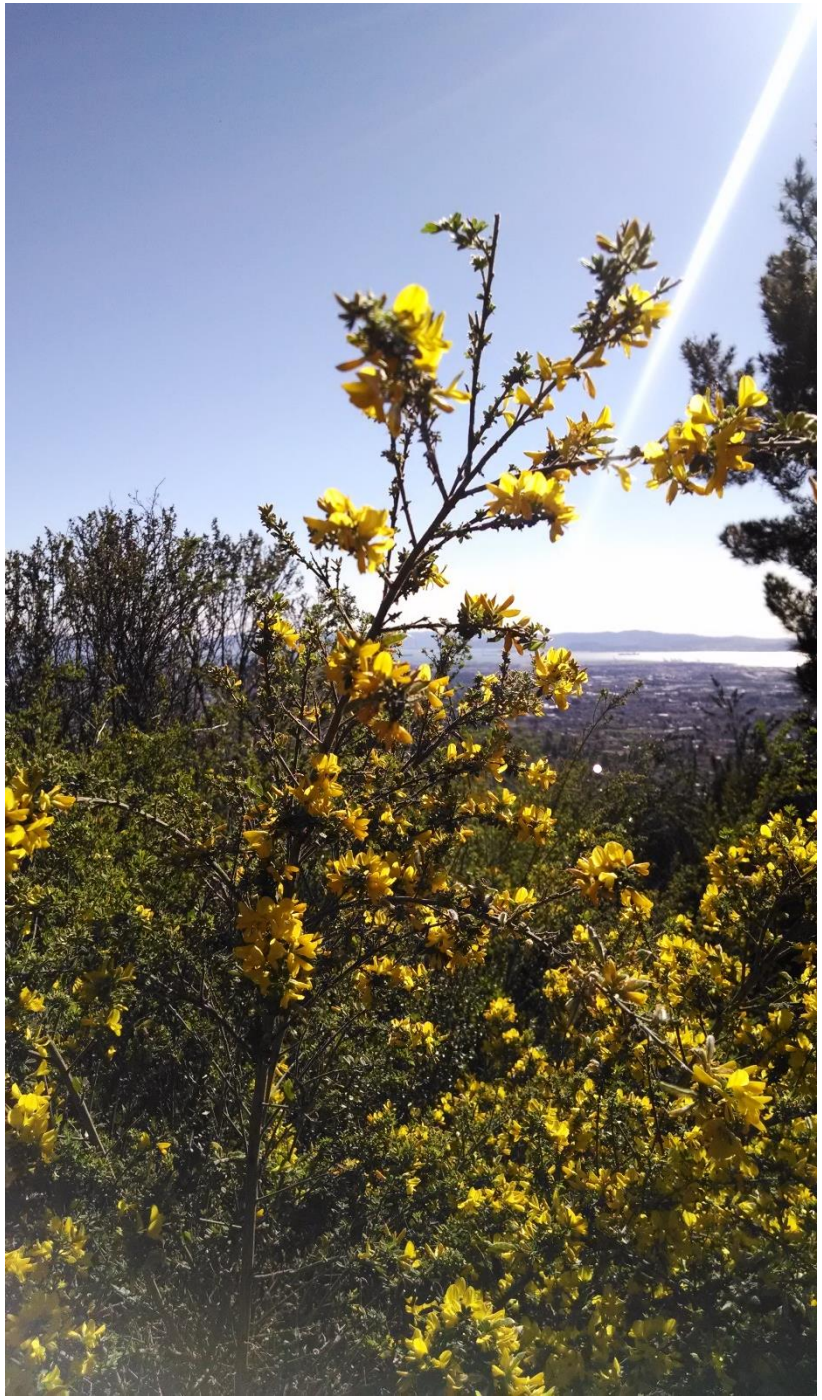

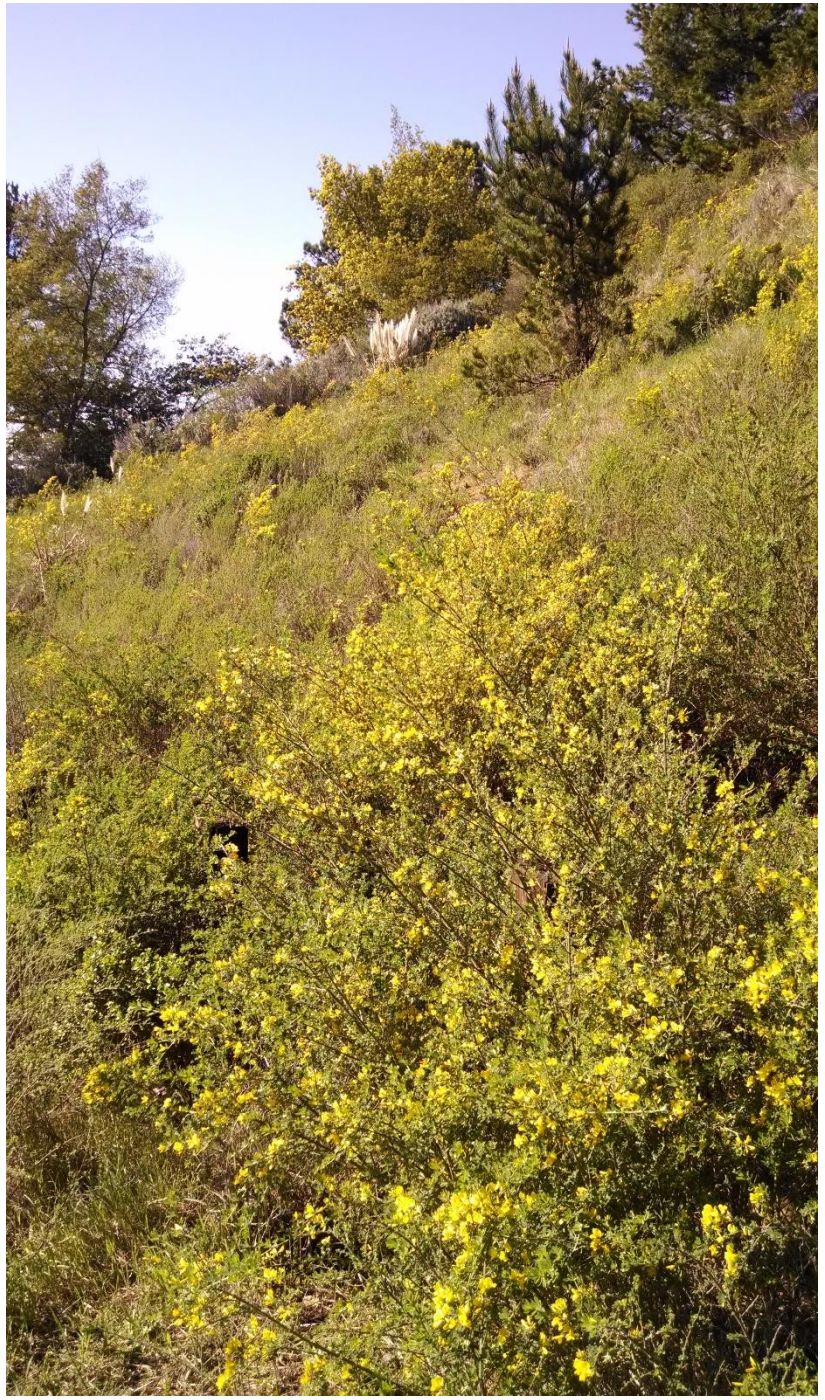

Legumes as a model system

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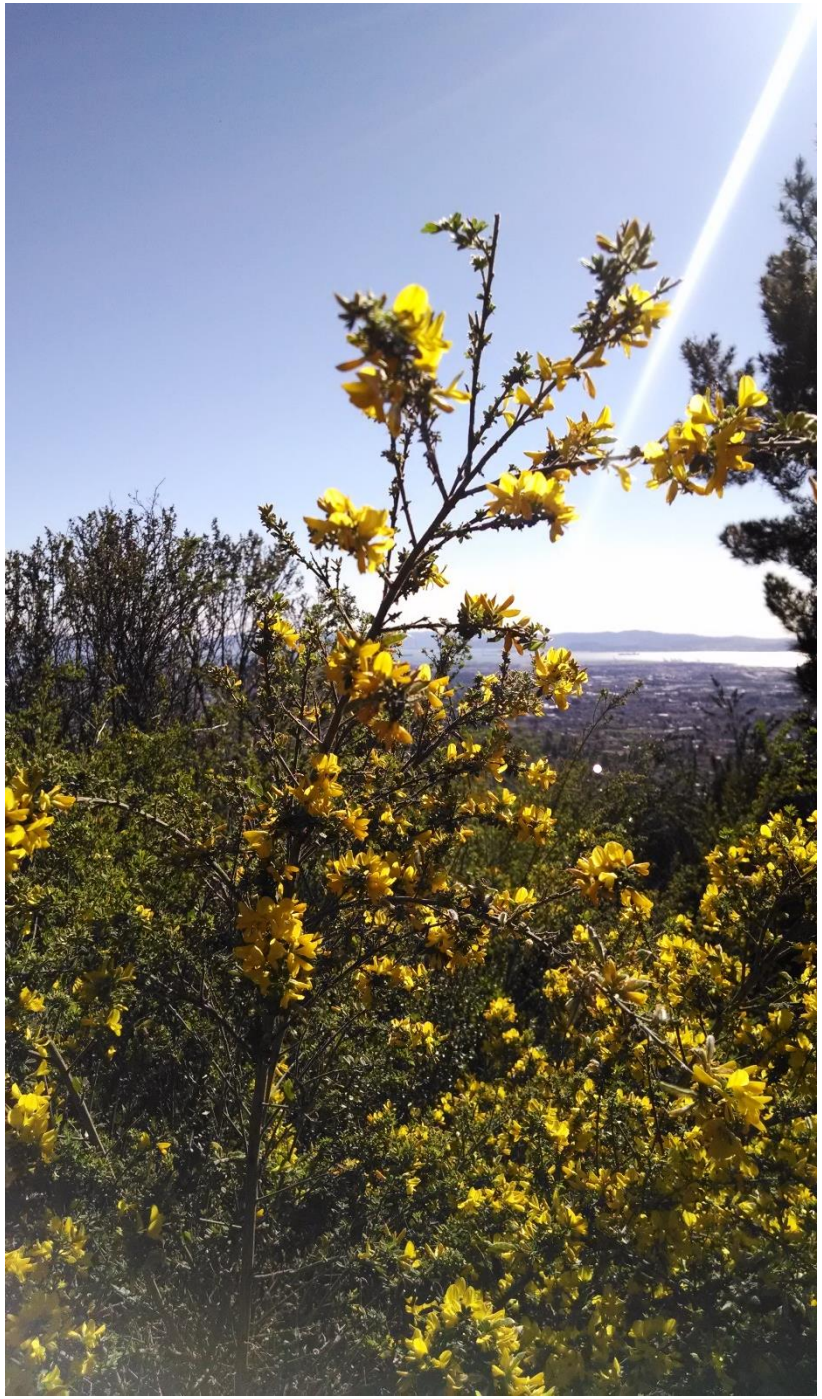

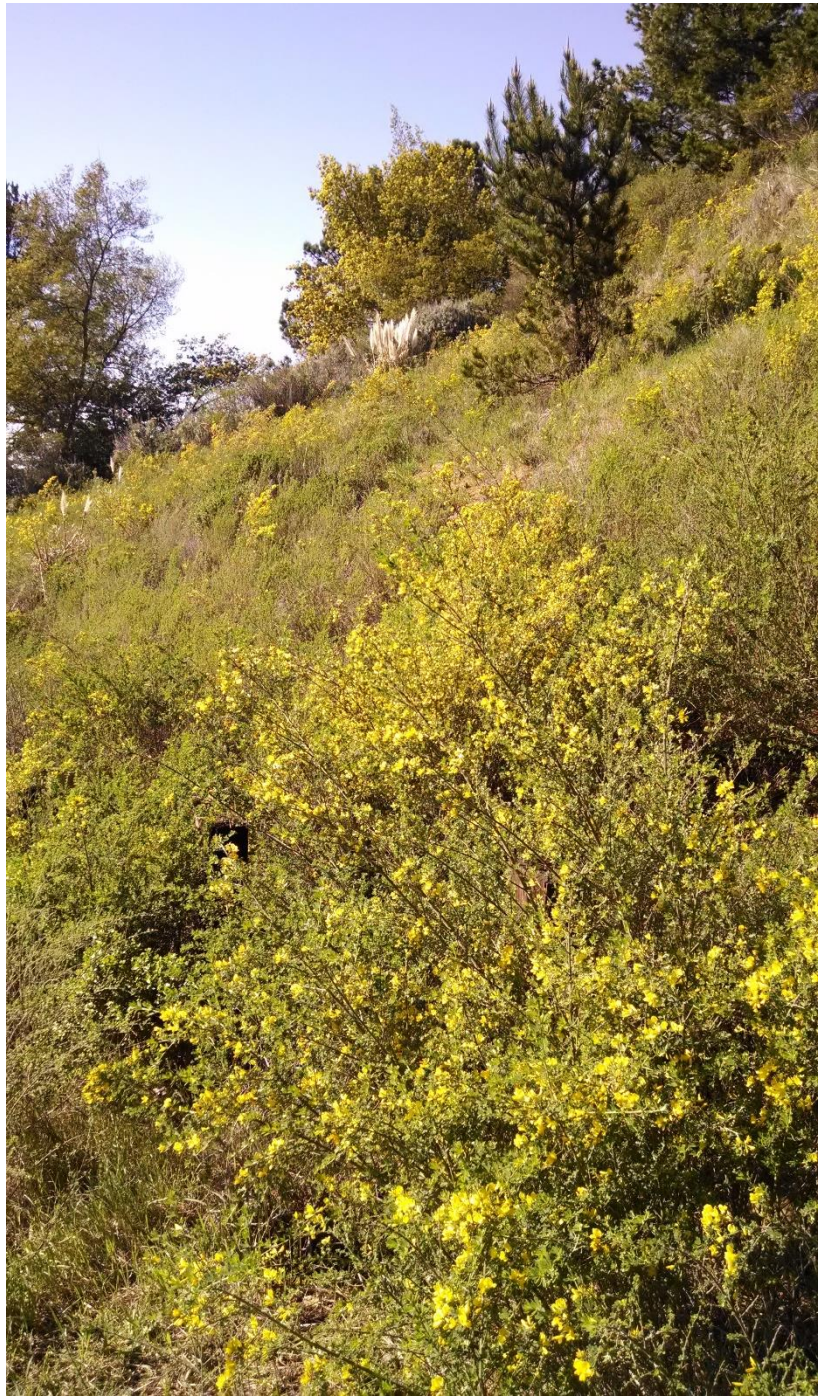

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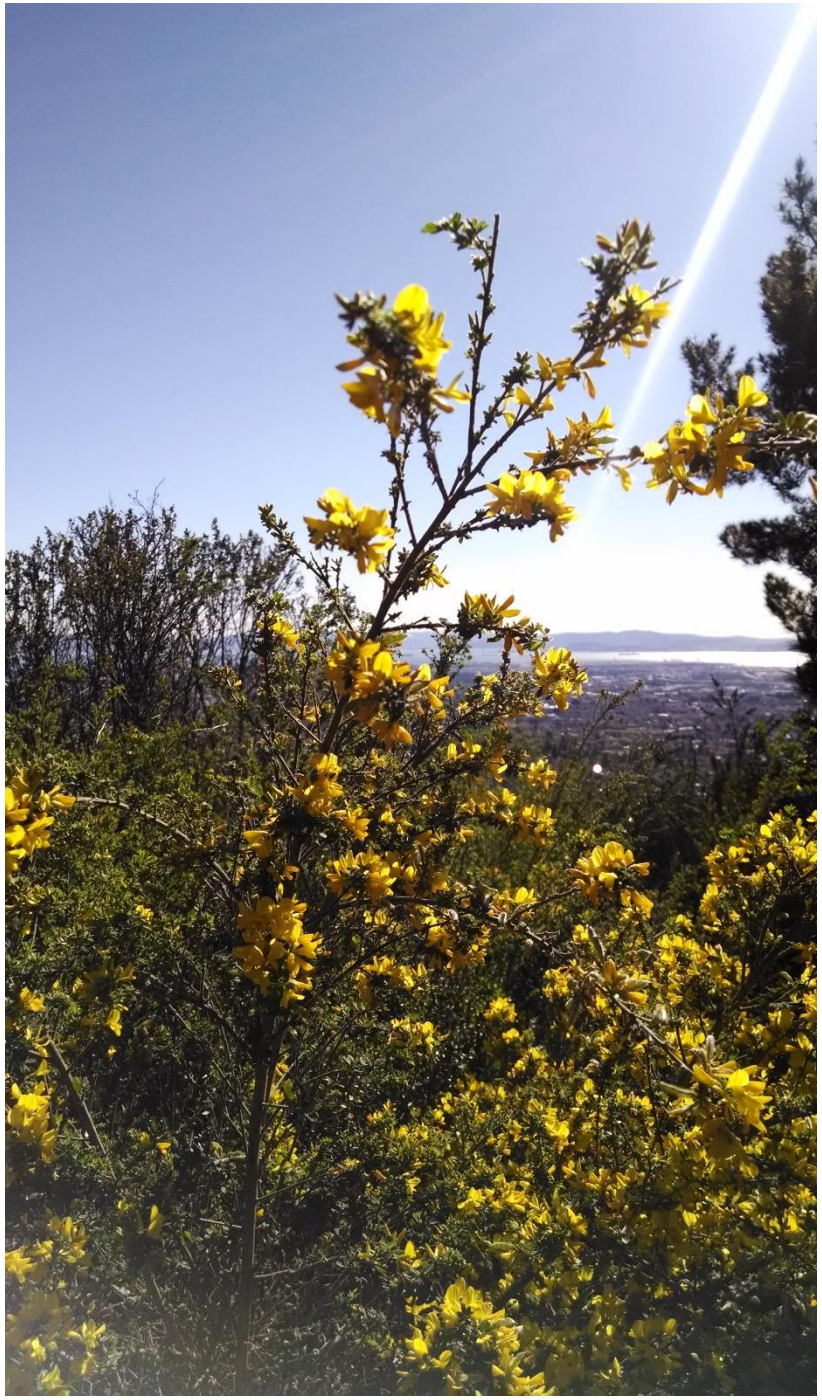

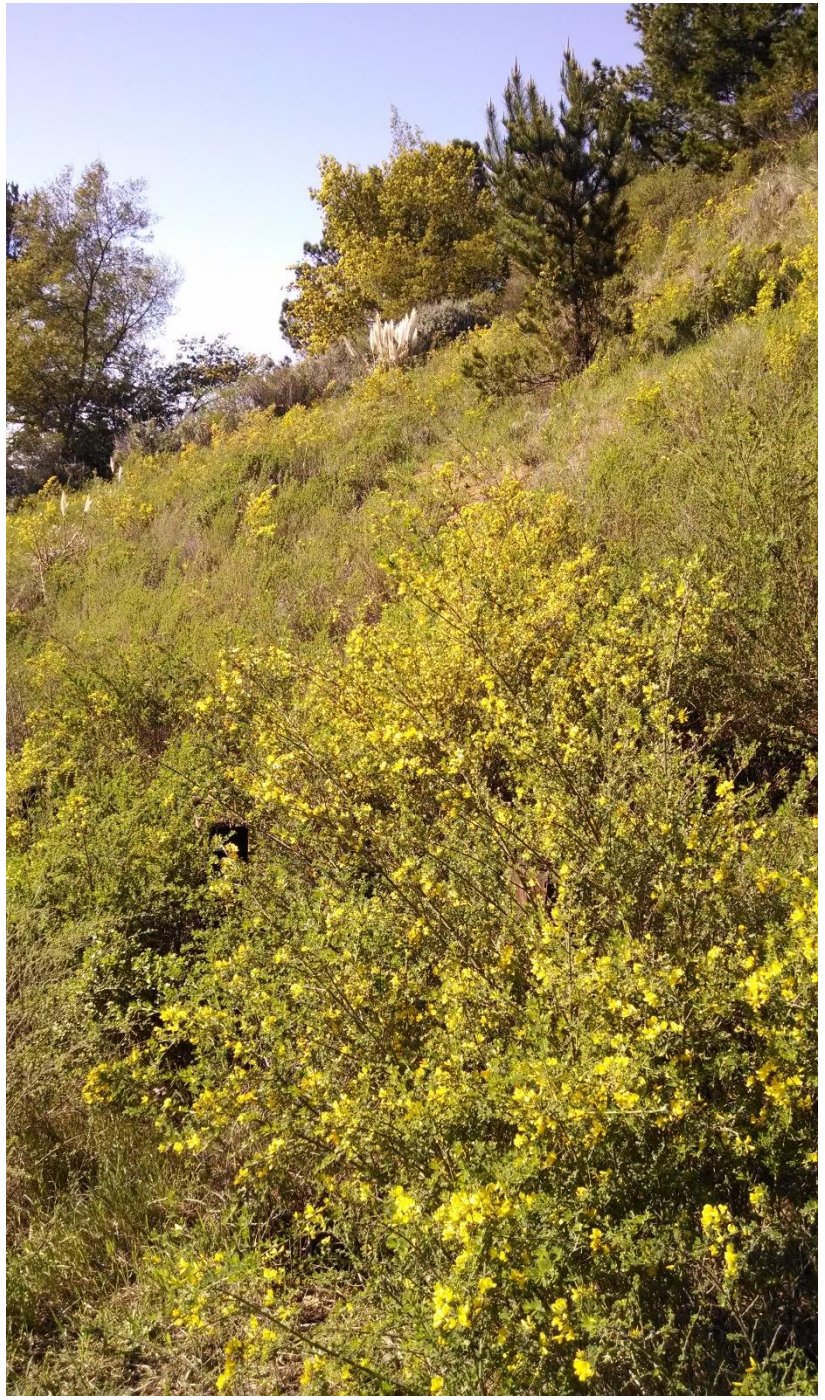

Legumes as a model system

- Pea family
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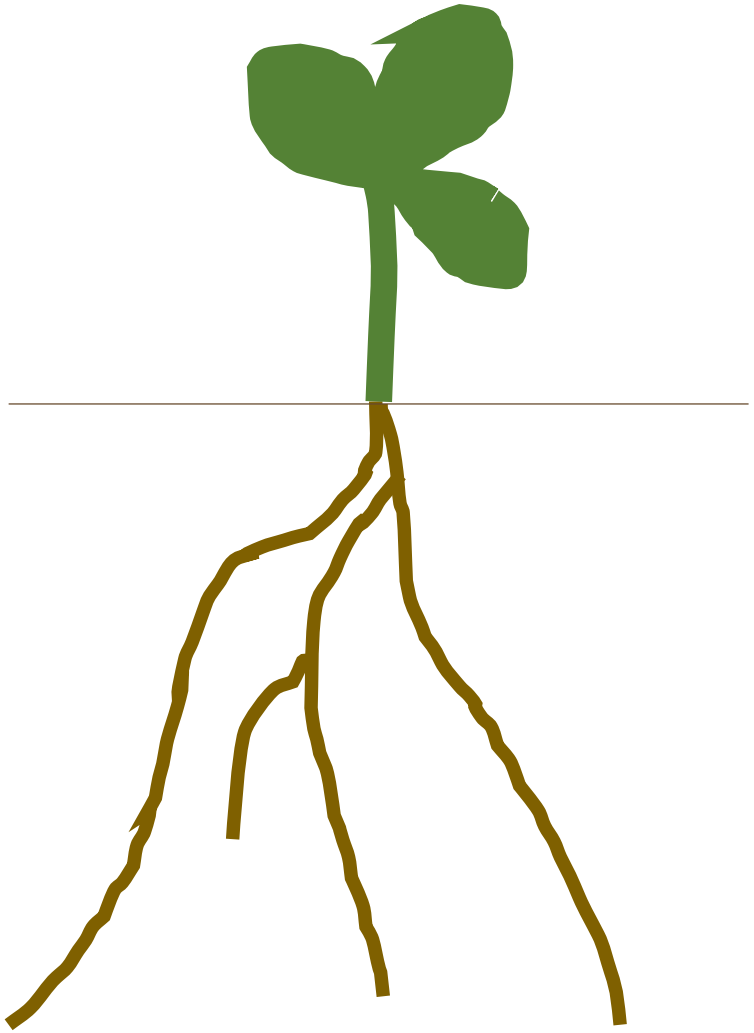
- displace native species
- alter N-cycling

Basics of rhizobial interactions with legumes



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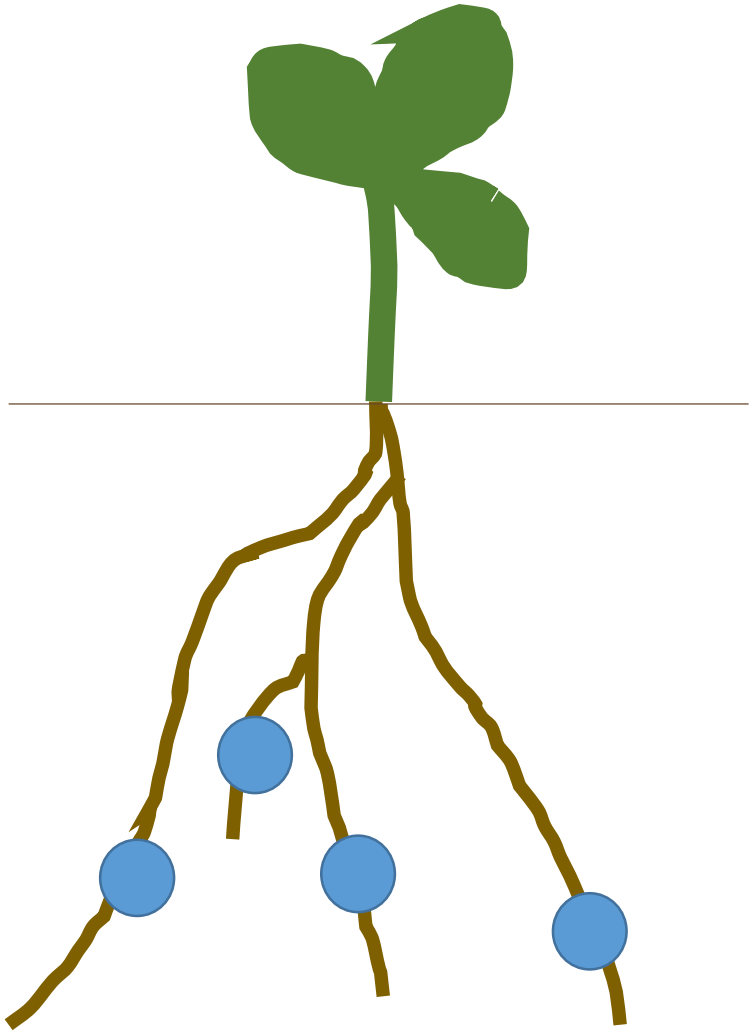

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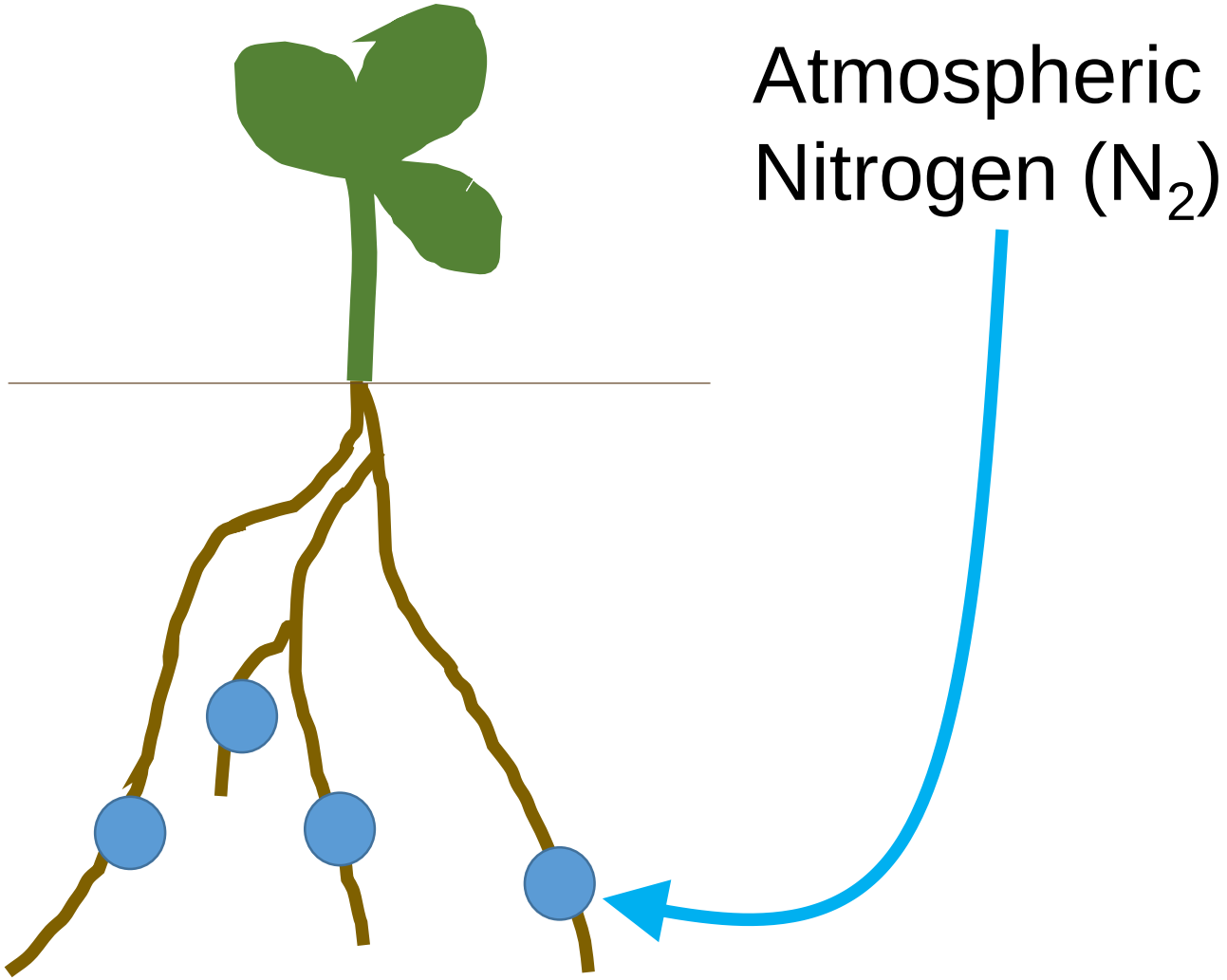

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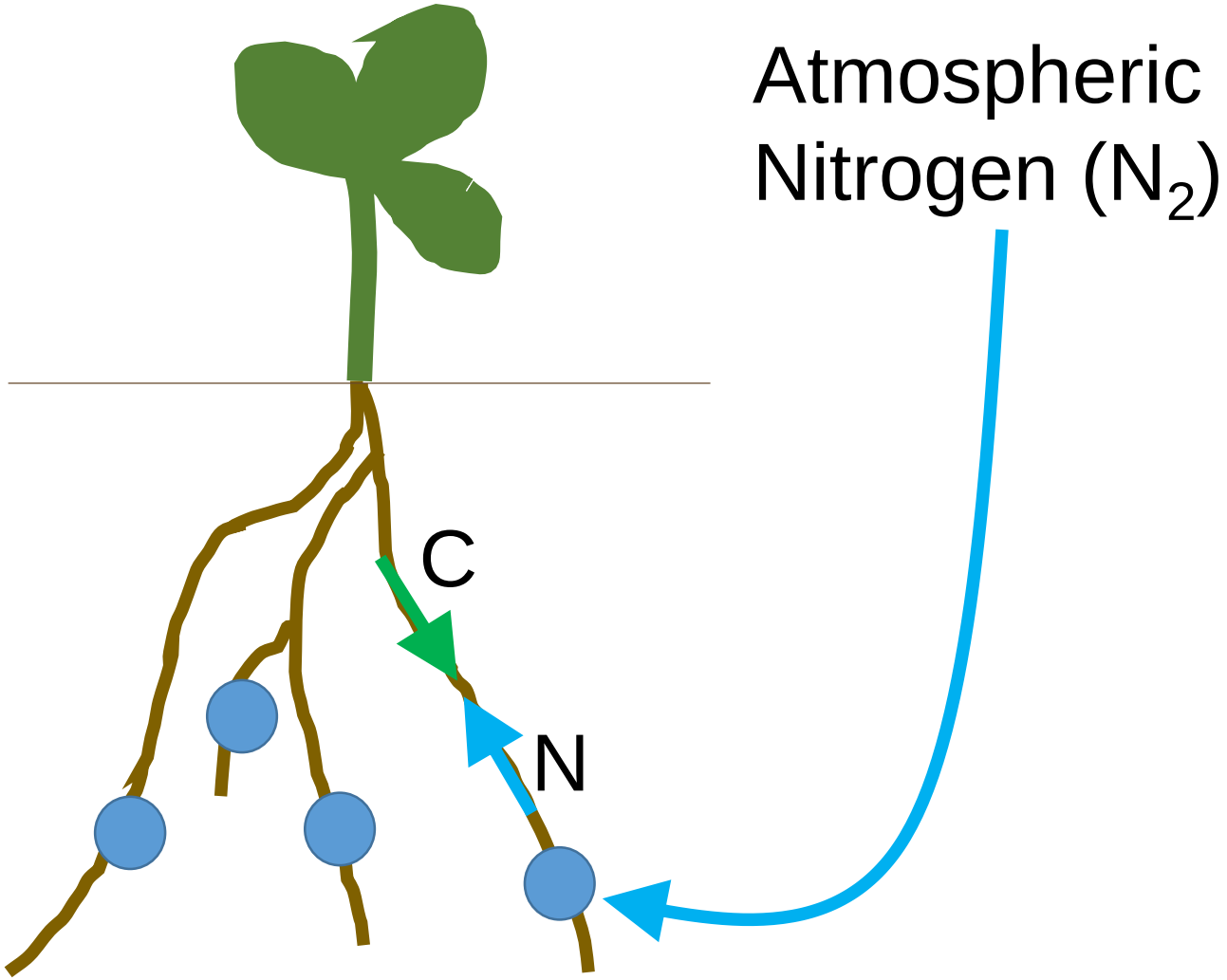

Basics of rhizobial interactions with legumes

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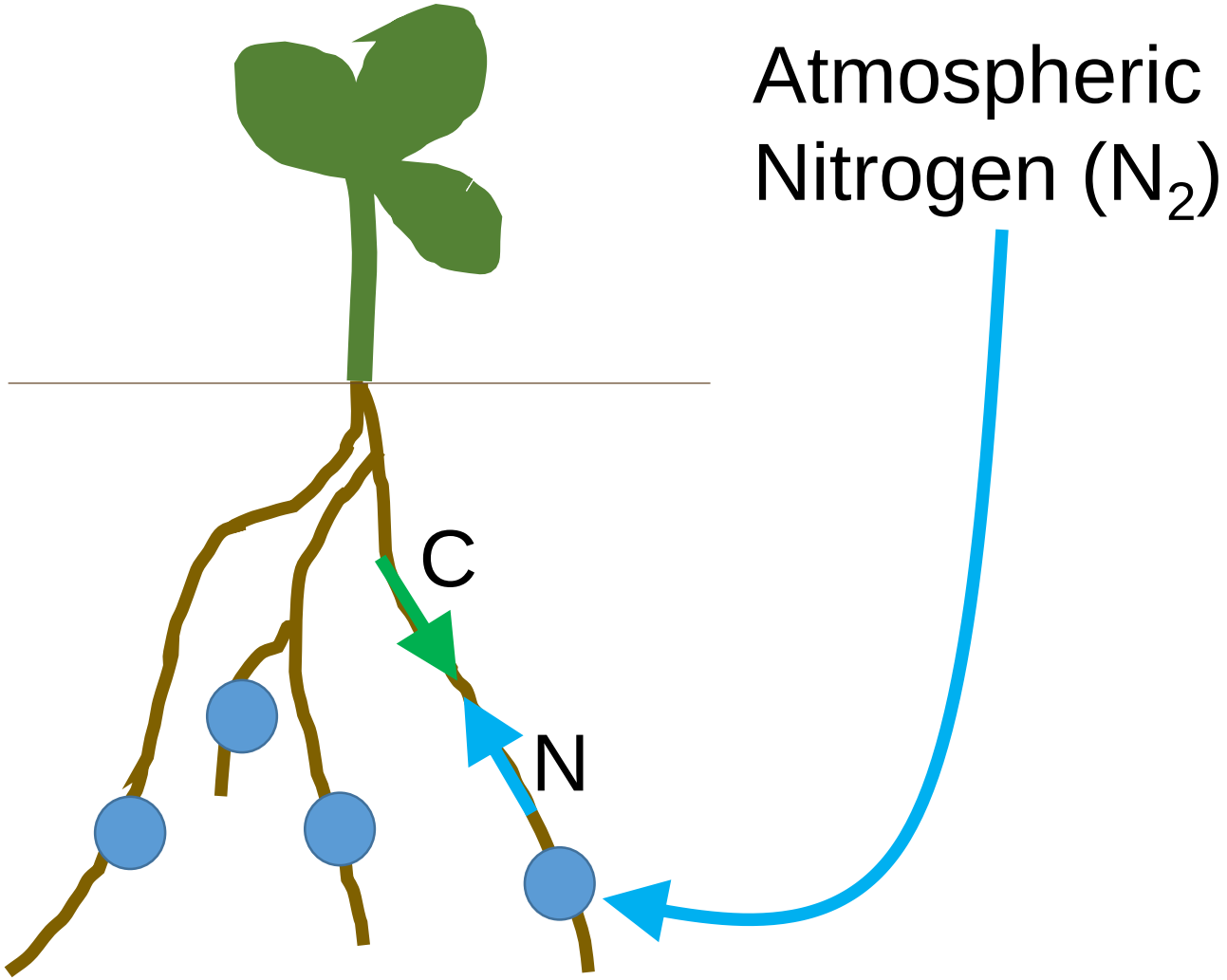
- this symbiosis allows legumes to differentiate their N-niche from non-legumes



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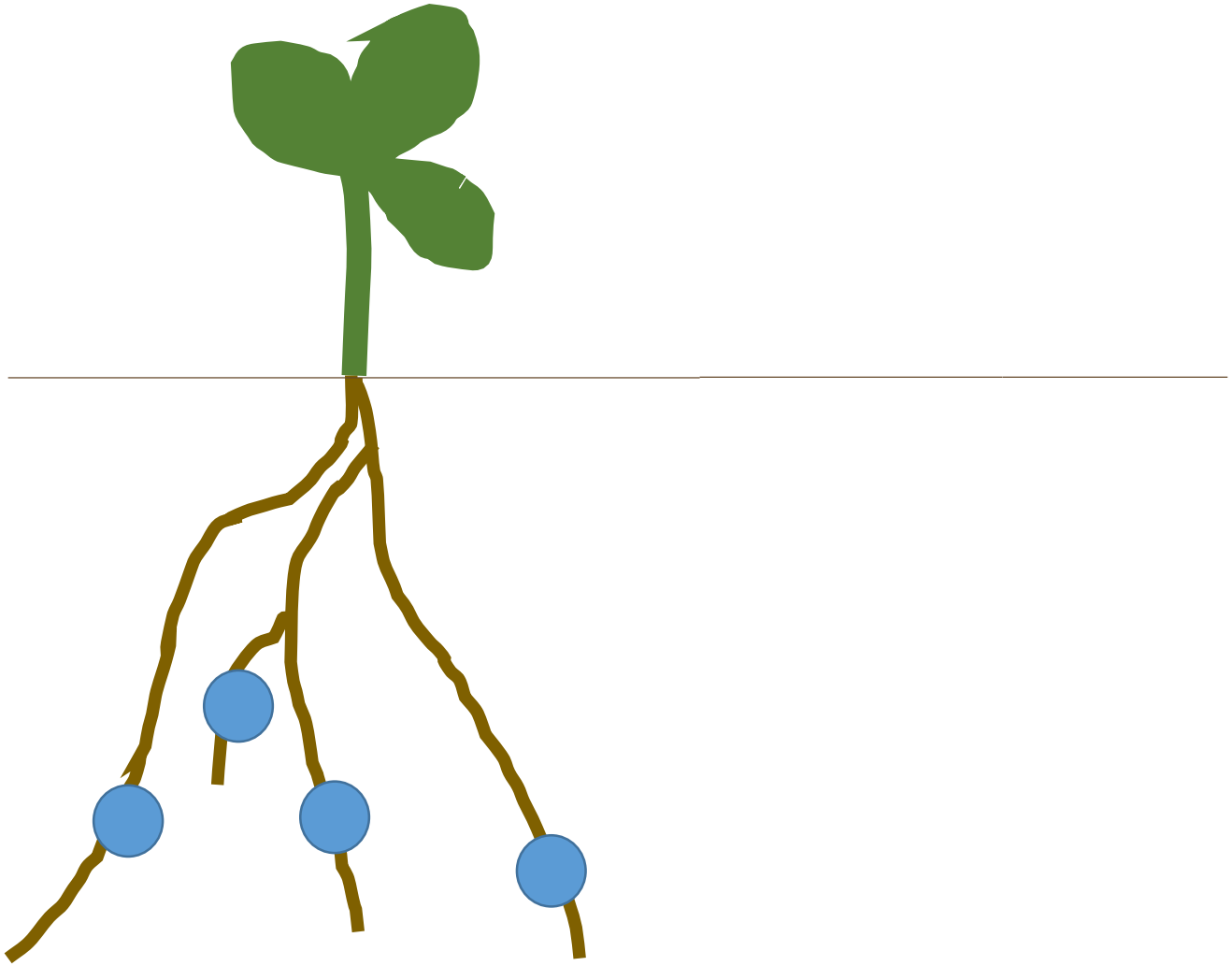

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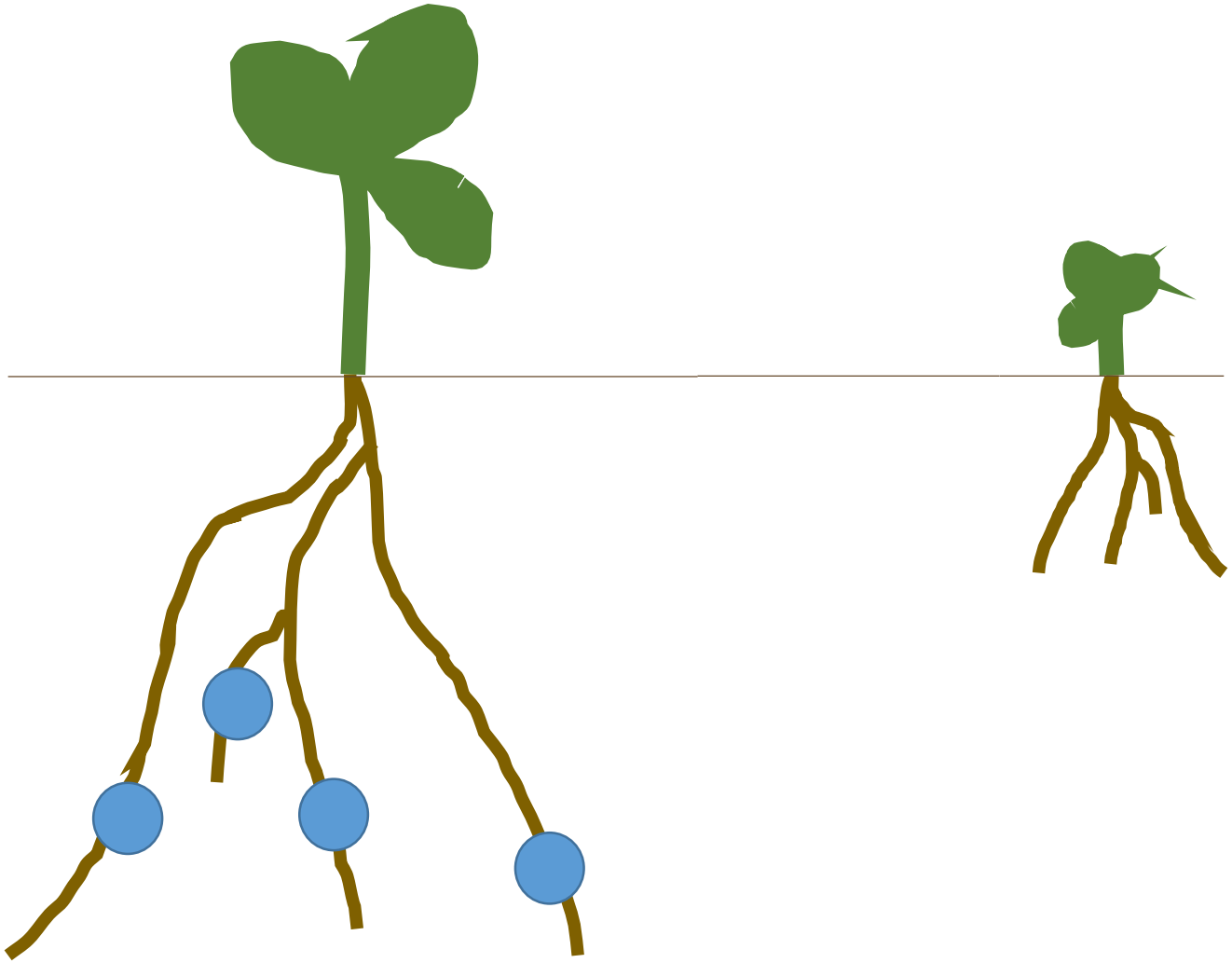

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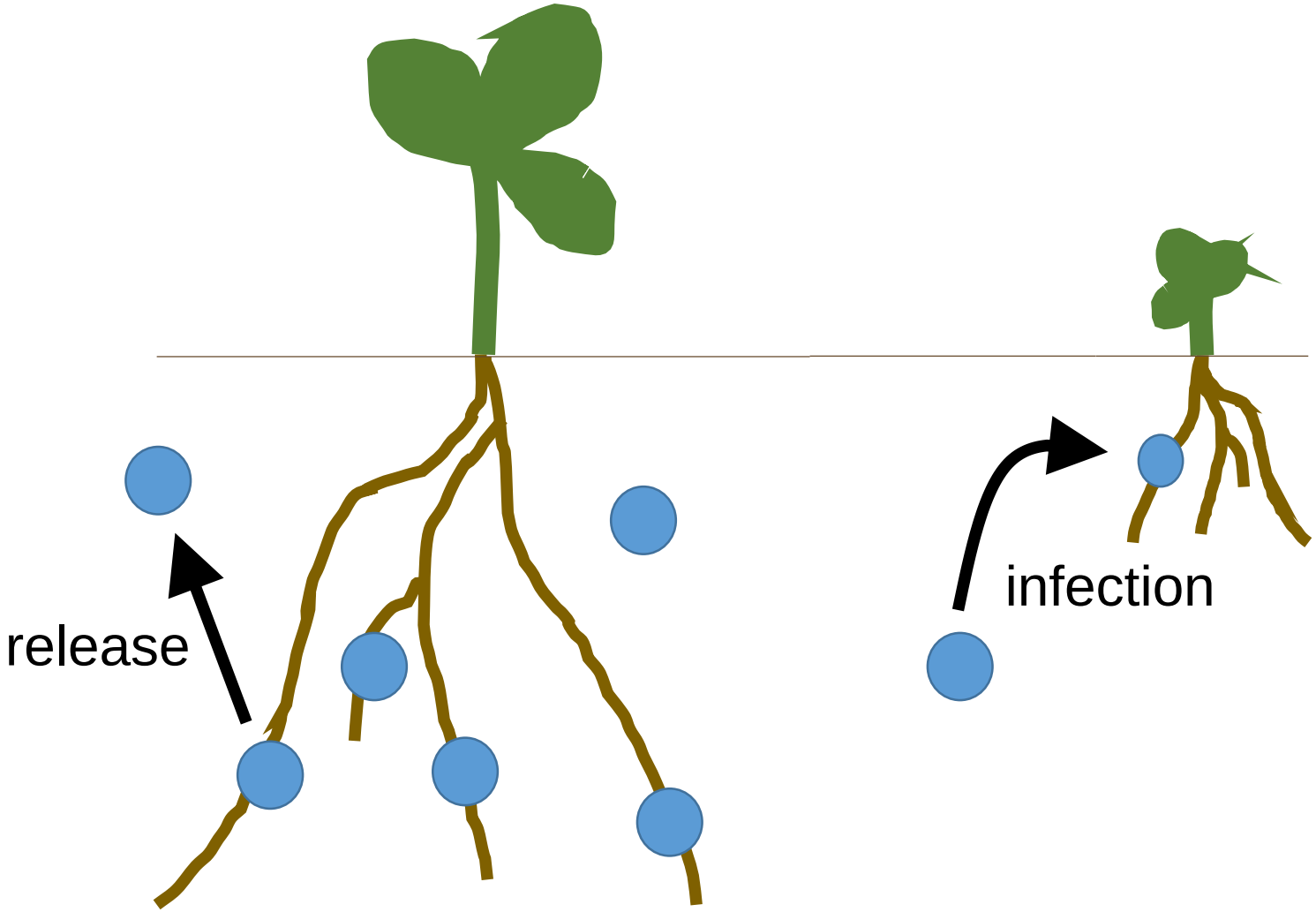

Where do invading legumes get their rhizobial associates?

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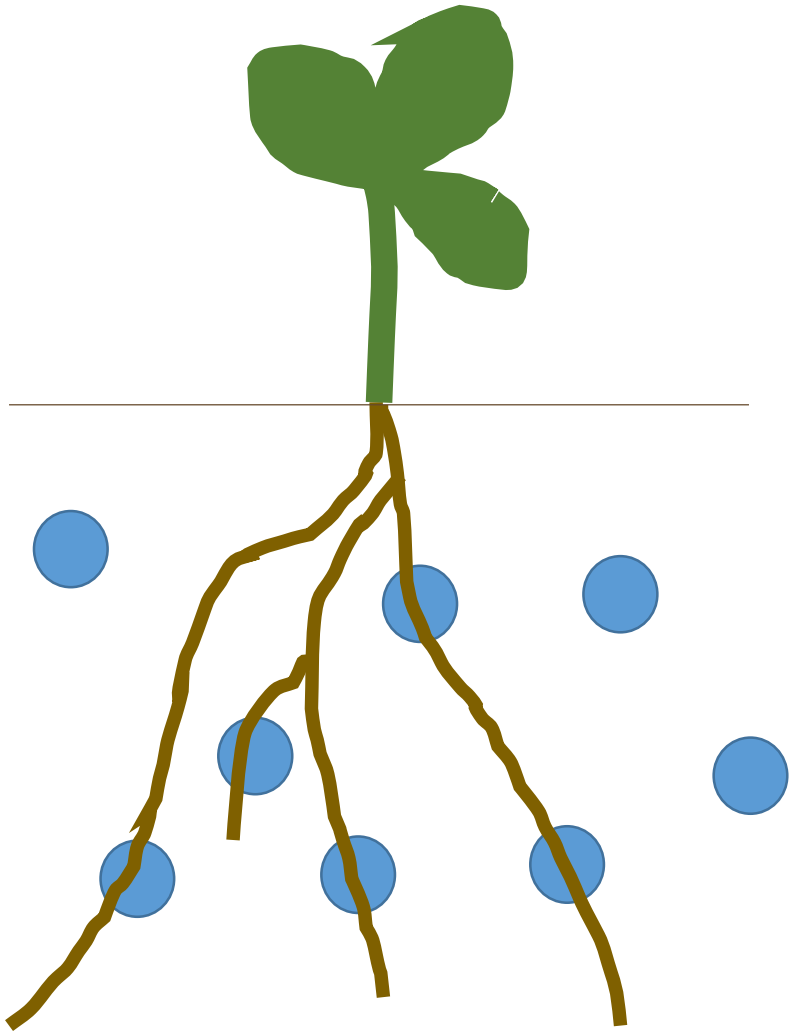

Native Range

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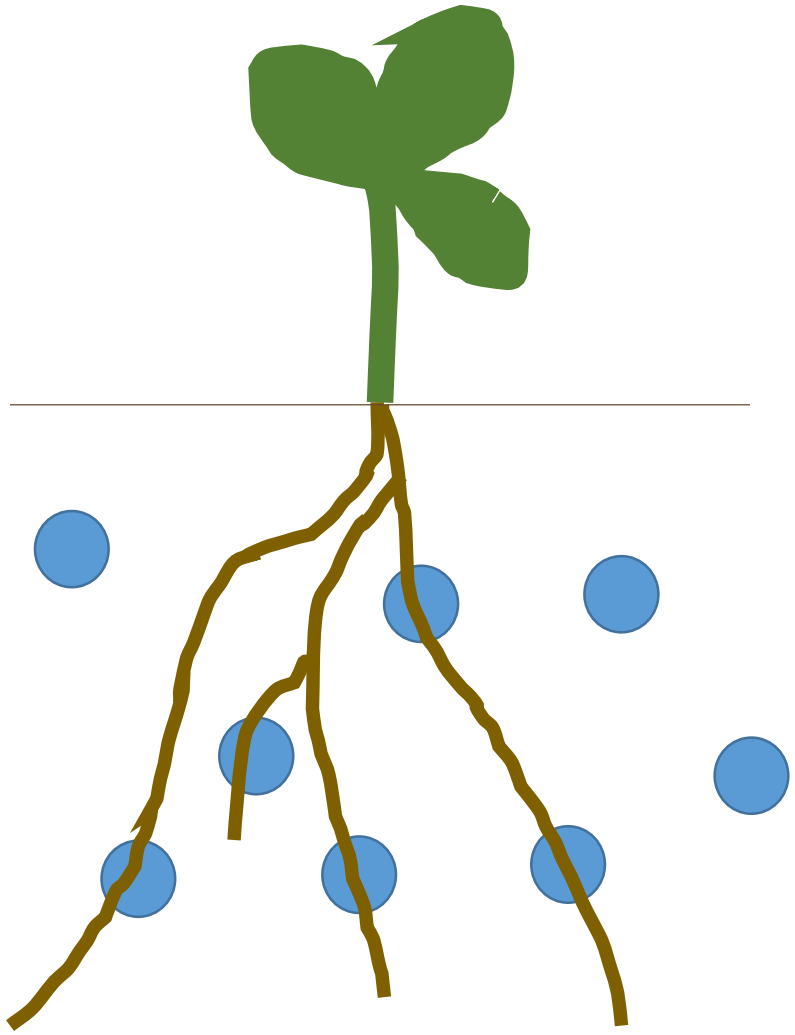

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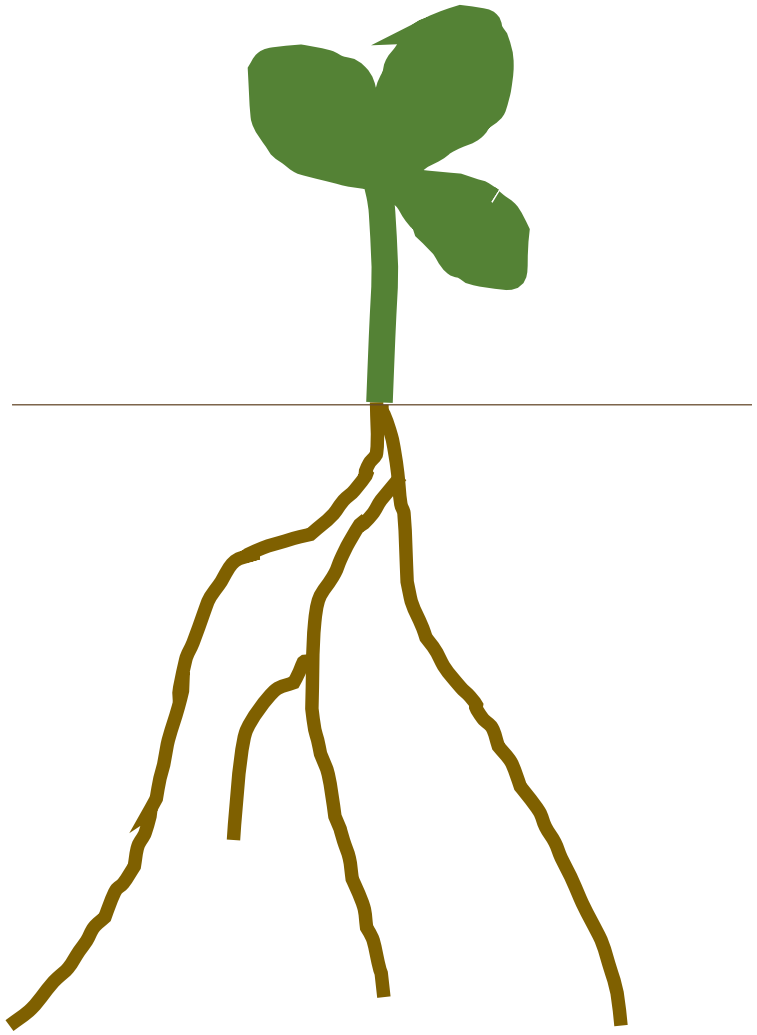

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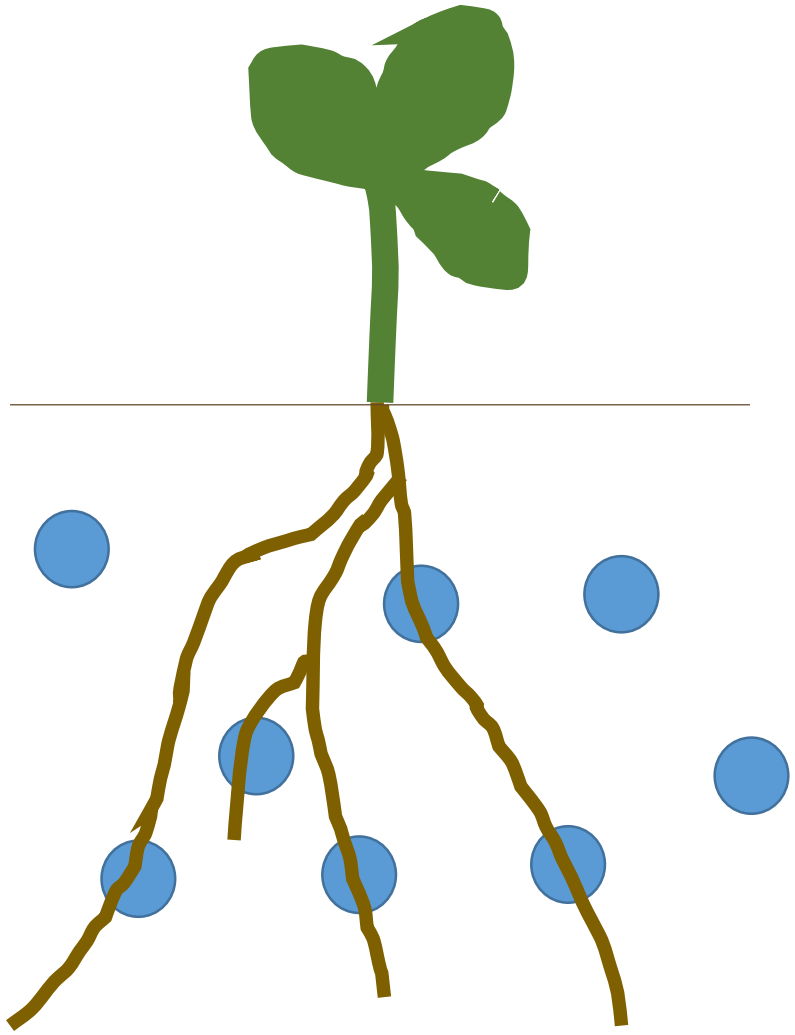

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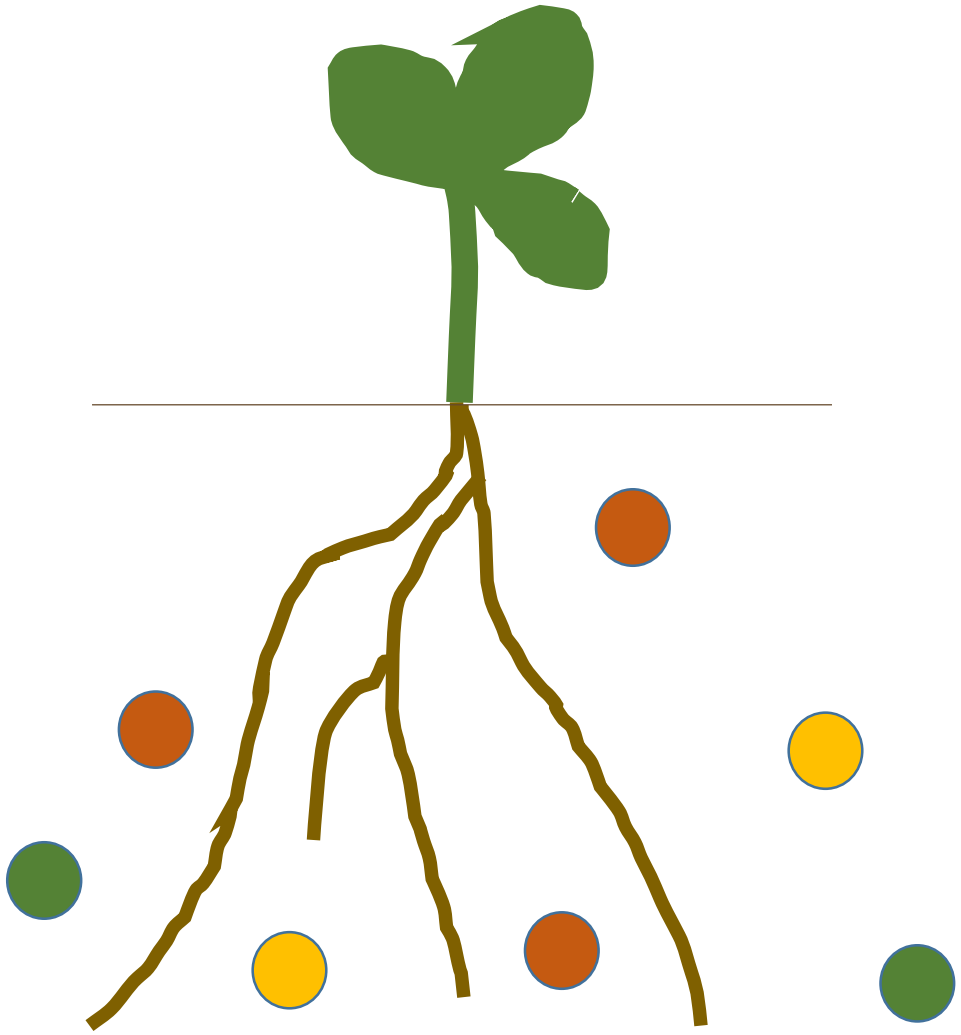

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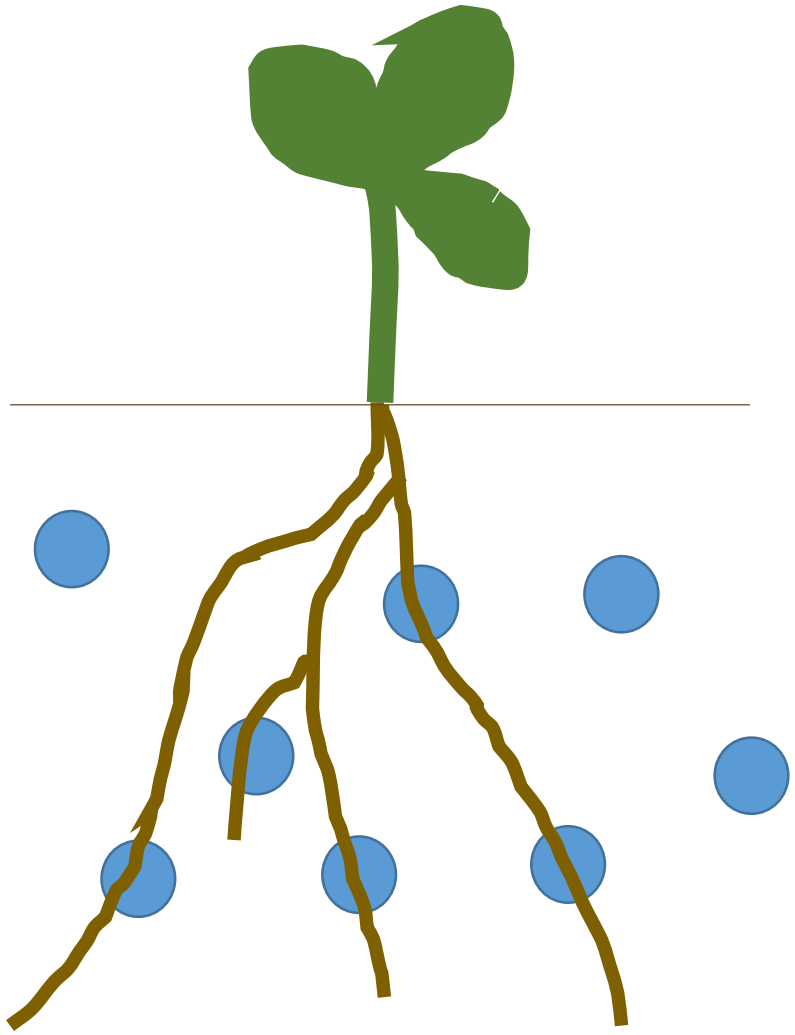

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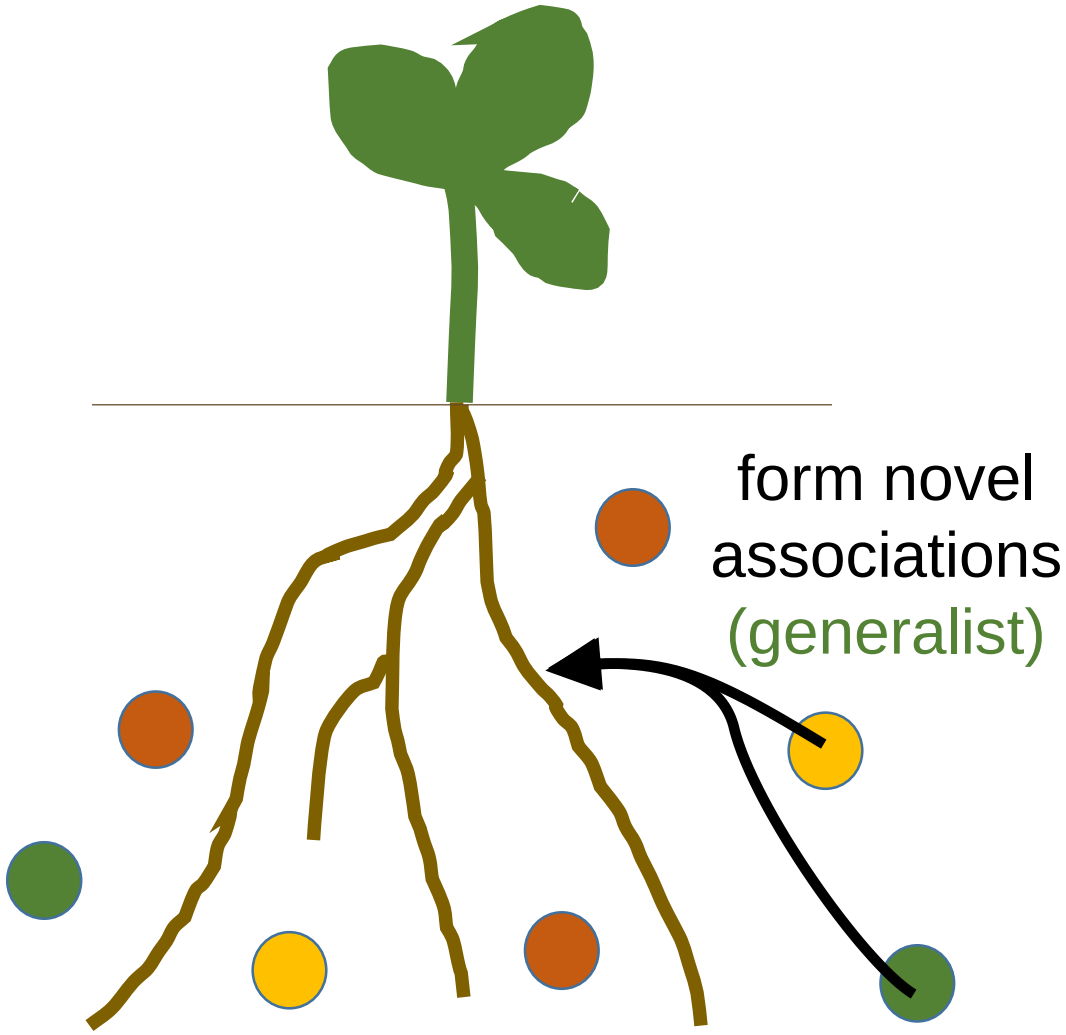

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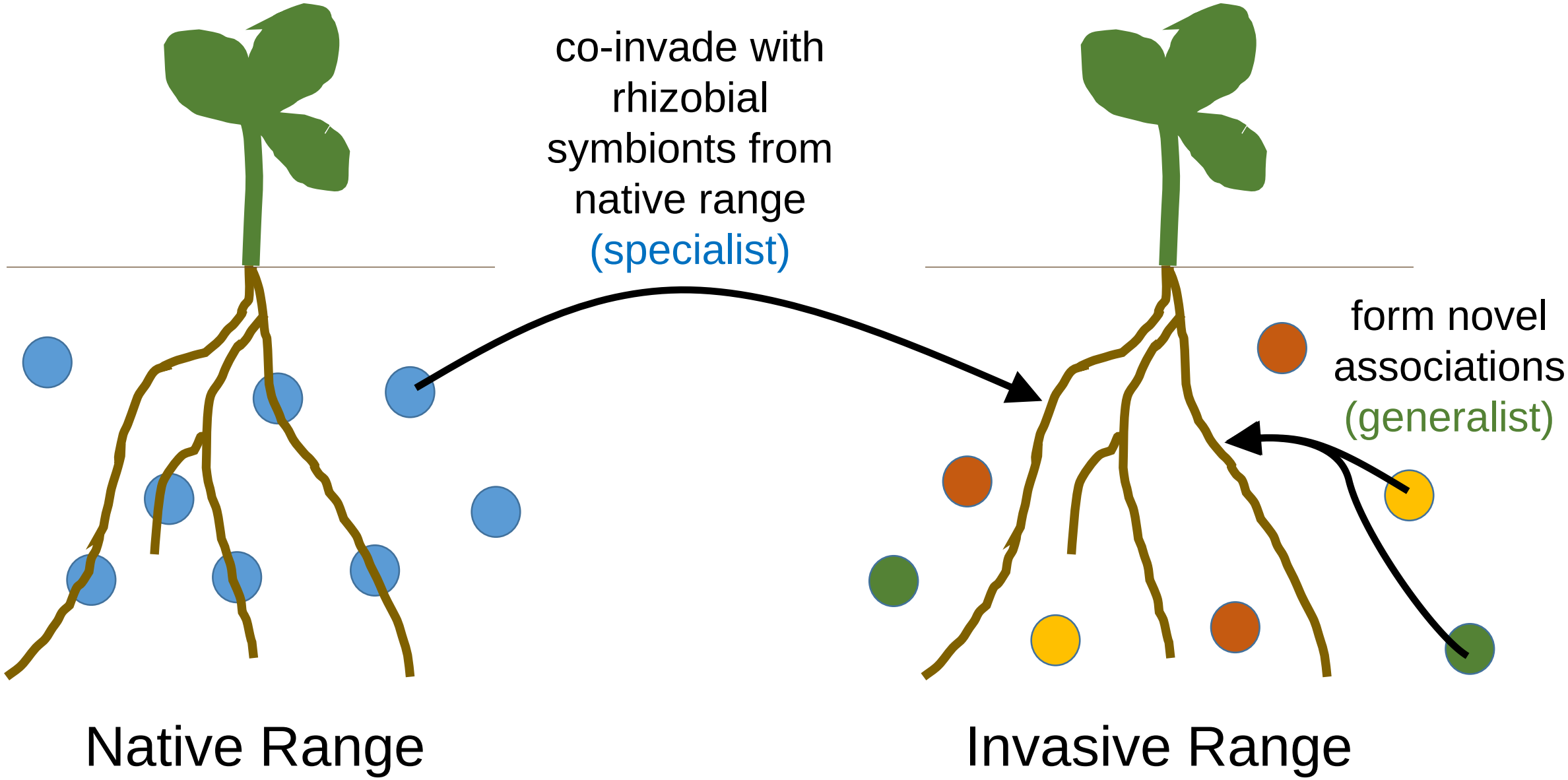

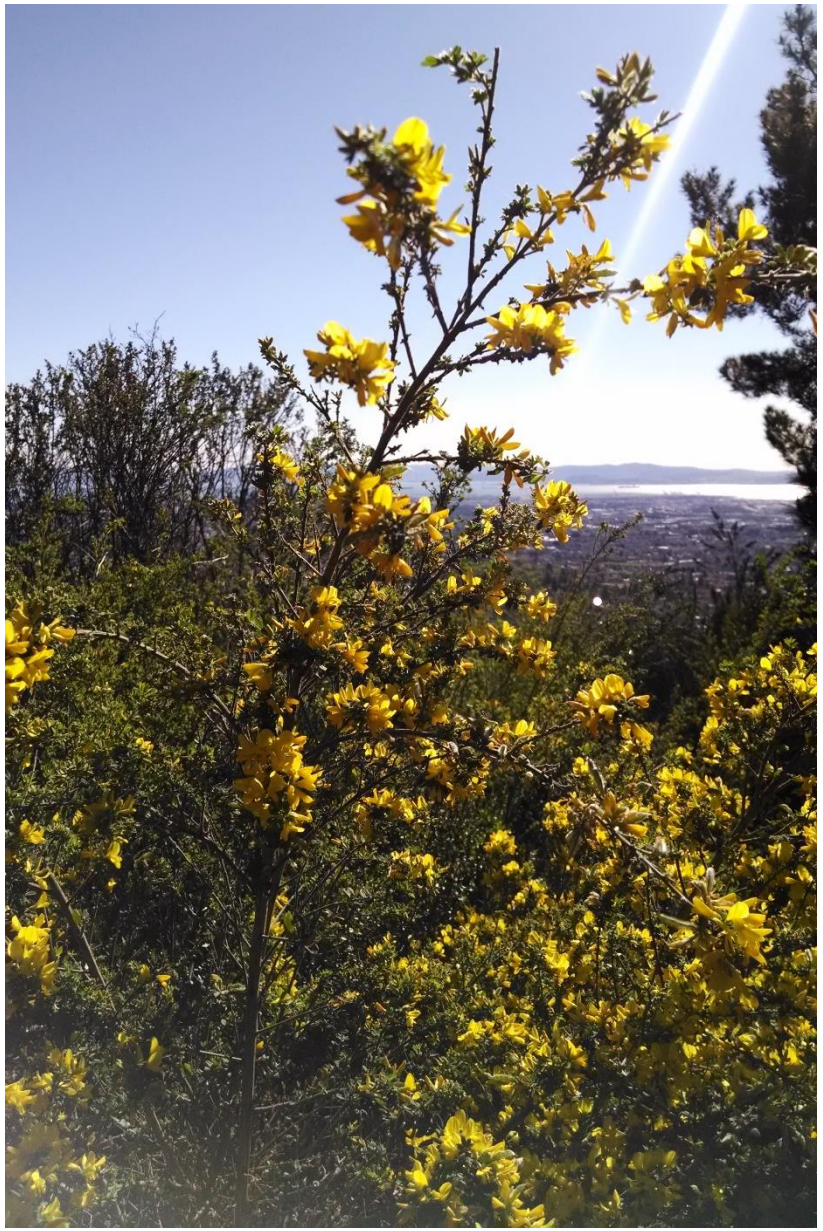

Questions

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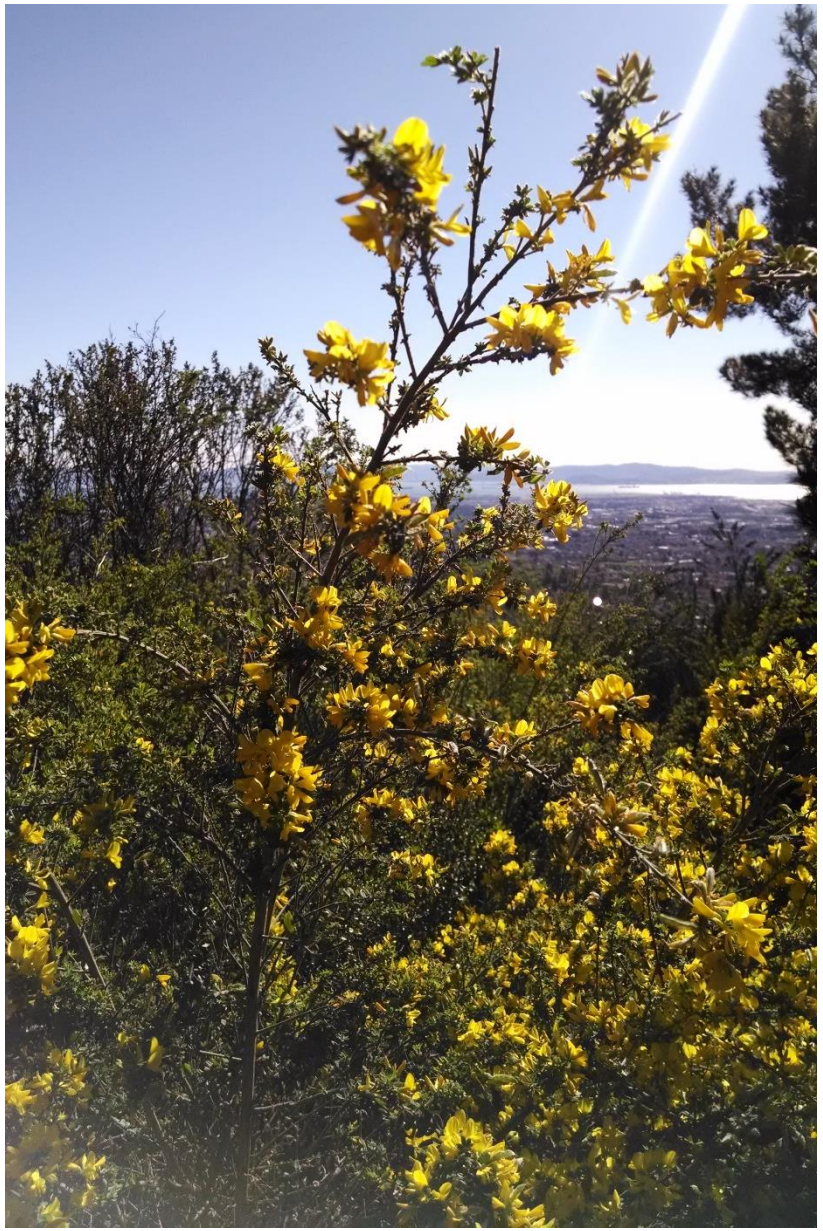

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Study Systems

Study Systems

(1) Local Scale

Study Systems

(1) Local Scale

(2) Global Scale

Study Systems

(1) Local Scale

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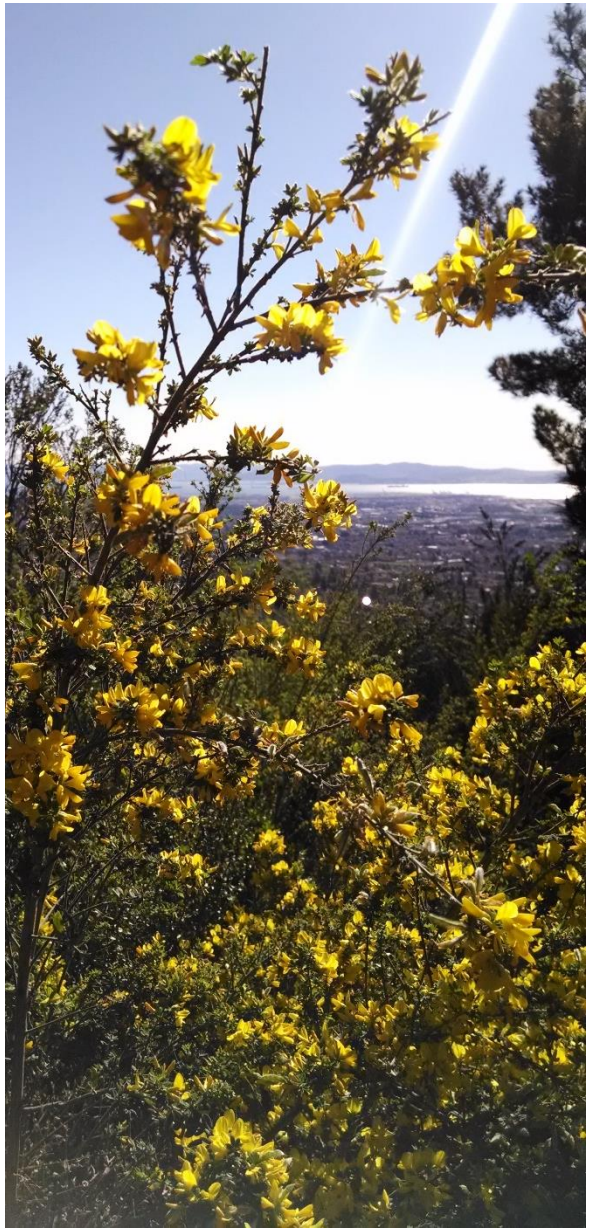
Genista monspessulana
(French broom)



Spartium junceum
(Spanish broom)

Ulex europaeus
(Gorse)

Lotus angustissimus
(Slender Bird's Foot Trefoil)

Genista monspessulana
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Spartium junceum
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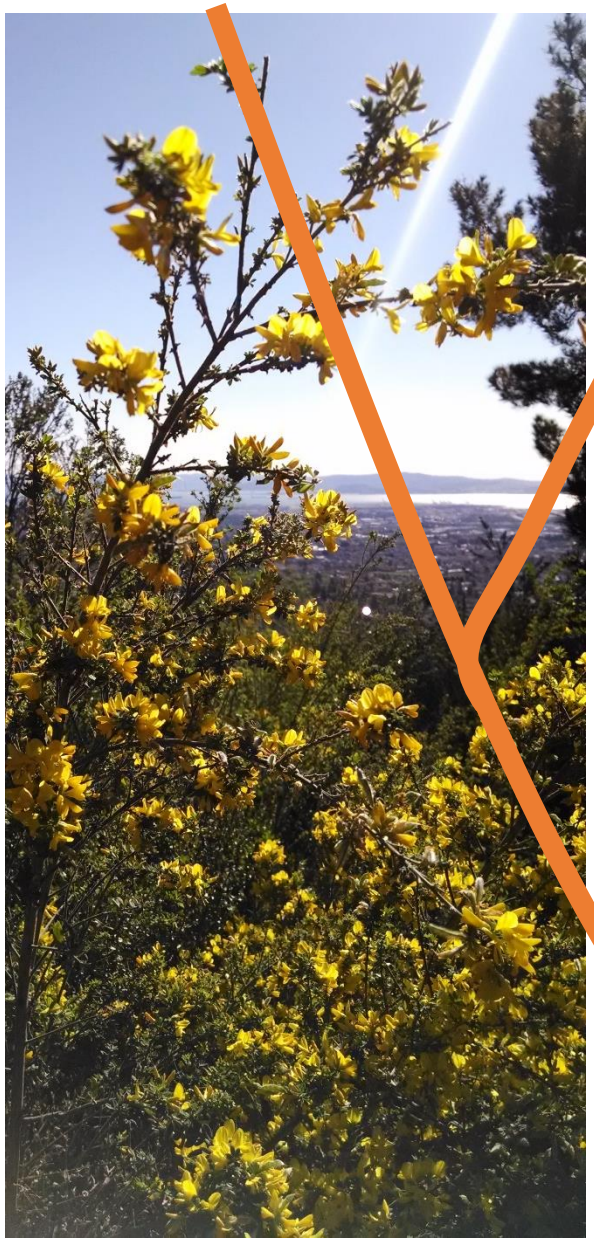
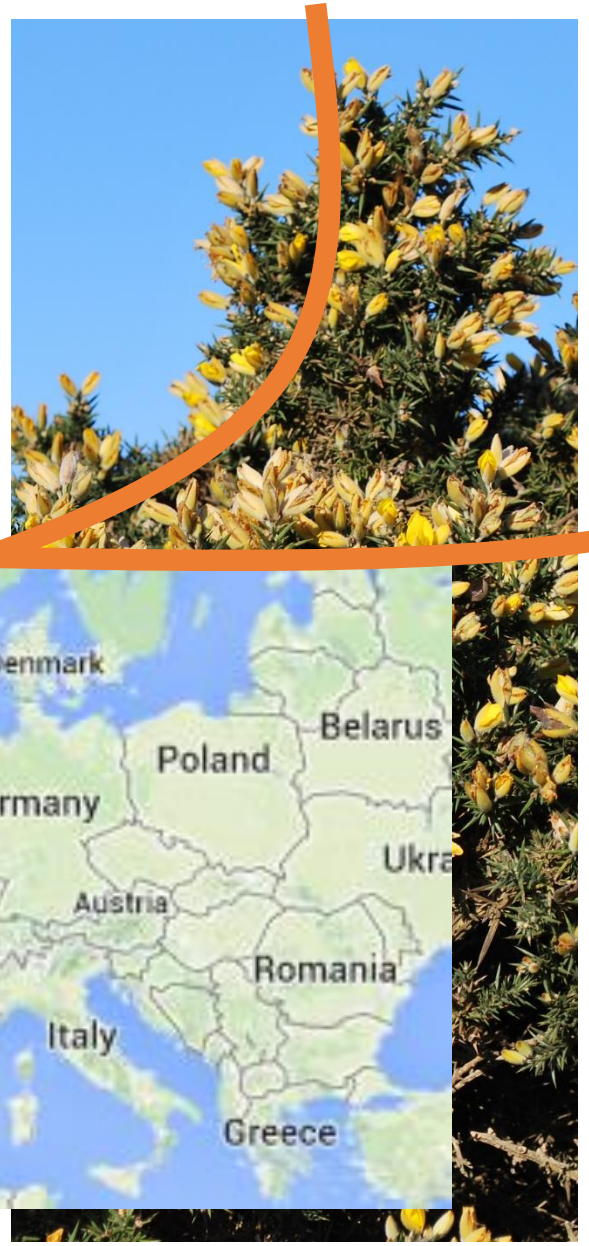
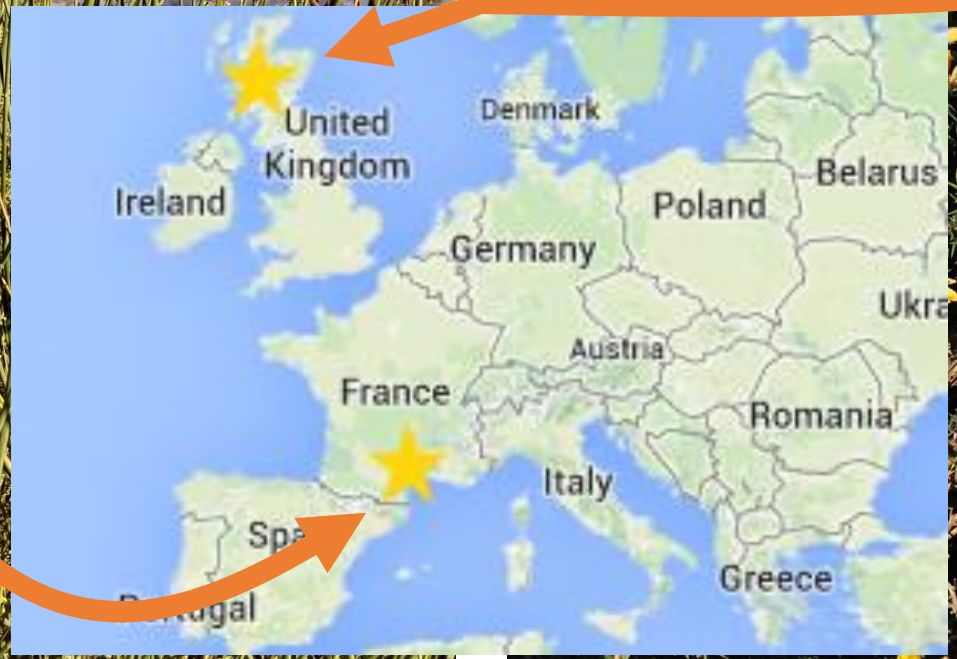






INVASIVE

Genista monspessulana

Spartium junceum

Ulex europaeus

Lotus angustissimus

NATIVE

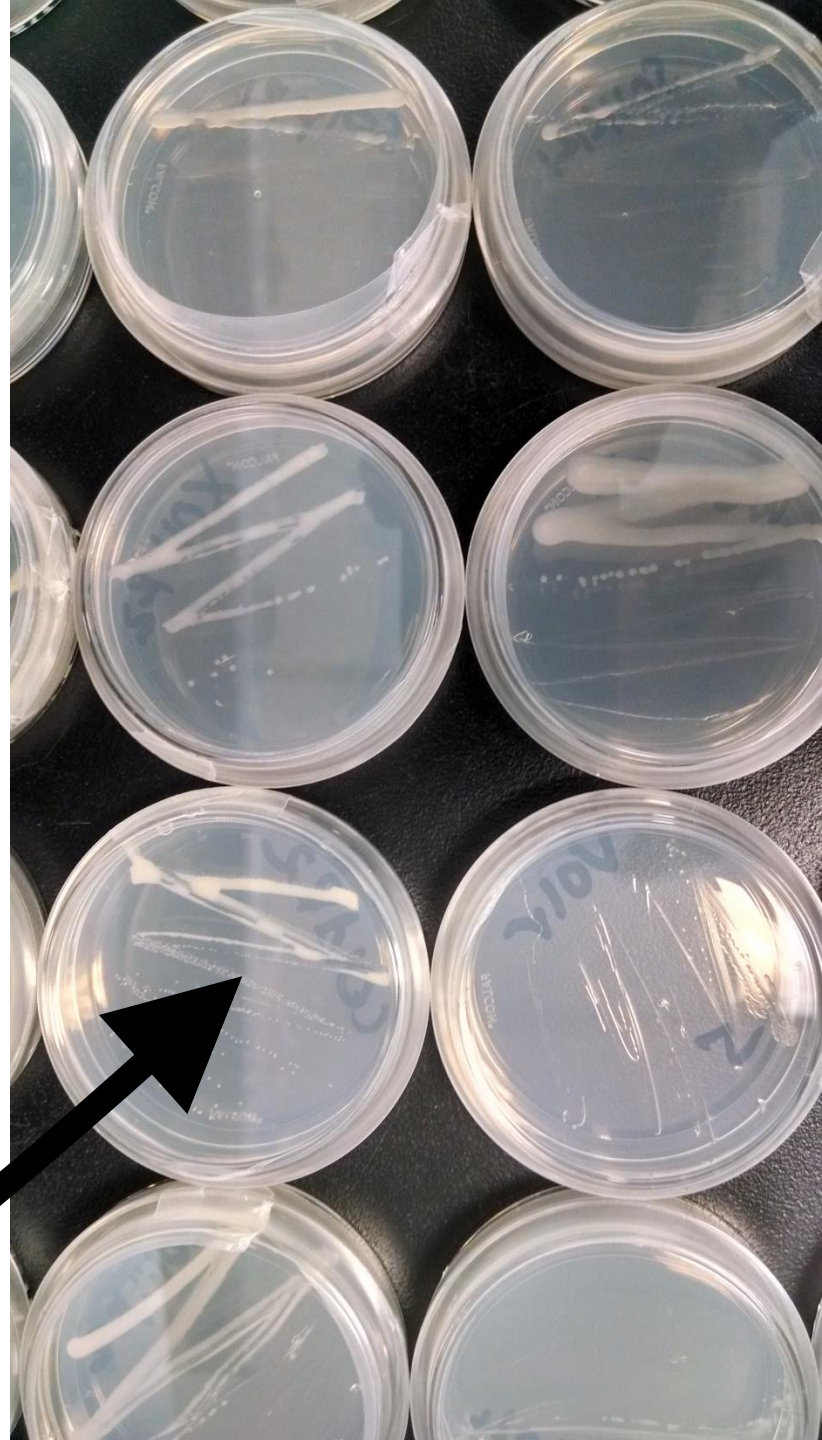
Acmispon heermannii

A. micranthus

A. strigosus

Lupinus arboreus

Lu. bicolor

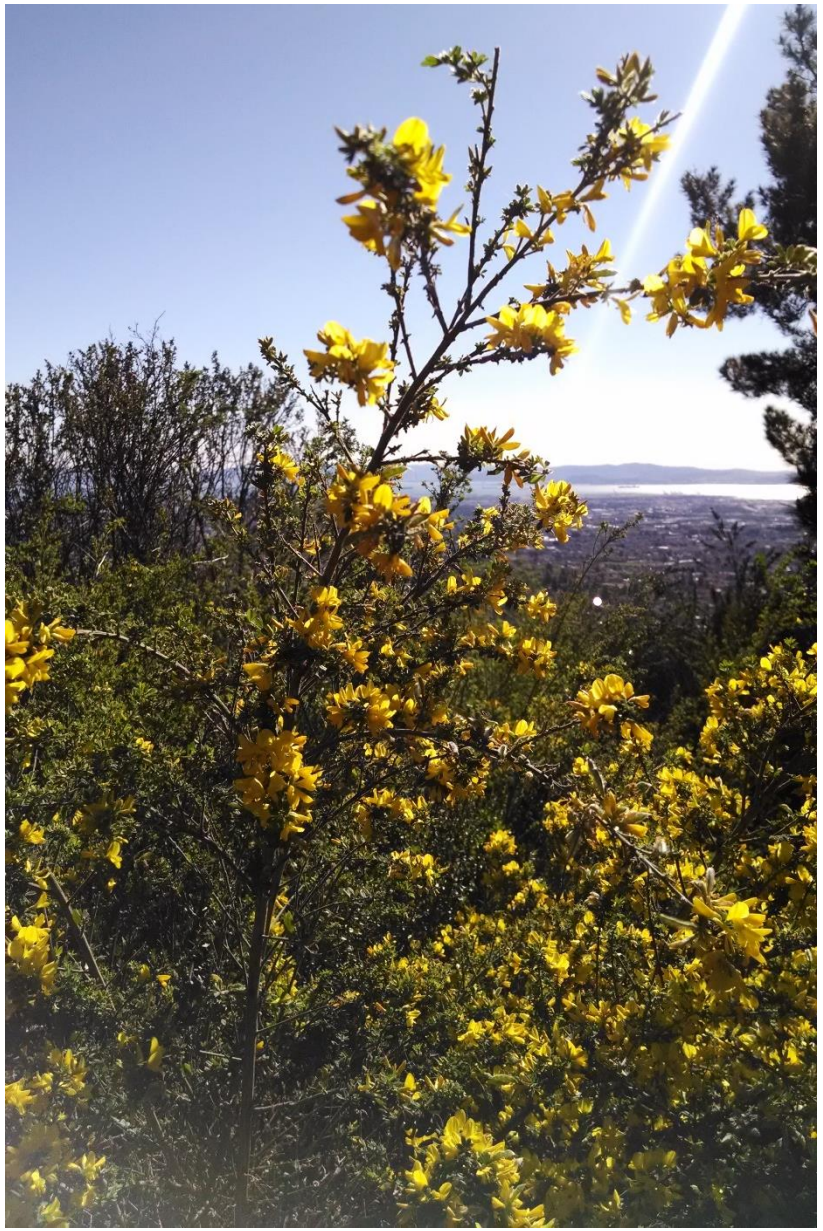


241 native isolates

301 invasive isolates

sequenced at 16S and ITS loci

54 unique strains



Questions – Bay Area

(1) Do invasive legumes form novel associations in their exotic range?

Or do invasive legumes co-invade with their familiar rhizobial associates?

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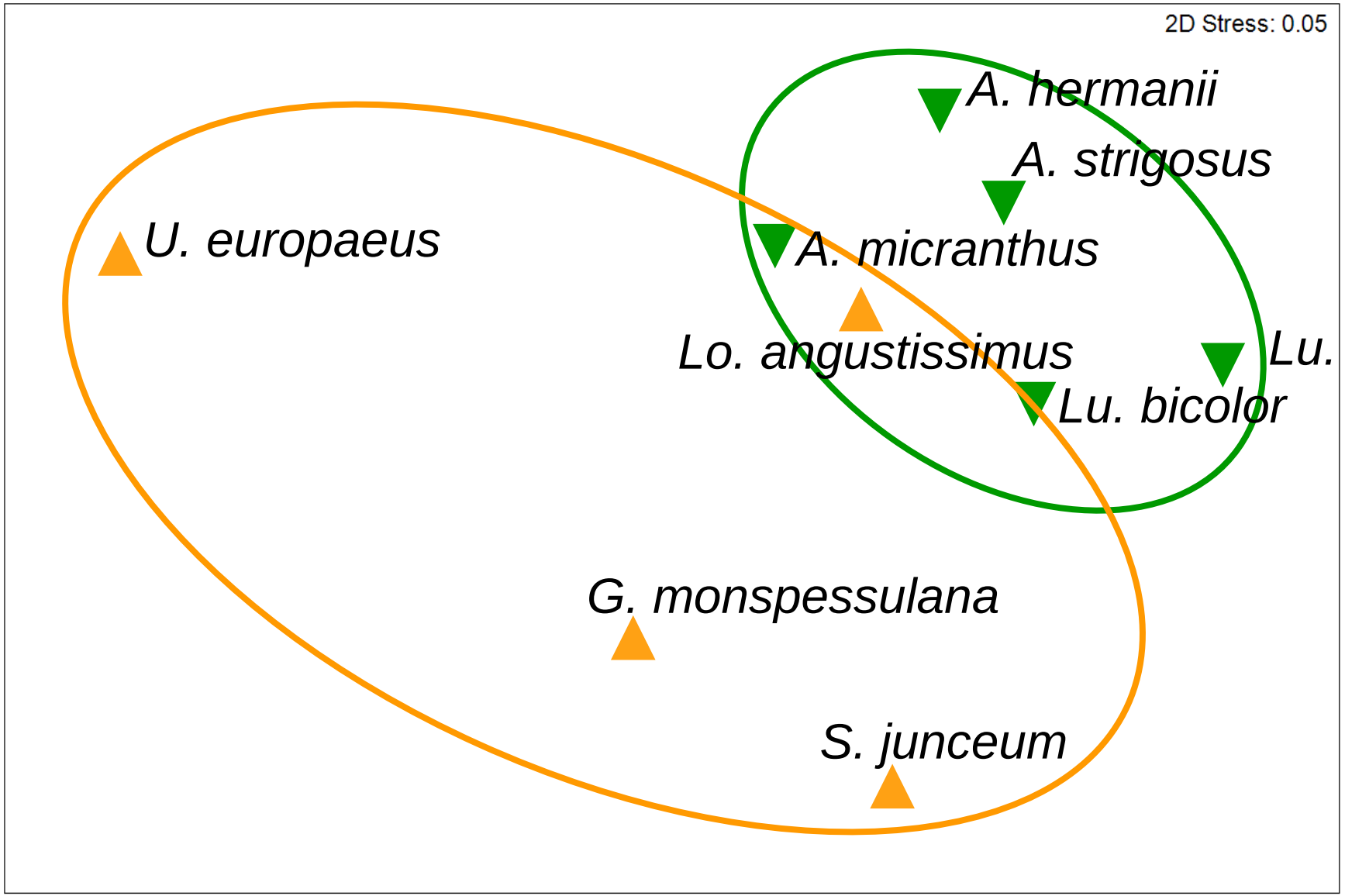
NMDS – invasive and native legumes do not share rhizobial strains



native

invasive

PERMANOVA:

pseudo-$F_{1,7}$ = 1.745

p = 0.029

Where do Bay Area invaders get their rhizobia?

L. angustissimus
(Slender Bird's Foot Trefoil)

G. monspessulana
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S. junceum
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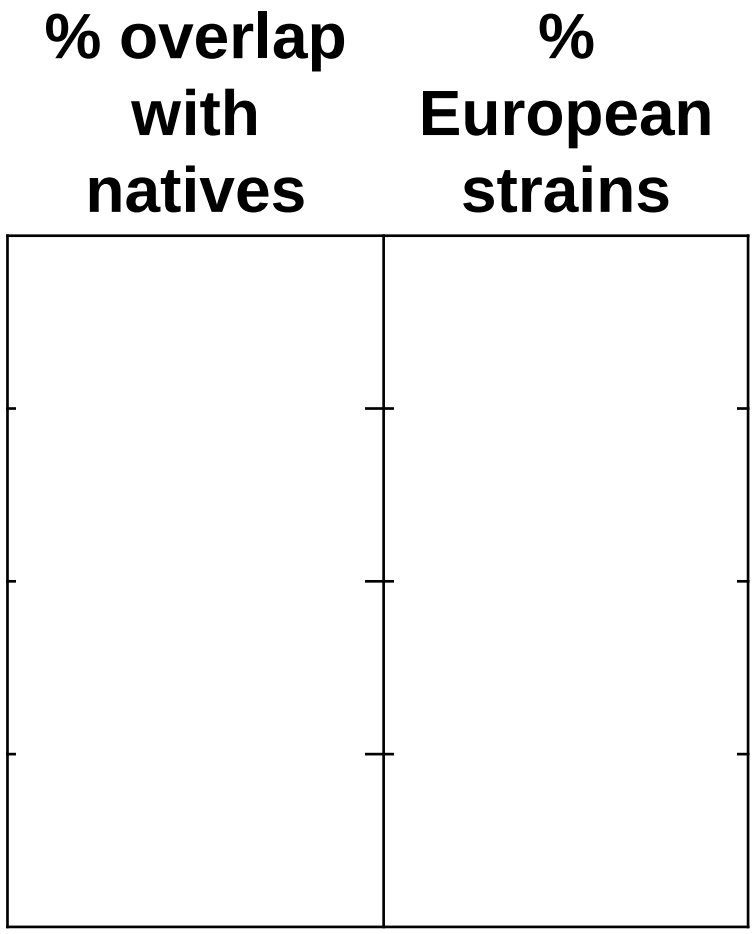
U. europaeus
(gorse)



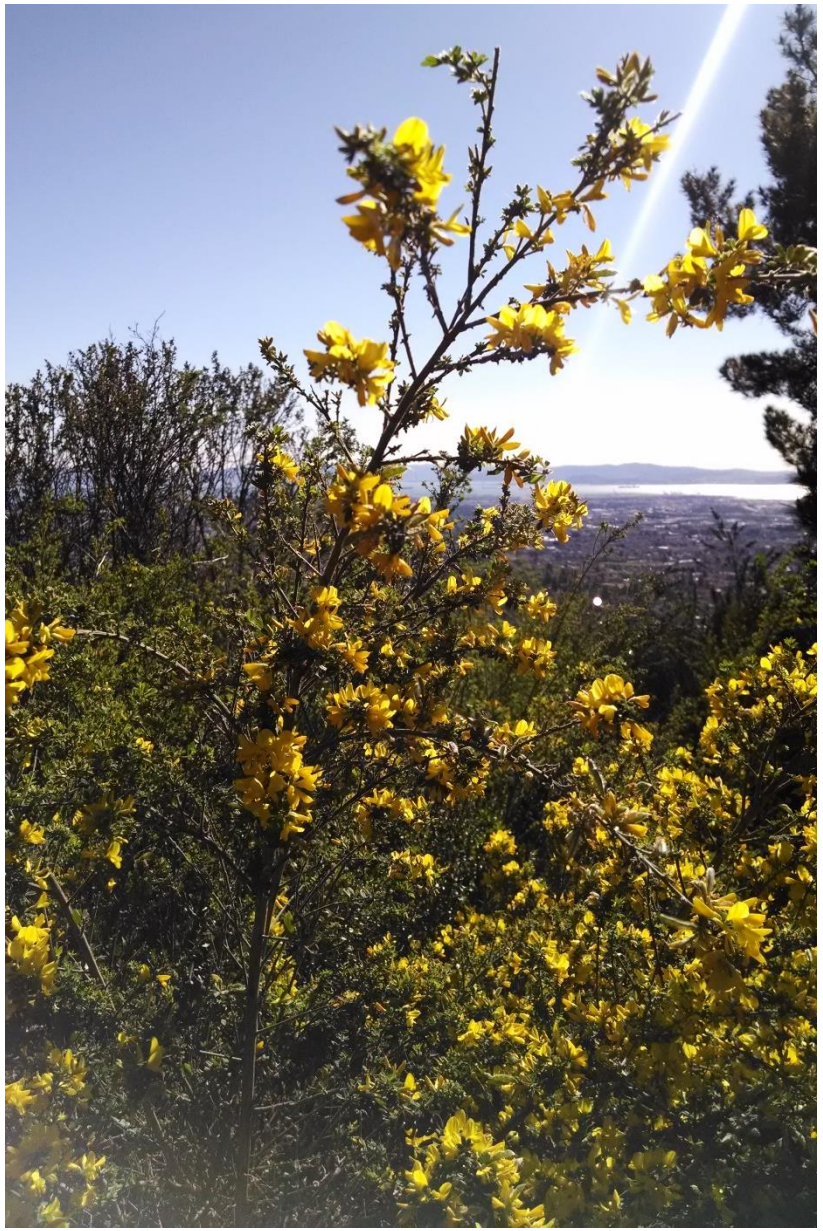
Where do Bay Area invaders get their rhizobia?

	% overlap with natives	% European strains
L. angustissimus (Slender Bird's Foot Trefoil)	100	
G. monspessulana (French broom)	47	
S. junceum (Spanish broom)	38	
U. europaeus (gorse)	20	

Where do Bay Area invaders get their rhizobia?

	% overlap with natives	% European strains
L. angustissimus (Slender Bird's Foot Trefoil)	100	0
G. monspessulana (French broom)	47	71
S. junceum (Spanish broom)	38	75
U. europaeus (gorse)	20	75

Invasive legumes coinvade with their rhizobial symbionts.



Questions – Bay Area

(1) Do invasive legumes form novel associations in their exotic range? No.

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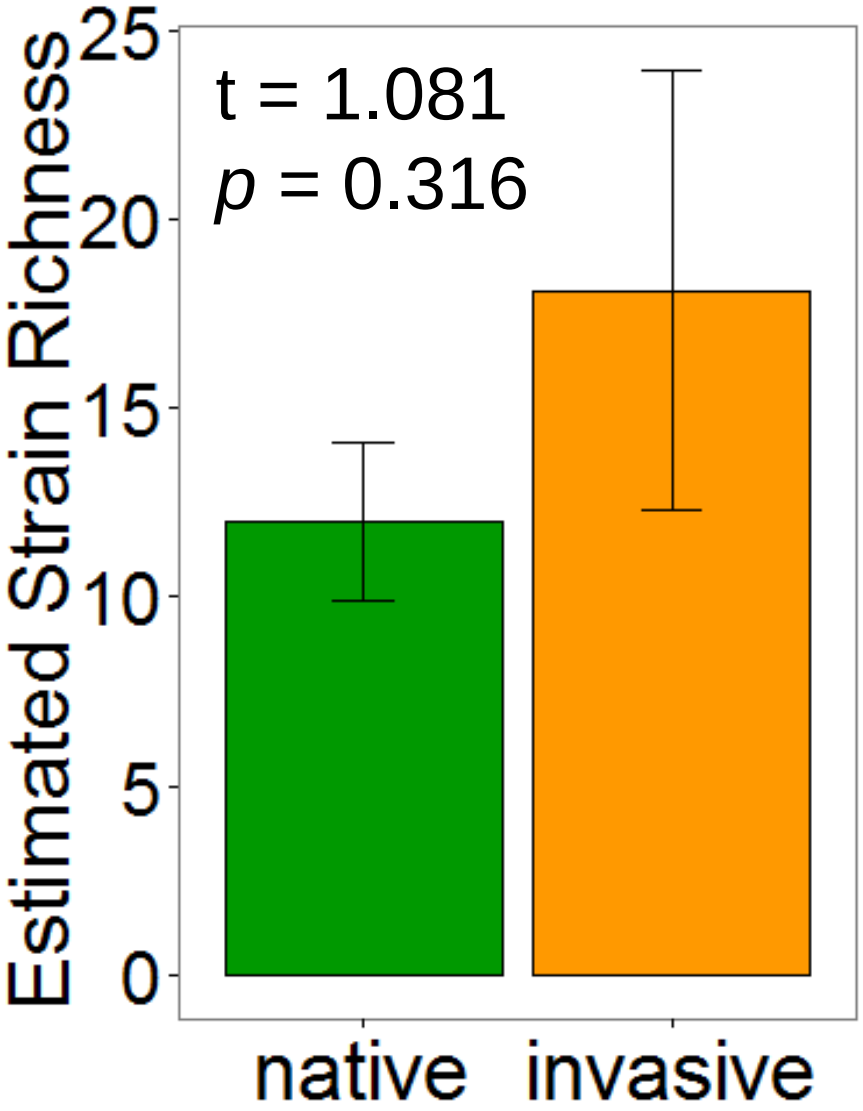
Number of Strains



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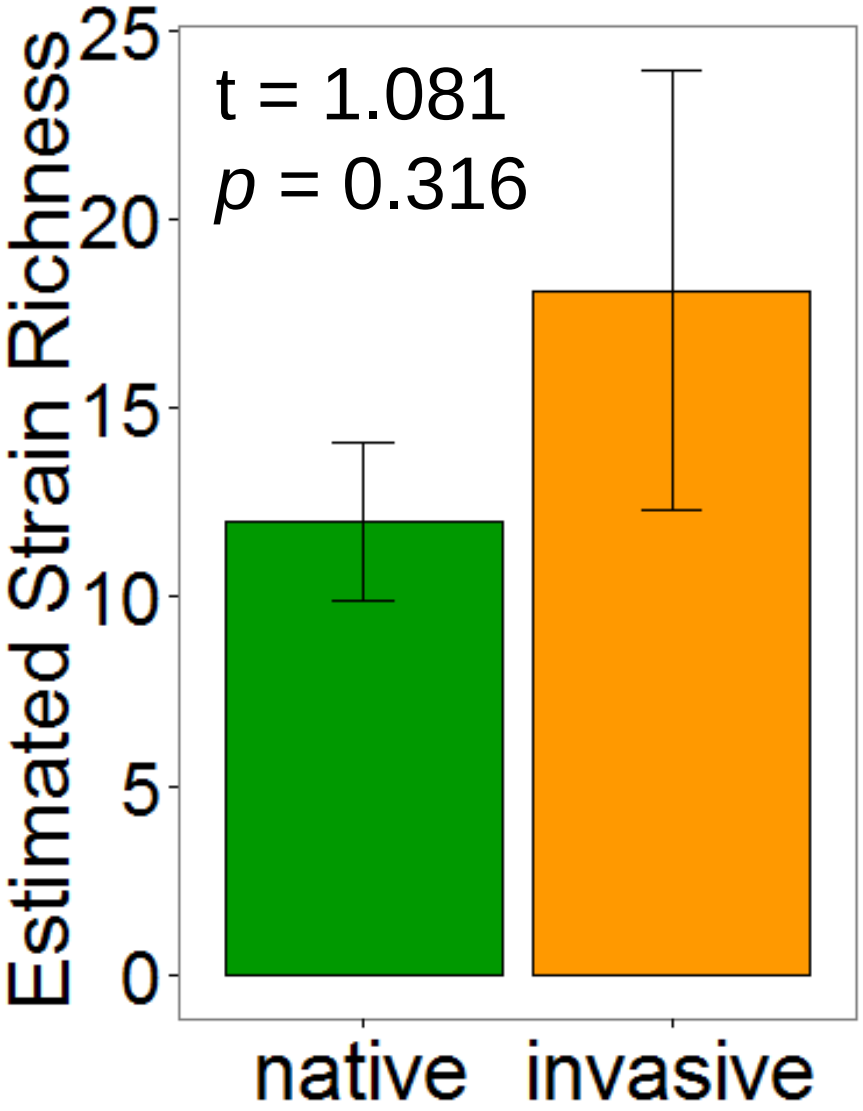
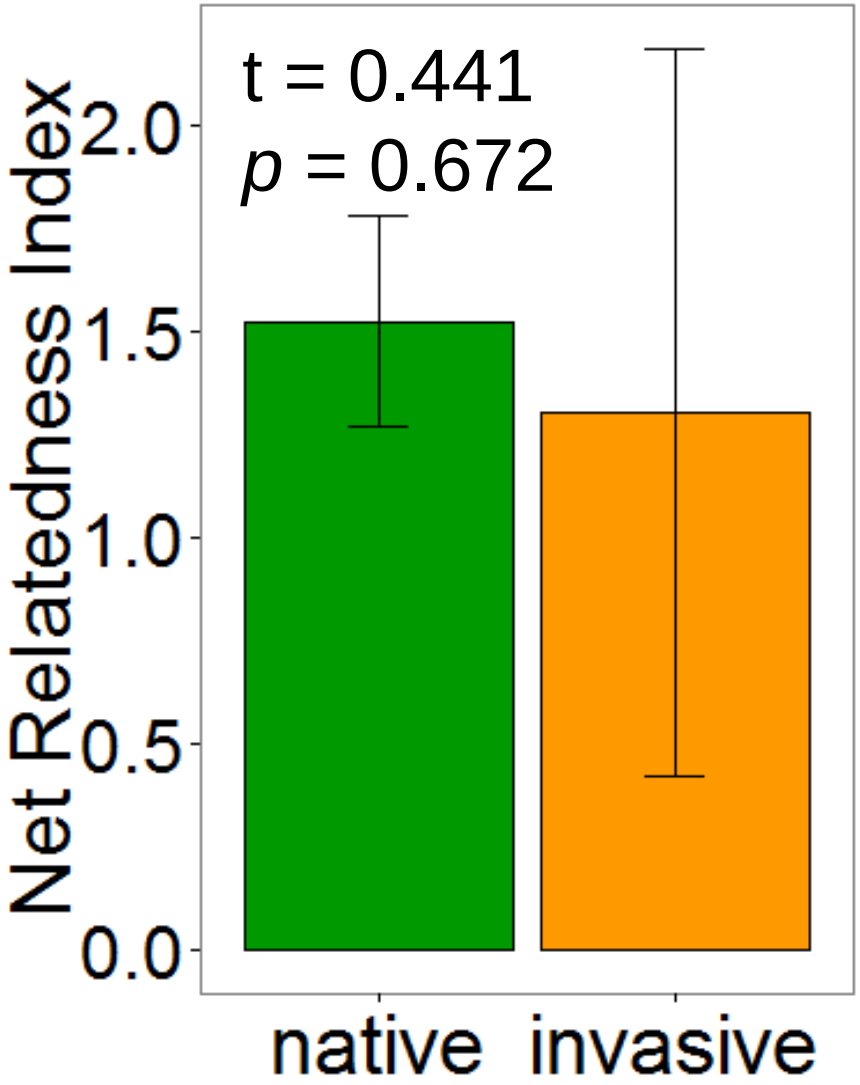


Phylogenetic Diversity of Strains



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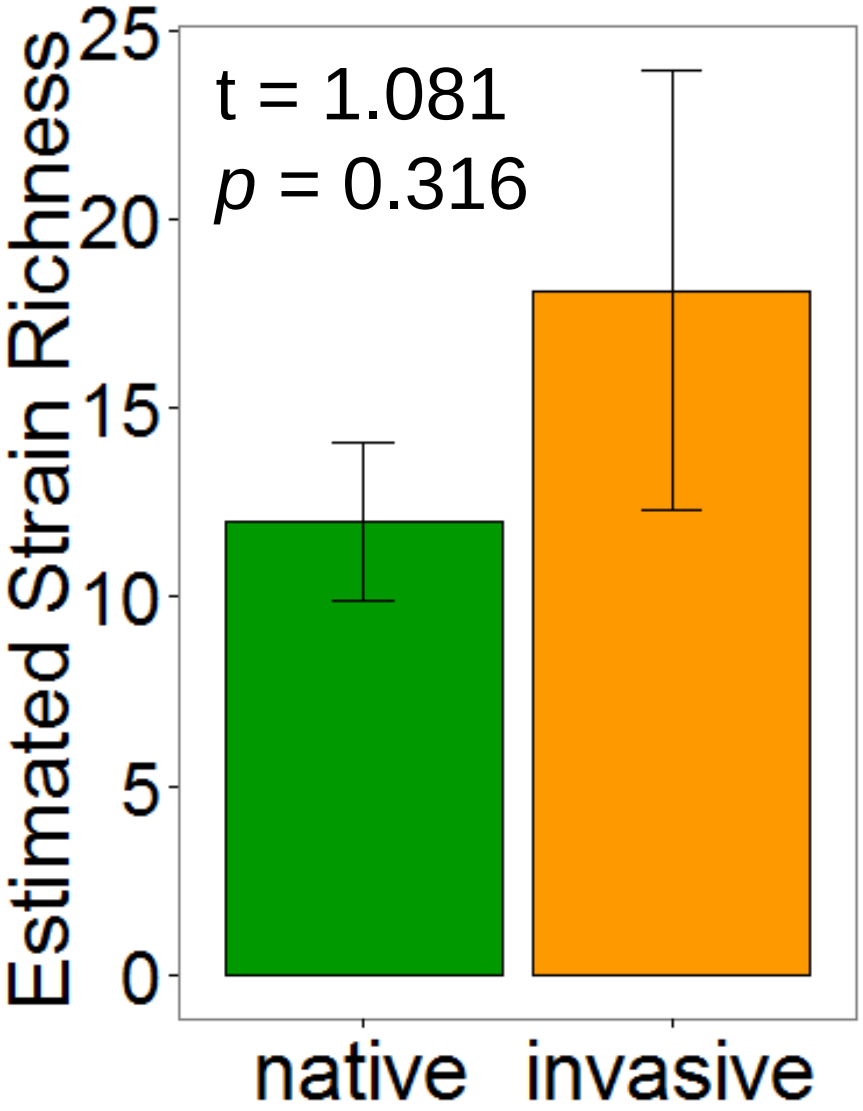

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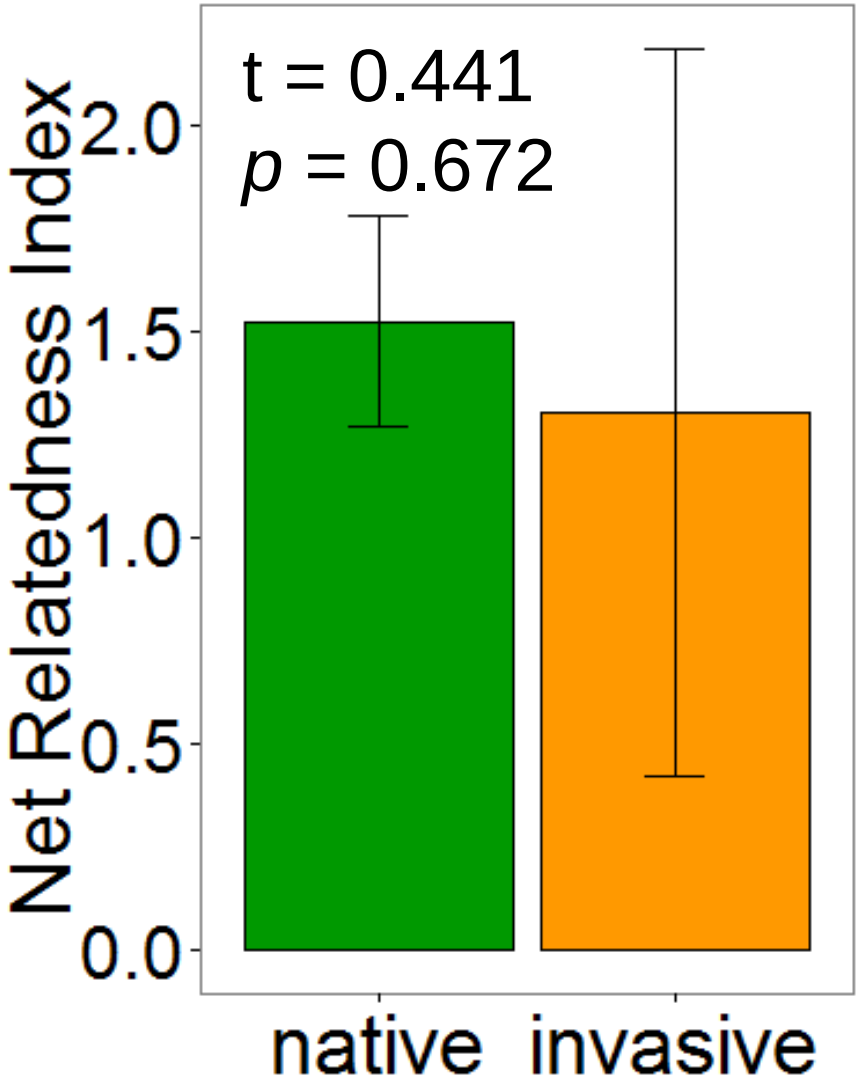

invasive legumes are not more general than native legumes

Study Systems

(1) Local Scale

(2) Global Scale

Study Systems

(1) Local Scale

(2) Global Scale

Global Meta-Analysis

- collected 53 papers
- 19 comparing overlap in rhizobial associates of native vs invasive plants
- 34 comparing the rhizobial associates of an invader in home and away regions

Do global patterns match Bay Area patterns?

	Bay Area	Global
novel associations in exotic range?	no	
co-invade with symbionts?	yes	
invaders more general than natives?		
number of strains	no	
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- Invasive legumes do not appear to take advantage of the existing rhizobial community during invasion.
- What other factors might make invasive legumes so successful?
  - Can invaders extract greater benefit from their rhizobial symbionts than natives?

Implications

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- Encourage best practices to reduce introductions of soil micro-organisms.
- Rhizobial community may be important in reinvasion of areas where invasive legumes have been removed.
- Rhizobia should be considered in restoration efforts.

Acknowledgements

Field and Lab Assistance:

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Land Access:

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- Romburg Tiburon Center
- Bodega Marine Reserve
- Sonoma Coast State Park
- Boyd Memorial Park
- Horse Hill State Preserve
- Cascade Canyon State Preserve

Simms Lab

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Questions
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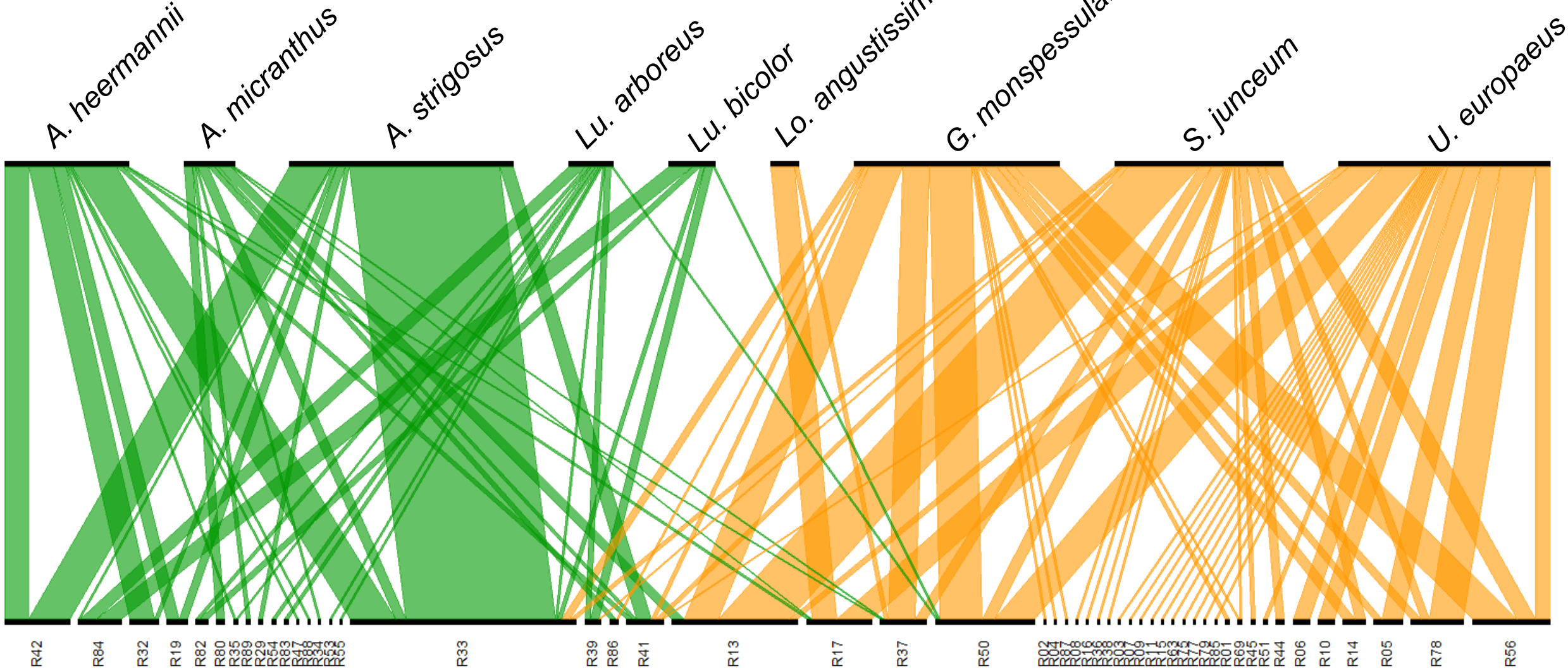
Network metrics – no difference between native and invasive legumes

	Native	**Invasive**
Mean # shared partners	3.833	2.500
Niche overlap	0.312	0.320
Connectance	0.342	0.368
Weighted Nestedness	0.112	0.382
Interaction Strength Asymmetry	-0.295	-0.333
H2 (specialization)	0.482	0.361


A. heermannii
A. micranthus
A. strigosus
Lu. arboreus
Lu. bicolor
Lo. angustissimus
G. monspessulana
S. junceum
U. europaeus
R42
R84
R32
R19
R82
R80
R35
R89
R29
R54
R83
R47
R88
R34
R53
R55
R33
R39
R86
R41
R13
R17
R37
R50
R02
R04
R87
R08
R16
R38
R03
R06
R11
R15
R63
R74
R72
R85
R01
R69
R45
R51
R44
R06
R10
R14
R05
R78
R56

- Sequenced:
  - 542 isolated strains at ITS locus

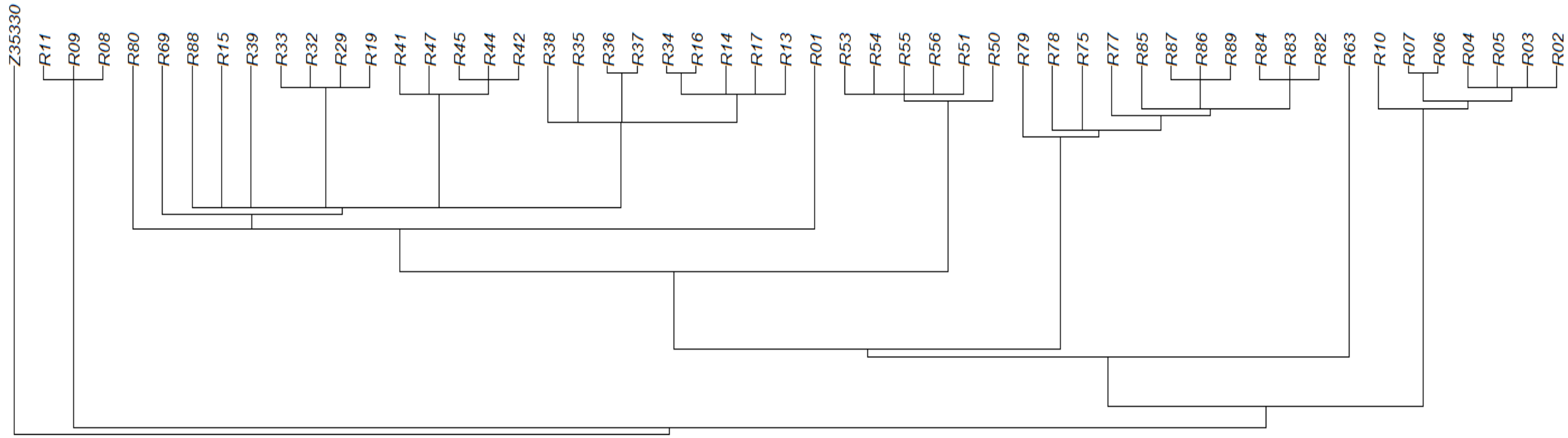
Host	Isolated Strains
Lo. angustissimus	14
G. monspessulana	100
S. junceum	83
U. europaeus	104
A. heermannii	61
A. micranthus	24
A. strigosus	111
Lu. arboreus	22
Lu. bicolor	23

Invasive = 301

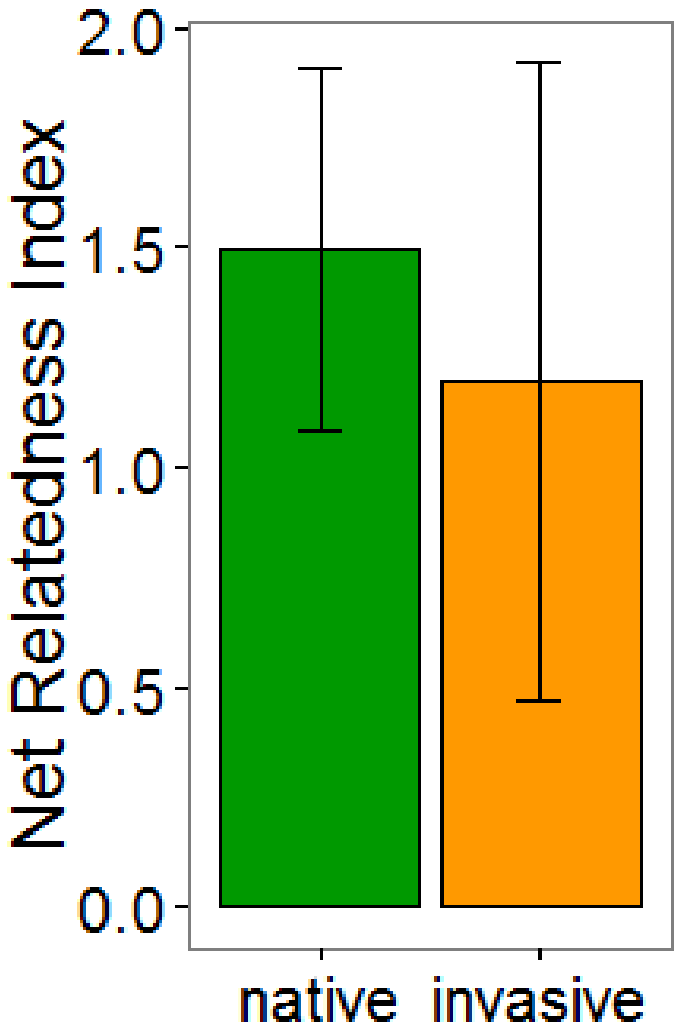
Native = 241

  - identified 53 unique rhizobial strains

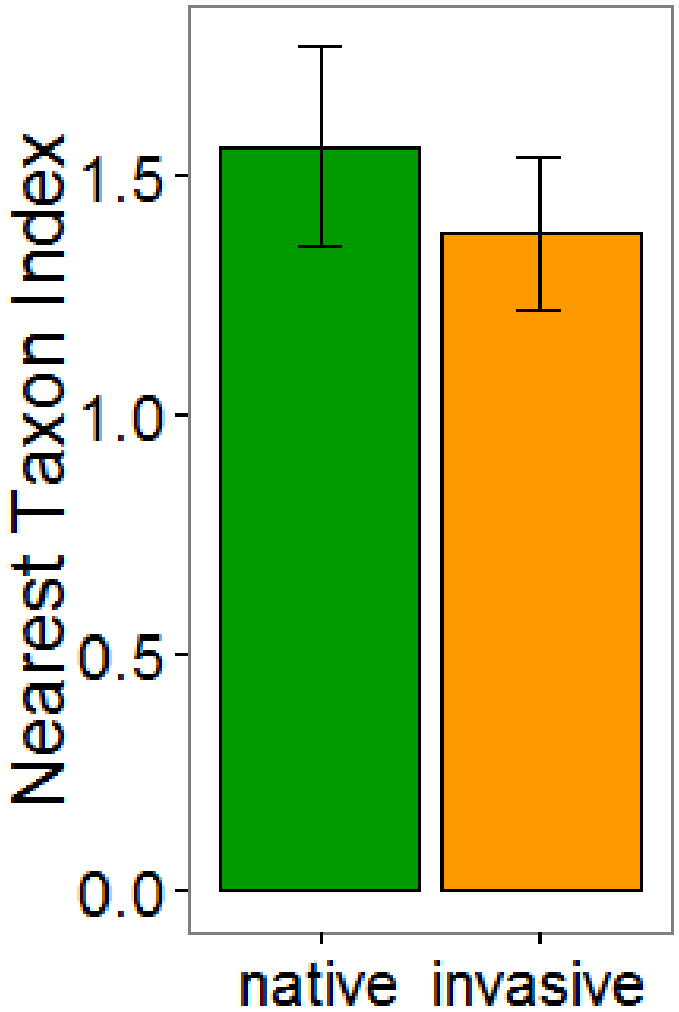
- Tree construction:
  - using Bayesian inference in MrBayes 3.2
- Q1: PERMANOVA (PRIMER) , network analysis (R bipartite)
- Q2: Chao richness (estimateS), NRI/NTI (R picante)



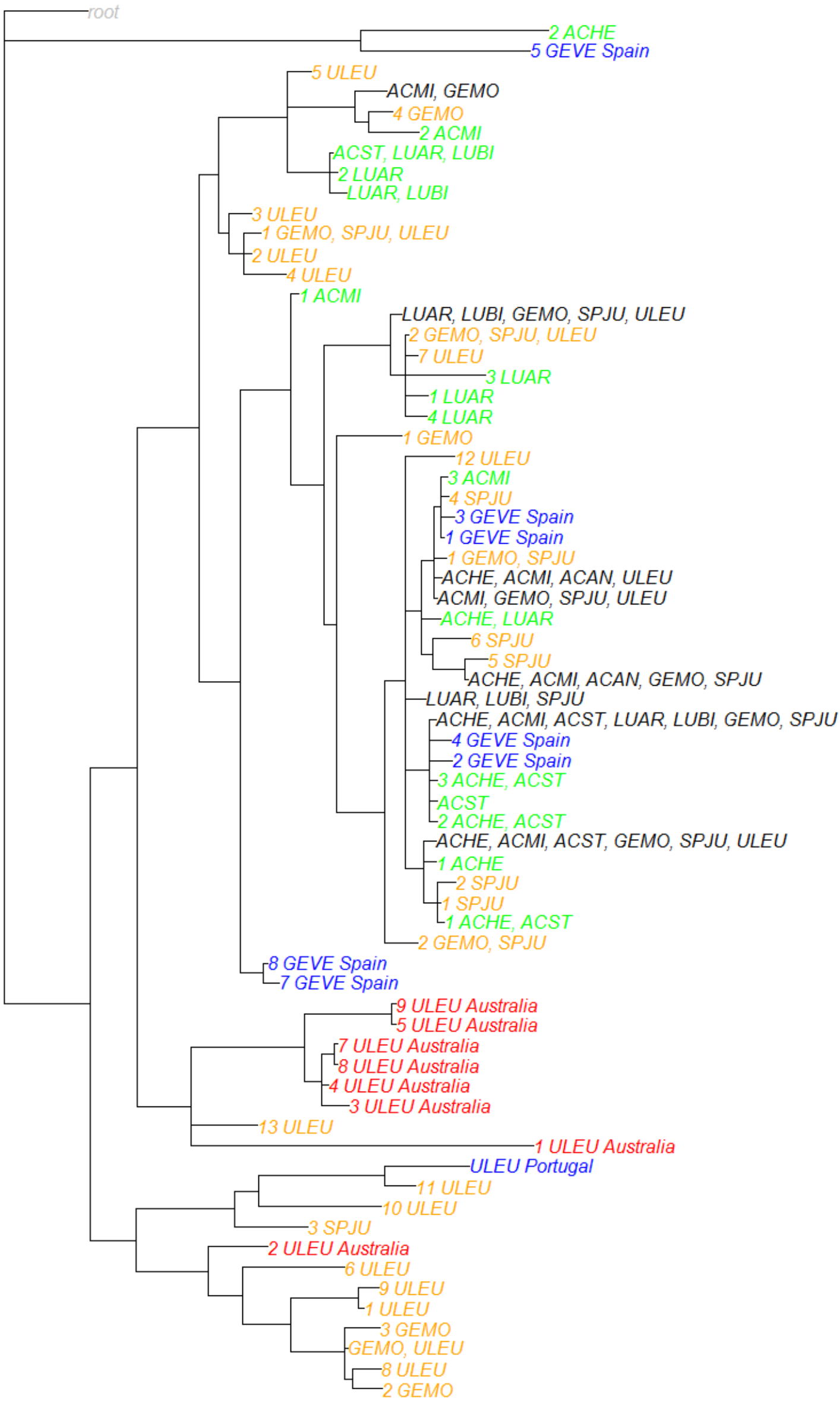
Strain Phylogenetic Diversity – no difference in the evolutionary diversity of strains associated with native and invasive legumes



t = 0.441
p = 0.672

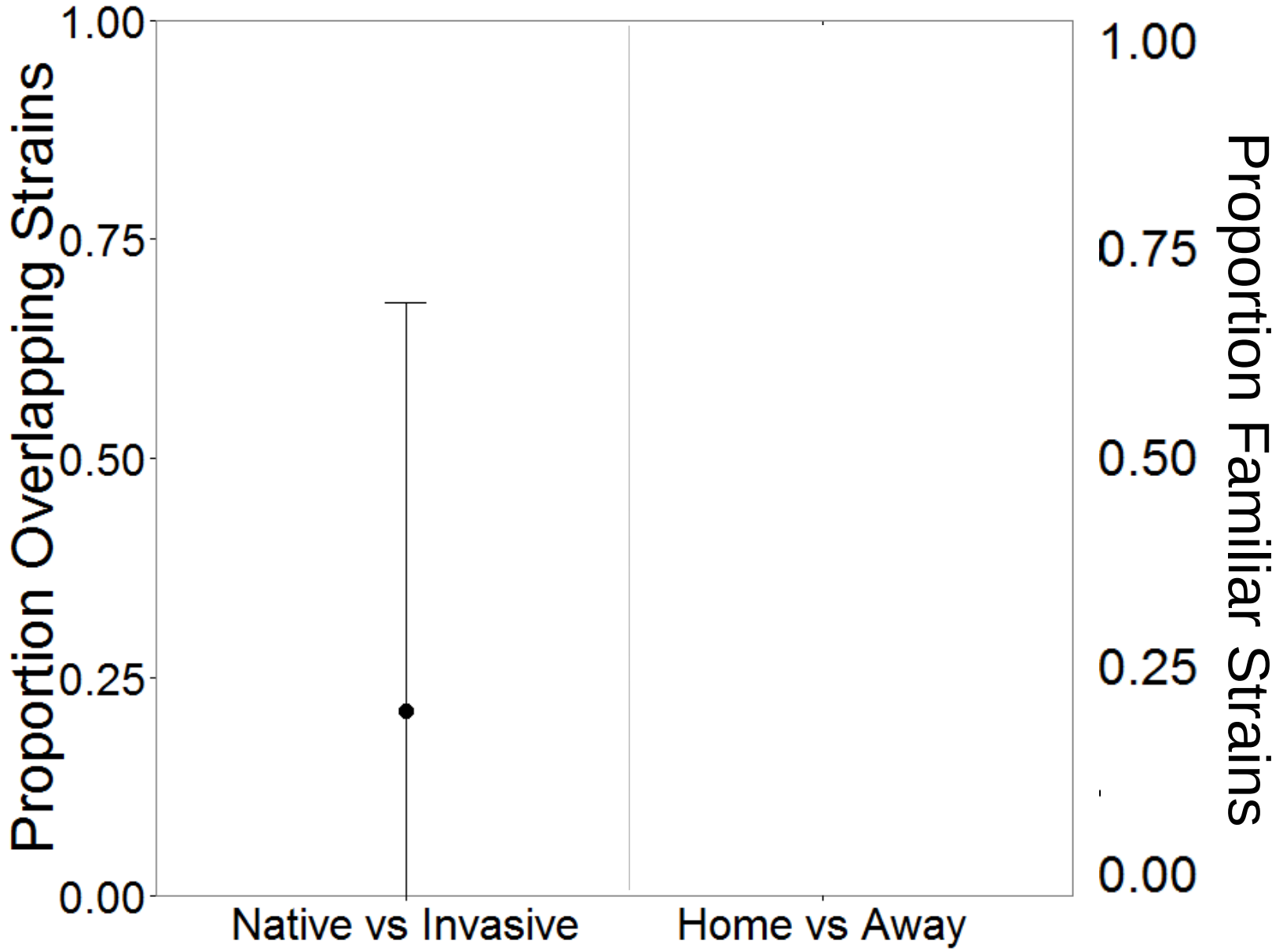


t = 1.065
p = 0.322

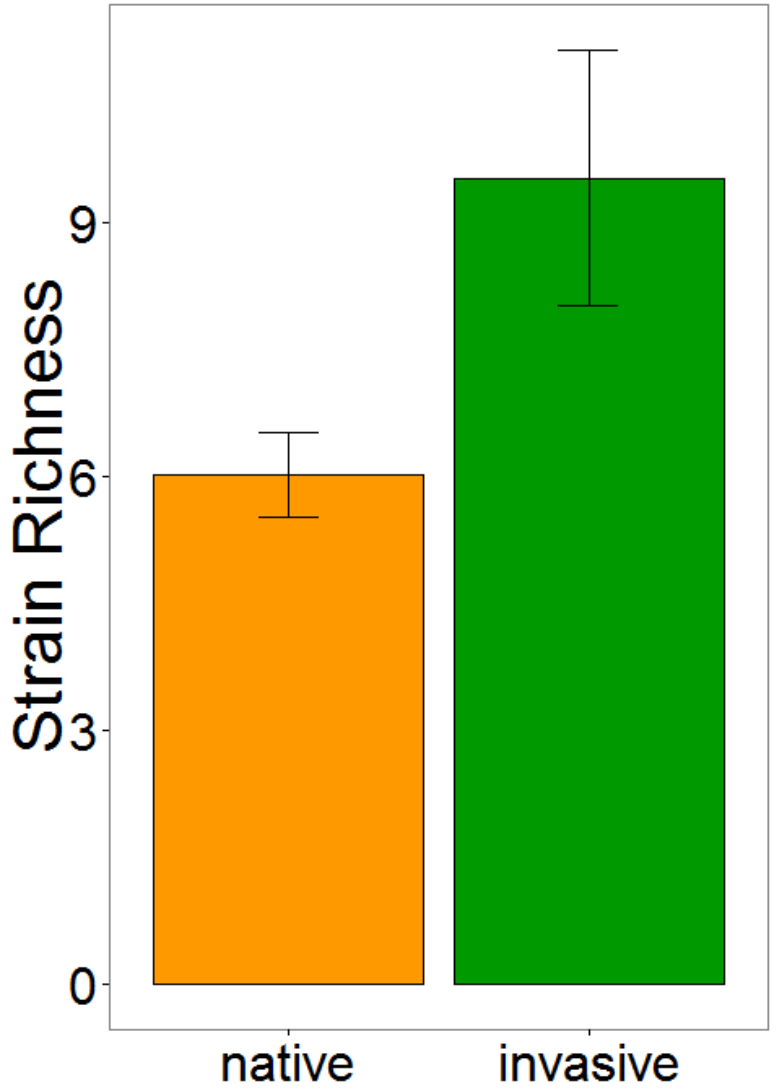

root
2 ACHE
5 GEVE Spain
5 ULEU
ACMI, GEMO
4 GEMO
2 ACMI
ACST, LUAR, LUBI
2 LUAR
LUAR, LUBI
3 ULEU
1 GEMO, SPJU, ULEU
2 ULEU
4 ULEU
1 ACMI
LUAR, LUBI, GEMO, SPJU, ULEU
2 GEMO, SPJU, ULEU
7 ULEU
3 LUAR
1 LUAR
4 LUAR
1 GEMO
12 ULEU
3 ACMI
4 SPJU
3 GEVE Spain
1 GEVE Spain
1 GEMO, SPJU
ACHE, ACMI, ACAN, ULEU
ACMI, GEMO, SPJU, ULEU
ACHE, LUAR
6 SPJU
5 SPJU
ACHE, ACMI, ACAN, GEMO, SPJU
LUAR, LUBI, SPJU
ACHE, ACMI, ACST, LUAR, LUBI, GEMO, SPJU
4 GEVE Spain
2 GEVE Spain
3 ACHE, ACST
ACST
2 ACHE, ACST
ACHE, ACMI, ACST, GEMO, SPJU, ULEU
1 ACHE
2 SPJU
1 SPJU
1 ACHE, ACST
2 GEMO, SPJU
8 GEVE Spain
7 GEVE Spain
9 ULEU Australia
5 ULEU Australia
7 ULEU Australia
8 ULEU Australia
4 ULEU Australia
3 ULEU Australia
13 ULEU
1 ULEU Australia
ULEU Portugal
11 ULEU
10 ULEU
3 SPJU
2 ULEU Australia
6 ULEU
9 ULEU
1 ULEU
3 GEMO
GEMO, ULEU
8 ULEU
2 GEMO

Where do invasive legumes get their rhizobia?

invasive legumes do not associate with novel strains in their exotic range



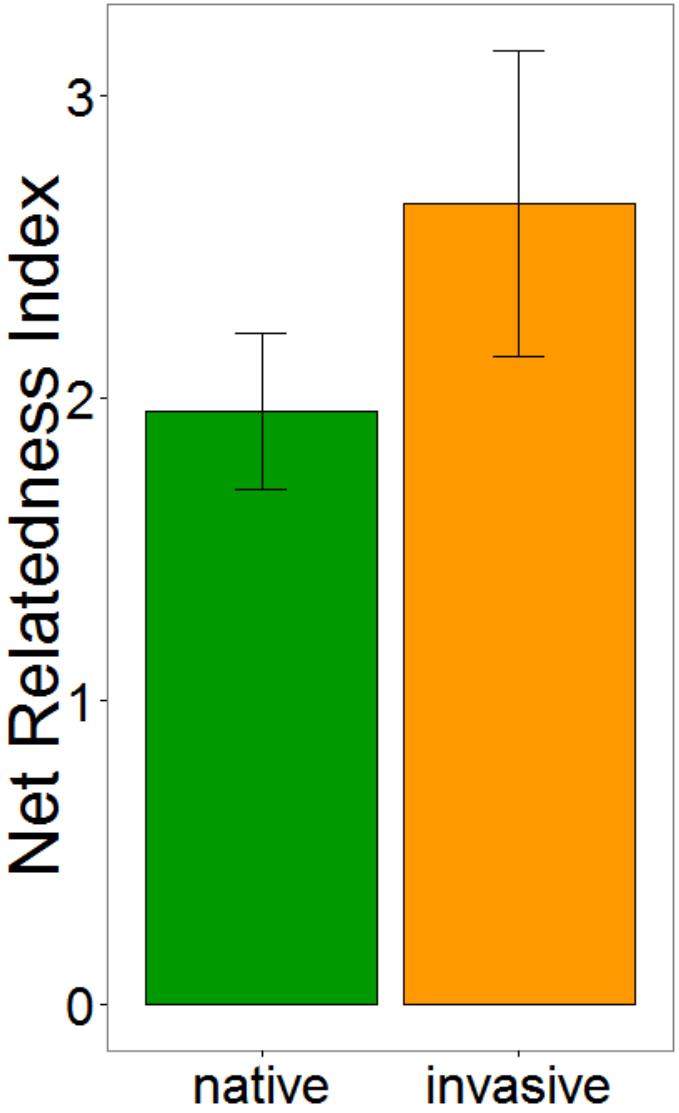
Strain Richness – invasive legumes do not associate with more strains than native legumes



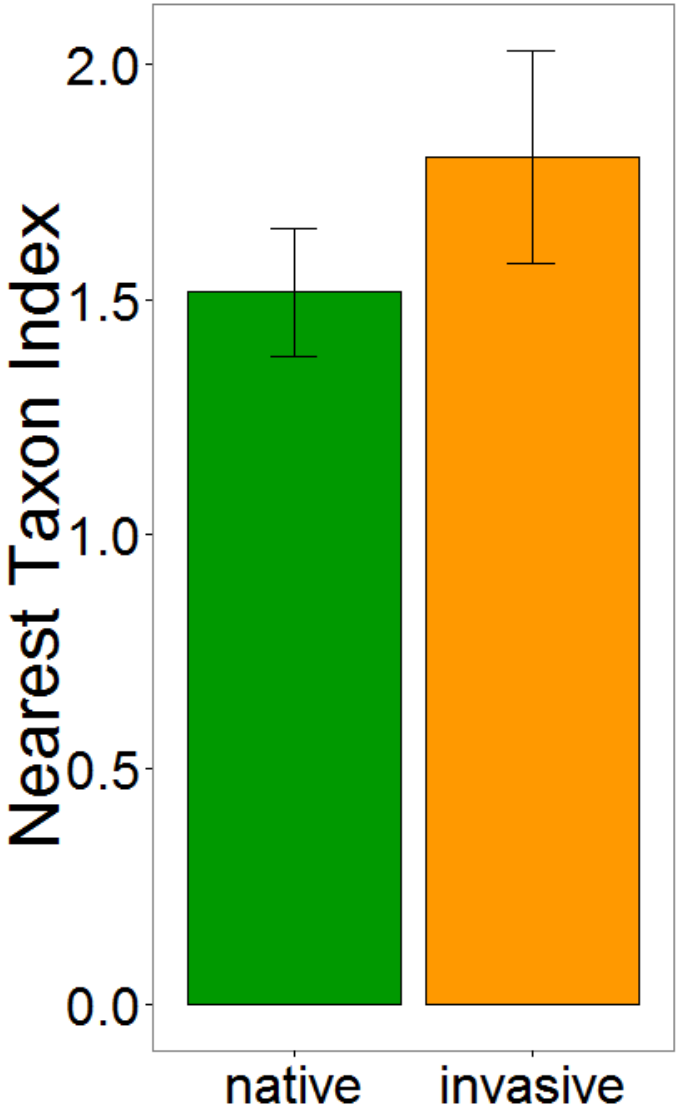
$F_{1,214} = 2.120$

$p = 0.147$

NRI & NTI – no difference in the phylogenetic diversity of strains associated with native and invasive legumes



$F_{1,18} = 0.008$
$p = 0.931$



$F_{1,18} = 0.246$
$p = 0.626$