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GYPWORLD
A GLOBAL INICIATIVE TO UNDERSTAND GYPSUM ECOSYSTEM ECOLOGY

Evaluating the presence of fungi associated with plant roots of gypsum environments

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- Hard surface crusts
- Low precipitation and high evapotranspiration
- Many sulphates and calcium cations in soil solution
- Nutrient poor and moderate salinity

Escudero et al. 2014 ; FAO, 1990; Mota et al. 2011; Pérez-García et al. 2017

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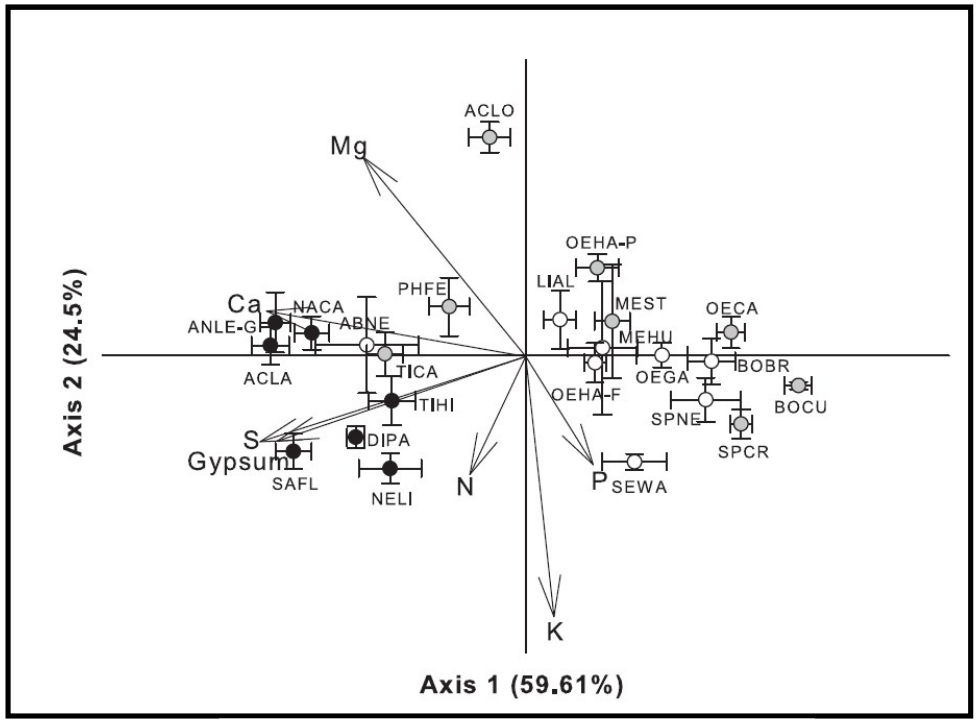
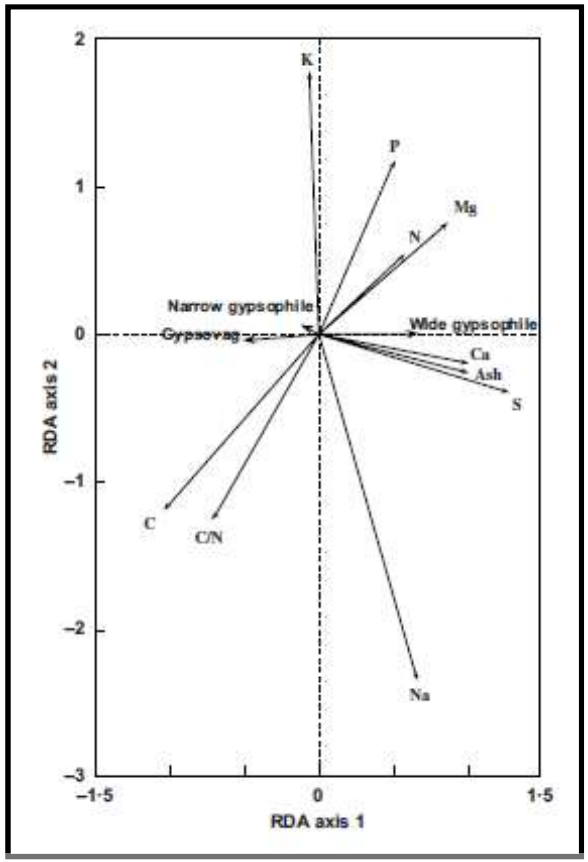


Muller et al. 2017 Am J Bot.



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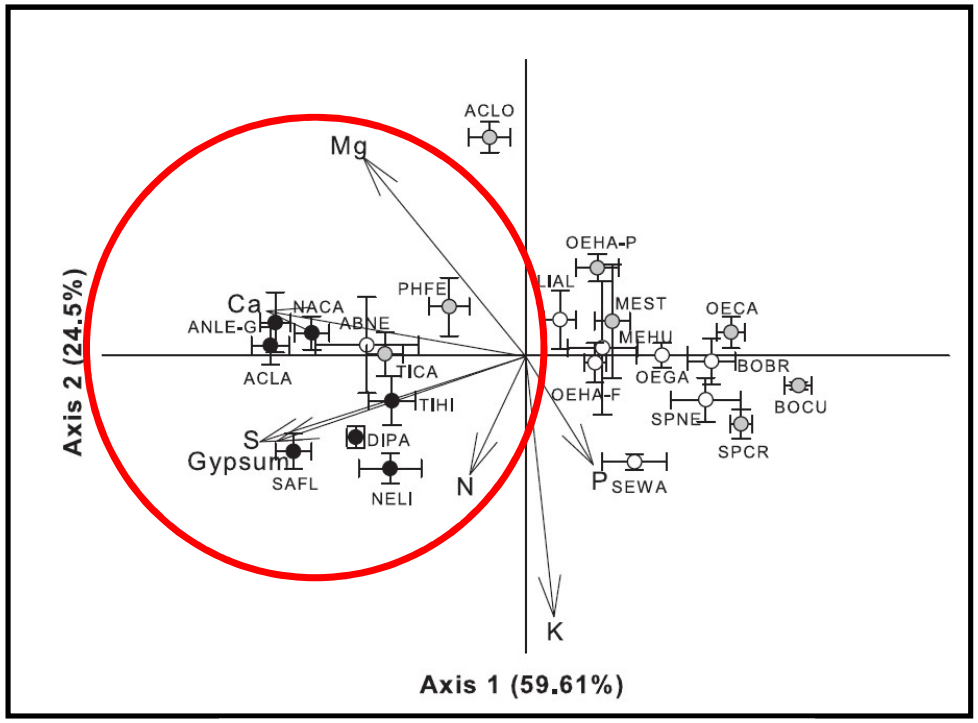

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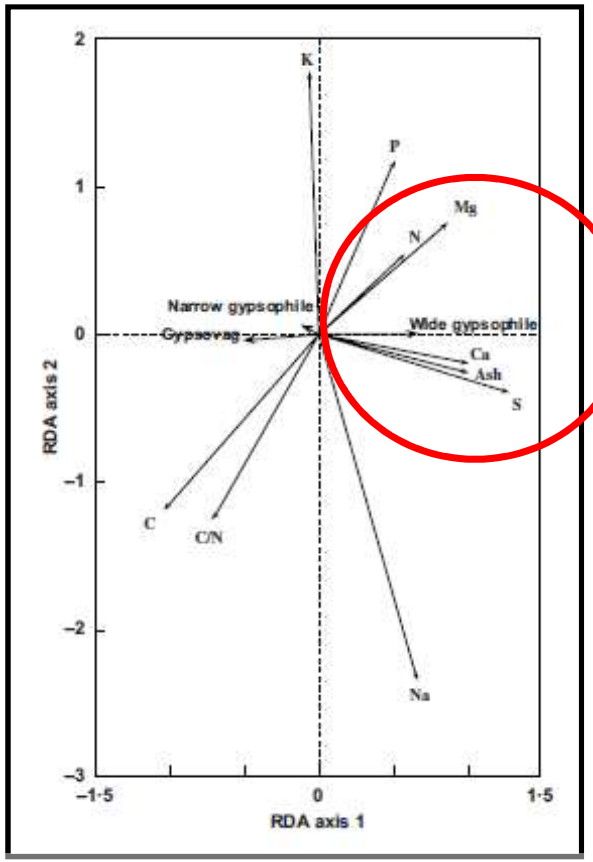

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Gypsophiles accumulate Ca, Mg and S (Merlo et al. 2019) and also N.

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  - Non-mycorrhiza fungi, as endophytes fungi
- Mycorrhizal symbioses (AMF and EMF) can enhance plant growth through a number of processes which include increased nutrient uptake (Richardson et al. 2009).

Previous knowledge on gypsum plants

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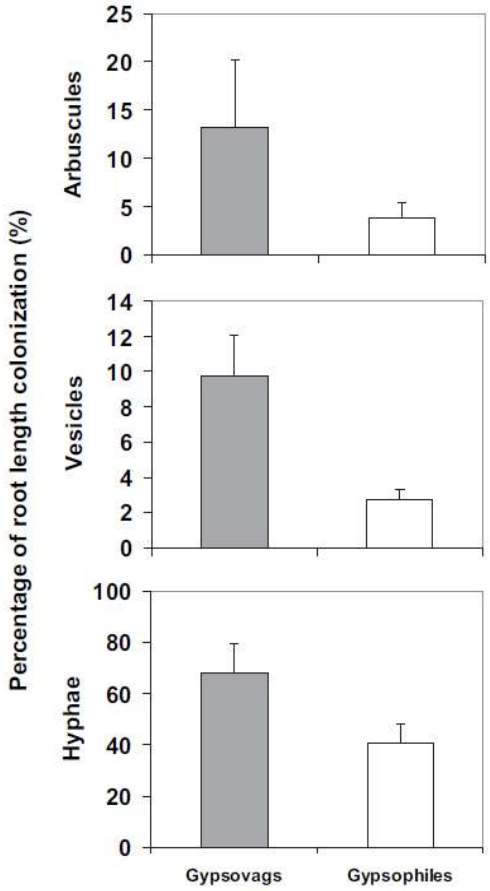

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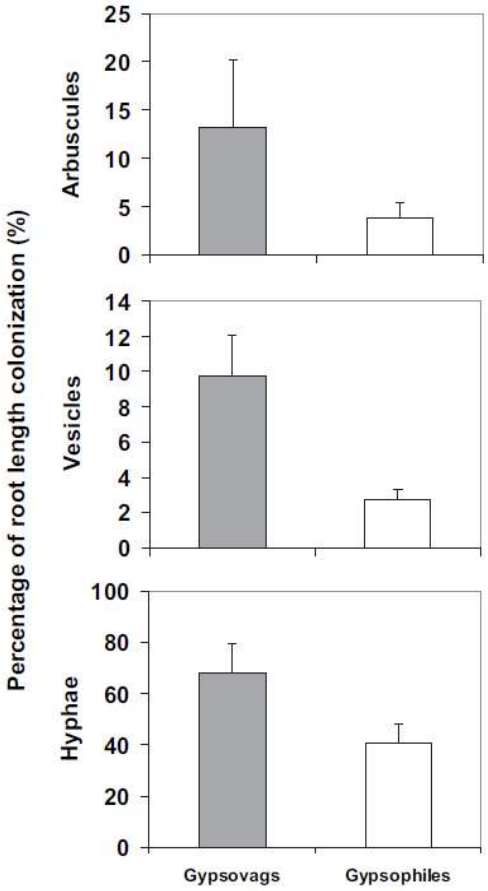

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Modularity

Gypsophiles

Gypsum area		0.185 (0.092–0.137)
Module E	D2, G11, G9, G23, G1, G10, G21, G26, G5, Ar1, G6	Gypsovag
Module F	Fu2, Cl3, Rh1, P1, G22, P5, G17, G14, Cl5	
Module G	Cl2, Cl6, G12, G15, G20, G8, Fu1, G18, G13	Gypsovag
Module H	G24, Re1, Cl1, S1, P4, G19, G4, G2, De1, D1, G3, G25	

[a] Modularity values and confidence intervals are presented for each subset of data considering (i) all interactions and (ii) only plants growing in the gypsum area. The assignment of AMF OTUs to each module is presented for each analysis. Four modules (A to D and E to H) were detected in both data sets.

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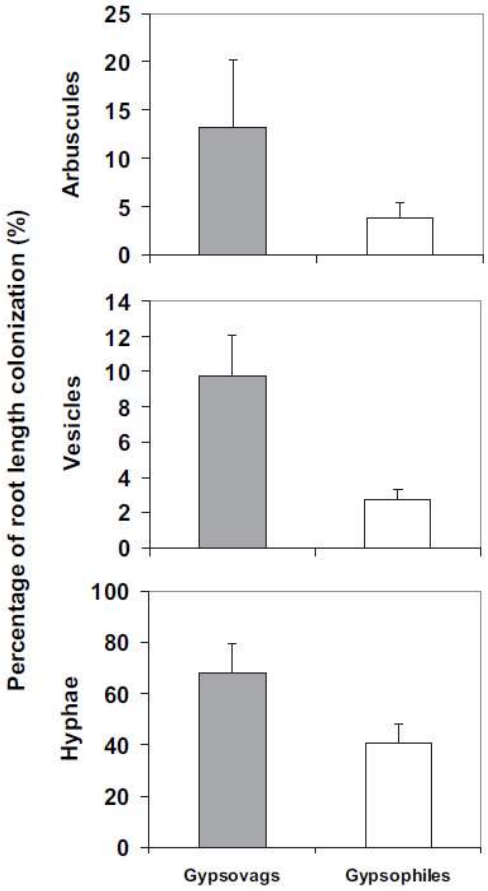

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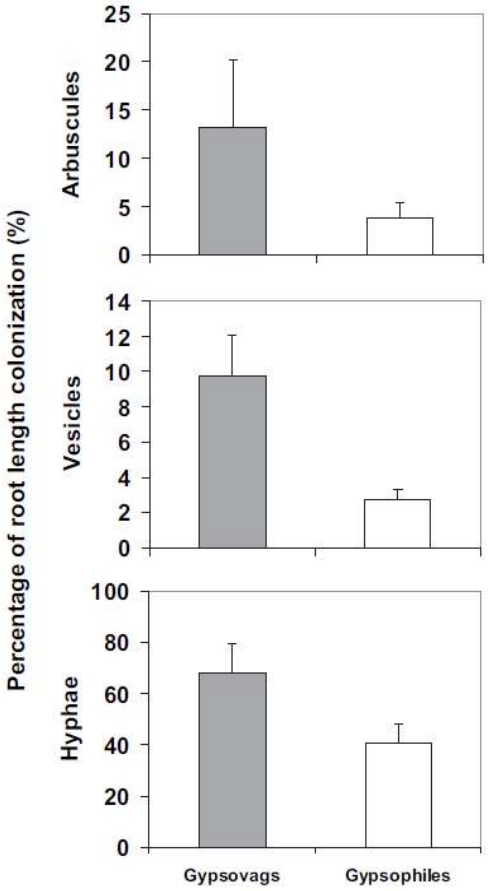

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Dark septate fungi were present in roots from Mexico (Porras-Alfaro, 2014)

Seasonality on gypsum soils

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Stipa tenacissima	Season	Water content	DON	NO_3^--N	NH_4^+-N
		g kg^{-1}	mg N kg^{-1} soil		
Beneath *Retama sphaerocarpa*	Winter	257.4 (14.2)	18.21 (5.00)	10.90 (1.51)	5.57 (1.39)
	Spring	212.8 (6.8)	8.46 (3.69)	18.41 (3.13)	4.32 (0.24)
	Summer	48.2 (4.9)	0.00 (0.00)	44.65 (10.36)	9.65 (1.19)
	Autumn	139.3 (10.1)	0.00 (0.00)	103.61 (23.84)	4.25 (0.33)
Beneath *Stipa tenacissima*	Winter	231.3 (9.0)	4.51 (2.35)	2.09 (0.72)	2.93 (0.45)
	Spring	219.3 (11.0)	4.57 (2.76)	14.97 (10.59)	4.16 (0.68)
	Summer	50.1 (37.4)	3.51 (1.69)	10.47 (3.21)	3.96 (1.01)
	Autumn	84.2 (21.9)	0.00 (0.00)	36.11 (5.56)	3.34 (0.44)
Bare soil	Winter	245.1 (11.0)	3.86 (0.78)	0.37 (0.18)	1.56 (0.36)
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	Autumn	36.9 (1.2)	1.99 (0.20)	3.50 (0.82)	3.58 (0.87)

[a)] Below detection limit (0.01 mg N kg^{-1} soil).

Delgado-Baquerizo et al. 2011 Pedosphere

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…if nitrogen form varies during the year, do root associated fungi change also?

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- The mycorrhizal colonization didn’t change between spring and autumn or increase in autumn in a Mediterranean shrubland (Varela-Cervero et al. 2014)

- The highest AMF activity could be expected in Mediterranean semi-arid soils (Alguacil *et al.,* 2009).

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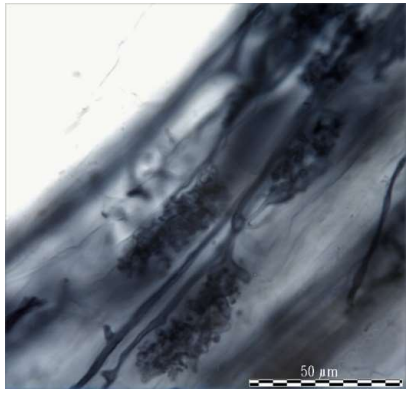
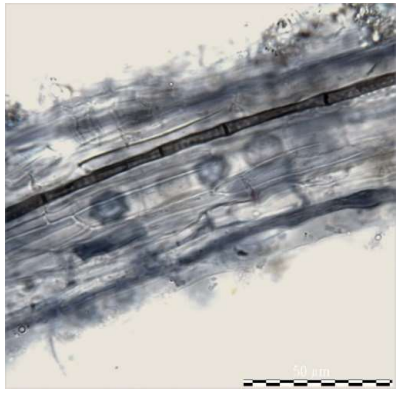
- Arbuscular mycorrhiza fungi have 4 types of structures:

mycorrhizal arbuscules (AC) vesicules (VC) fungal hyphae (FC) spores





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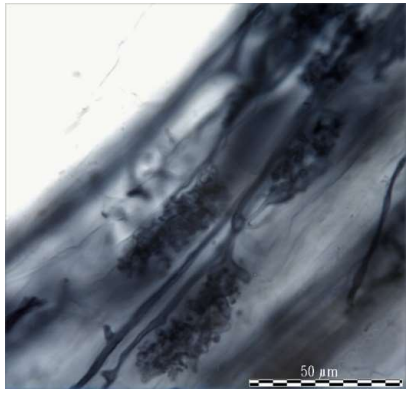

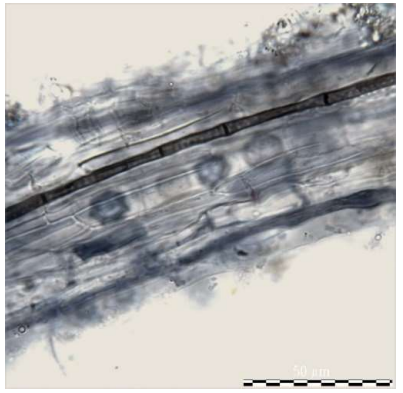

AC values have been interpreted as indicative of active AMF simbiosis, since arbuscules are sites of resource exchange between plant and fungi (McGonigle et al. 1990), however not imply efficiency (Cavagnaro et al. 2005).

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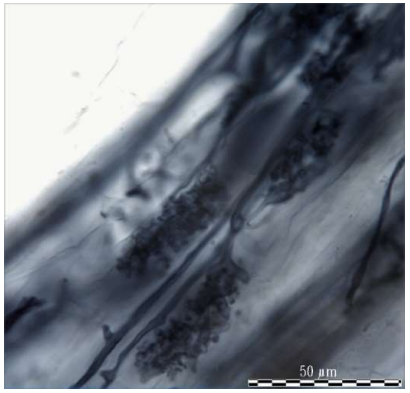

vesicules (VC)

fungal hyphae (FC)

In 3 gypsophiles: *Helianthemum squamatum*, *Lepidium subulatum* and *Gypsophila struthium*

And 2 gypsovags: *Matthiola fruticulosa* and *Helianthemum syriacum*

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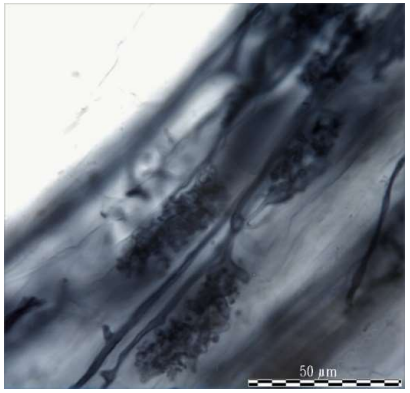

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-Quantified soil variables such contents of gypsum, soluble nitrate, soluble ammonium, total nitrogen, assimilable phosphorus and organic matter.

Methodology

Field work in the same hill (Villamayor, Zaragoza)

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Sampled
November 28 of 2017 → Autumn 2017
April 26 of 2018 → Spring 2018
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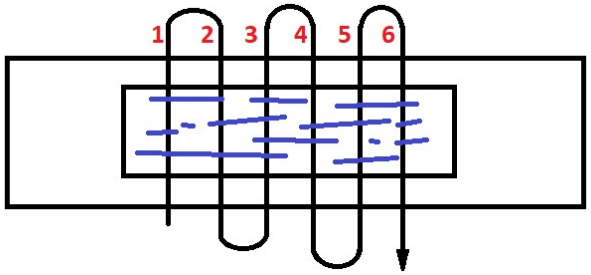
	Percentage of Gypsum (Range)		Phenology	
	Autumn	Spring	Autumn	Spring
Gypsophila hispanica	7,8 - 43,5	54,5 - 69,1	G	G
Lepidium subulatum	48,2 - 72,0	50,2 - 76,8	G	F
Matthiola fruticulosa	0,2 - 2,0	12,6 - 40,0	SD	F
Helianthemum squamatum	46,9 - 80,3	31,7 - 67,4	G	FB
Helianthemum syriacum	45,5 - 69,2	50,0 - 73,2	G	FB

Methodology

Lab work

Following McGonigle *et al.* 1990



Código: GH30617 Porta: 9 Fecha: 21-04-18 Autor: EDuplal

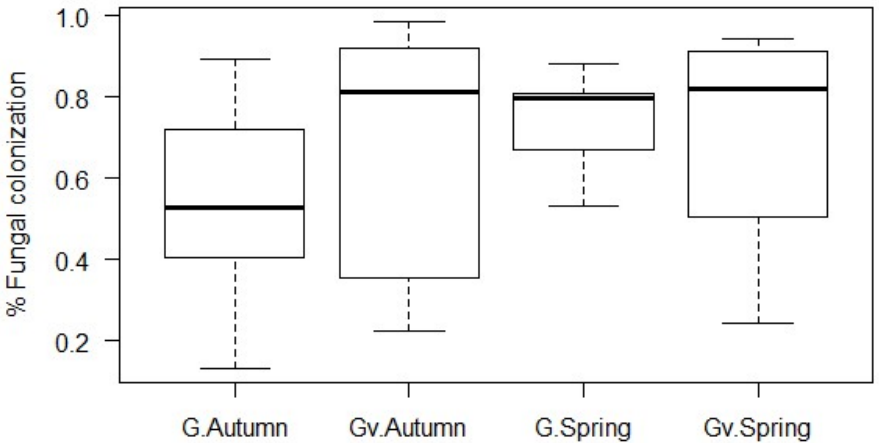
Cubre	Línea	Sin Hongo	Hifas	Arb.	Ves.	Total	Observaciones
a	1	●○○○○○ ○○○○○○	x + ×	○○○○○○ ○○○○○○	○○○○○○ ○○○○○○	3	Diusas
I 9	2	●●○○○○ ○○○○○○	• x + – • •	○○○○○○ ○○○○○○	○○○○○○ ○○○○○○	8	EPP, EPT, Diusas
F 159	3	●●●●●○ ○○○○○○	• • • •	○○○○○○ ○○○○○○	●○○○○○ ○○○○○○	10	Diusas
	4	●●●●○○ ○○○○○○	– • † + ✓	○○○○○○ ○○○○○○	○○○○○○ ○○○○○○	9	EPP, Diusas
	5	○○○○○○ ○○○○○○	+ + • × +	○○○○○○ ○○○○○○	○○○○○○ ○○○○○○	3	Diusas
	6	○○○○○○ ○○○○○○	—	○○○○○○ ○○○○○○	○○○○○○ ○○○○○○	—	
	7	○○○○○○ ○○○○○○	—	○○○○○○ ○○○○○○	○○○○○○ ○○○○○○	—	
	Total	13	19	—	1	33	

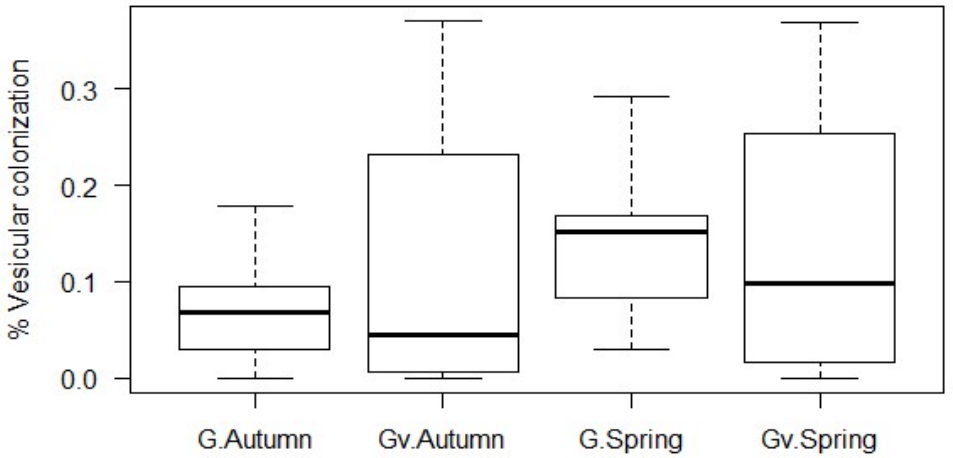
Hifas leyenda

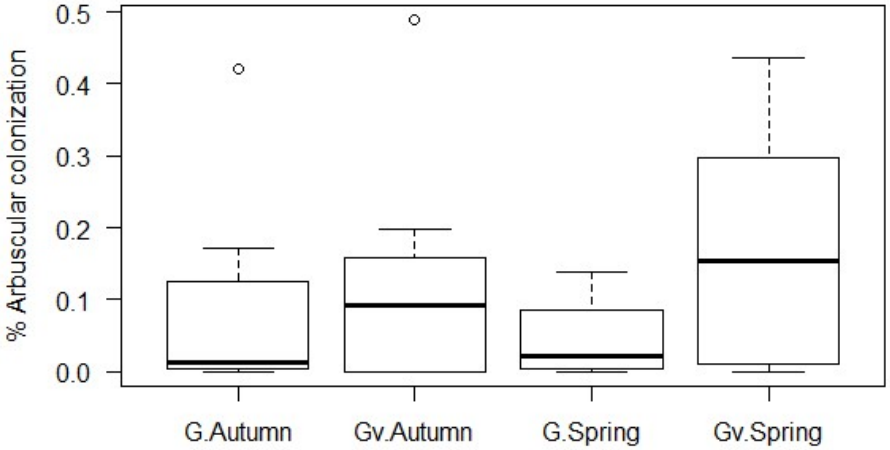
- • = hifa típica (40-2)
- – = hifa parda recta (45-2)
- † = hifa parda tortuosa (43-1)
- / = hifa fibulada (38-1)
- X = hifa pseudoconectiva(39-2)
- Δ = red de hartig (46-2)

Cubre	Línea	Sin Hongo	Hifas	Arb.	Ves.	Total	Observaciones
b	1	●●○○○○ ○○○○○○	+	○○○○○○ ○○○○○○	●○○○○○ ○○○○○○	4	EPP
I	2	●●●●●○ ○○○○○○	✓ • •	○○○○○○ ○○○○○○	●○○○○○ ○○○○○○	9	EPP, Anastomosis, Diusas, EPT
F 131	3	●●○○○○ ○○○○○○	• † • ∓ Δ	○○○○○○ ○○○○○○	●●○○○○ ○○○○○○	10	EPT, Diusas, EPP
	4	●○○○○○ ○○○○○○	+ † Δ ×	○○○○○○ ○○○○○○	●●○○○○ ○○○○○○	6	EPP, EPT
	5	●●○○○○ ○○○○○○	x • x + + –	○○○○○○ ○○○○○○	○○○○○○ ○○○○○○	6	Diusas
	6	○○○○○○ ○○○○○○	—	○○○○○○ ○○○○○○	○○○○○○ ○○○○○○	—	
	7	○○○○○○ ○○○○○○	—	○○○○○○ ○○○○○○	○○○○○○ ○○○○○○	—	
	Total	12	17	—	6	35	

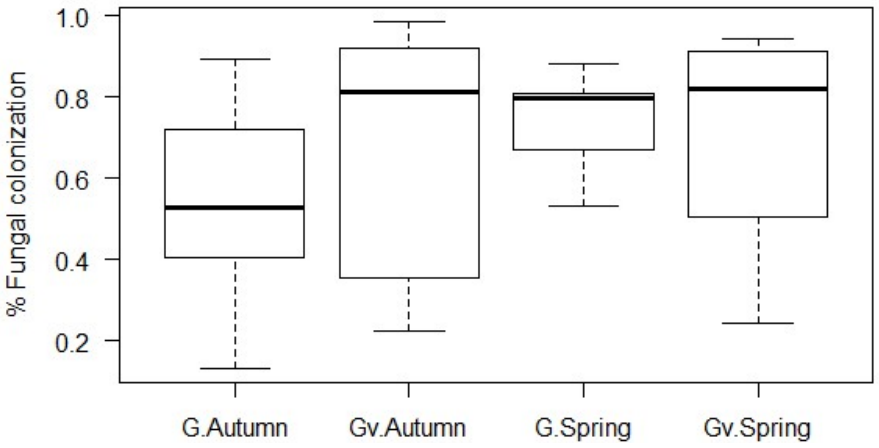
Results

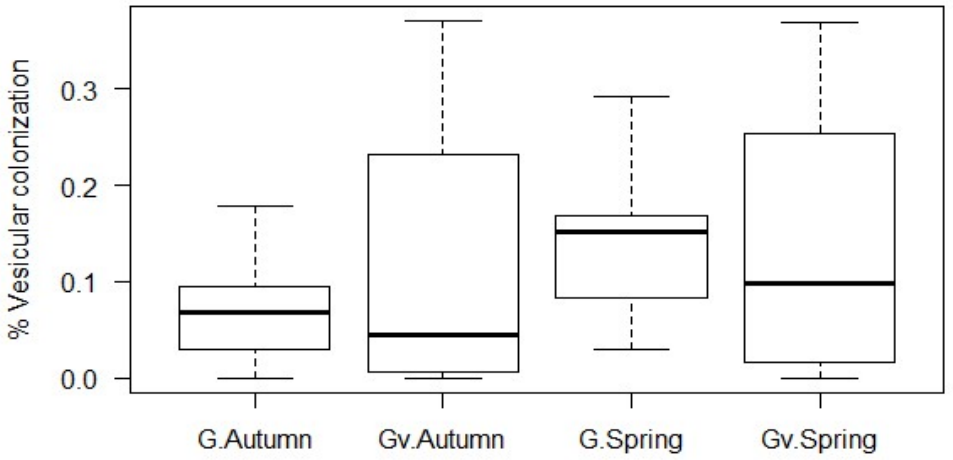

% Fungal colonization
1.0
0.8
0.6
0.4
0.2
G.Autumn
Gv.Autumn
G.Spring
Gv.Spring

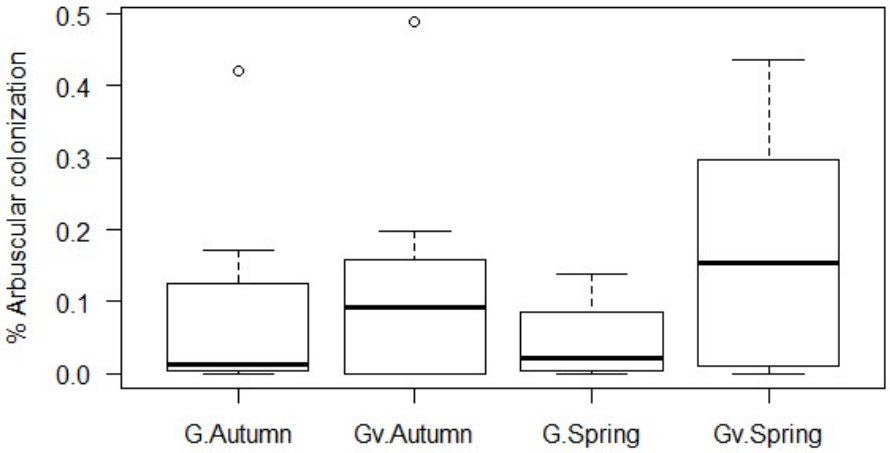

% Vesicular colonization
0.3
0.2
0.1
0.0
G.Autumn
Gv.Autumn
G.Spring
Gv.Spring


% Arbuscular colonization
0.5
0.4
0.3
0.2
0.1
0.0
G.Autumn
Gv.Autumn
G.Spring
Gv.Spring

Results







	Type (p-value)	Season (p-value)	Type*Season (p-value)
FC	0,948	0,001	0,074
VC	0,833	0,005	0,377
AC	0,449	0,518	0,069

lme(fixed=variable~type*season, random= ~1|specie

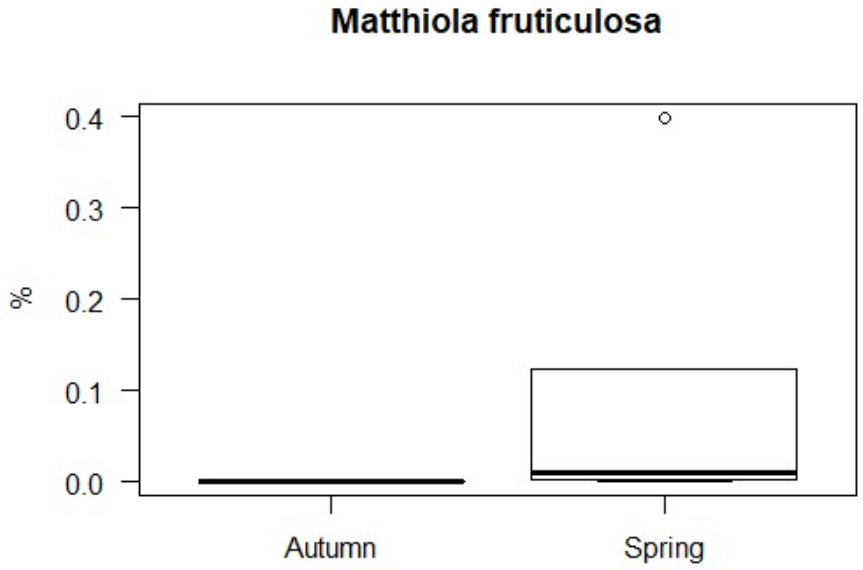
FC and VC are higher in spring than autumn

Results: Arbuscular colonization

AC values have been interpreted as indicative of active AMF simbiosis, since arbuscules are sites of resource exchange between plant and fungi (McGonigle et al. 1990), however not imply efficiency (Cavagnaro et al. 2005).

Results: Arbuscular colonization

	Mean Fall'17 (SD)	Mean Spring'18 (SD)
GyHi	0,5 (±0,6)	0,3 (±7,0)
HeSq	20,2 (±18,1)	11,1 (±17,2)
HeSy	20,0 (±15,7)	24,7 (±12,7)
LeSu	0,9 (±3,4)	3,1 (±4,6)
MaFr	0,0 (±0,0)	10,7 (±4,1)



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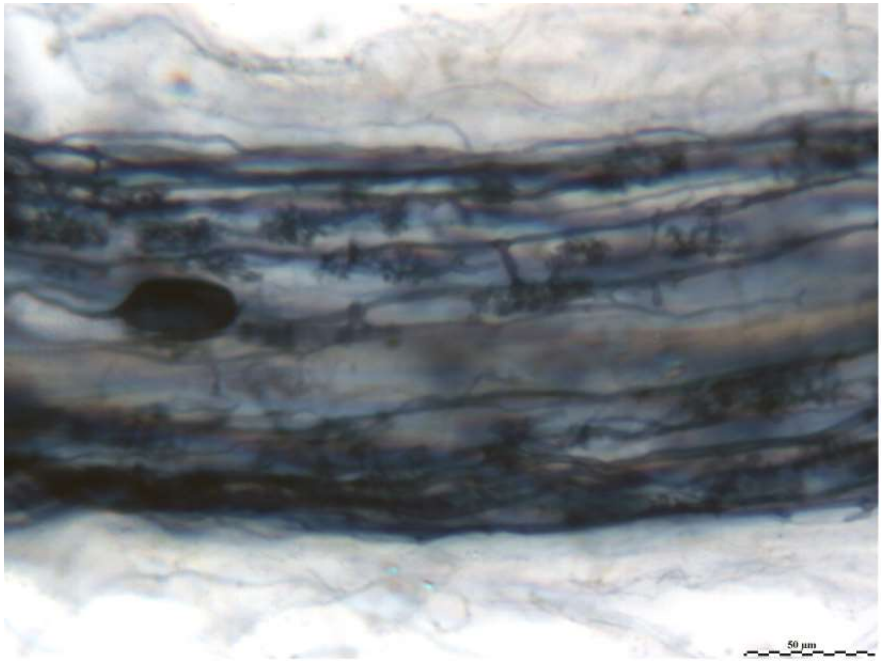

Arbuscules of LeSu roots in fall. By: Estephania

Matthiola fruticulosa (gypsovag and Brassicaceae) do not have arbuscules in autumn

Results: Features of soil

lme(fixed=variable~season, random= ~1|specie,data=data)

	Mean Fall 2018	Mean Spring 2018	Between season (p-value)
dissolved nitrate	6,16(±5,48)	1,18(±0,49)	<0.001
dissolved ammonium(mg/Kg)	2,41(±2,02)	2,32(±1,48)	0.8504
assimilable phosphorus(mg/Kg)	3,16(±5,63)	0,7(±0,45)	0,0059
organic matter (%)	1,13(±0,45)	1,25(±0,51)	0.3607

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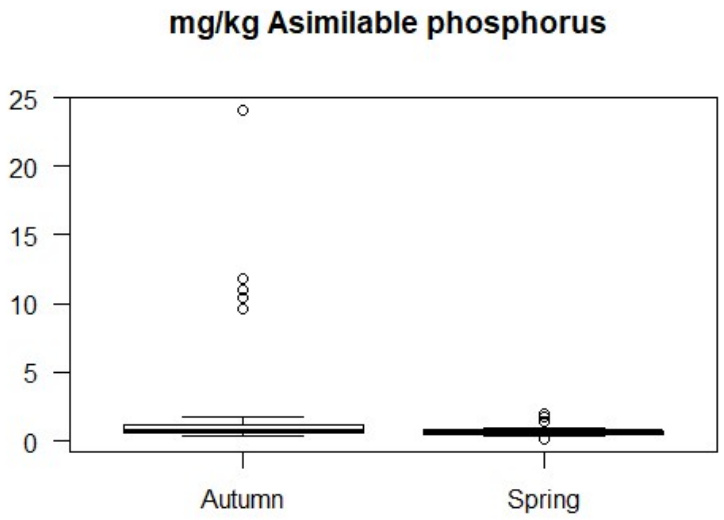
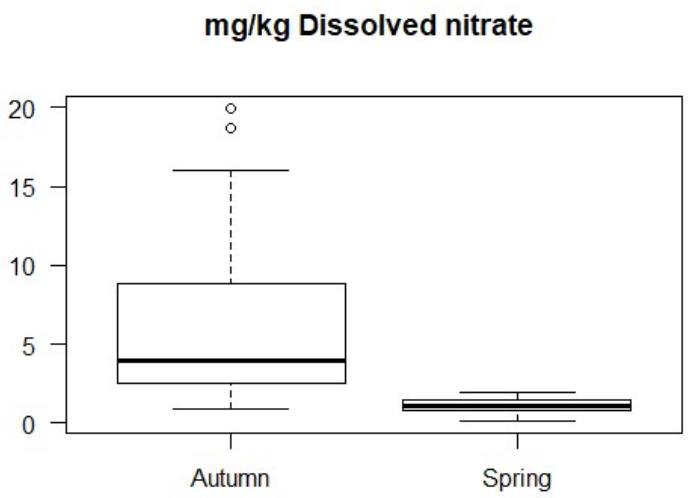
Dissolved nitrate and assimilable phosphorus are higher in autumn





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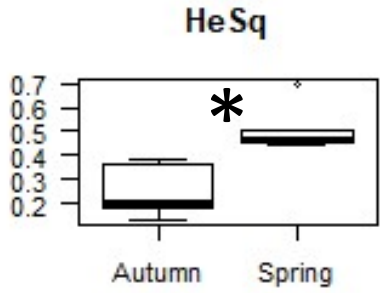
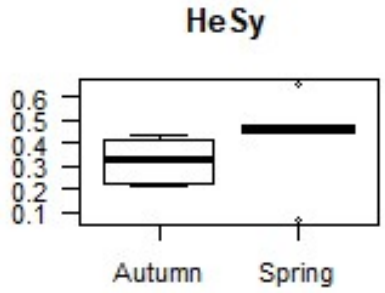
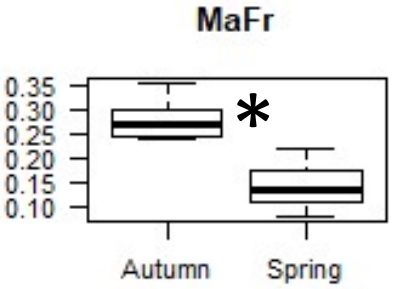
Next steps

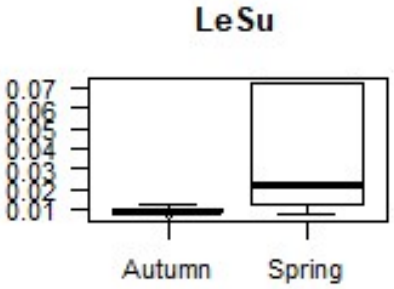
- Analyze summer 2018 and autumn 2019 samples to complete the year
- Analyze leaf and root nitrogen concentration

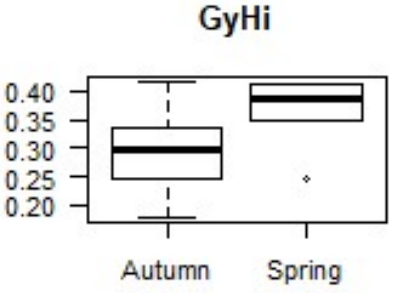
Observational notes: Dark septate fungi



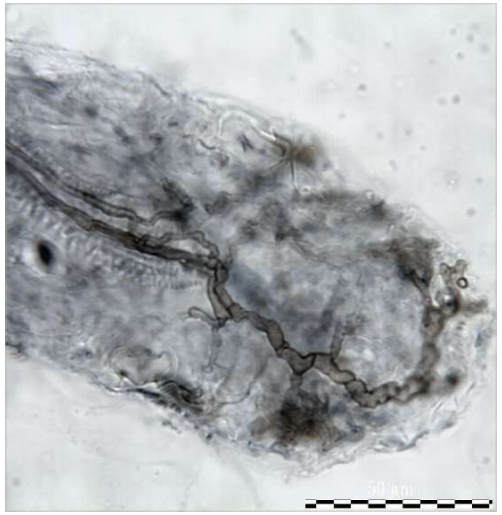


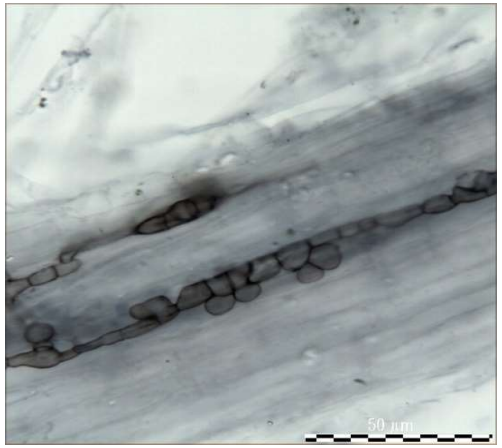






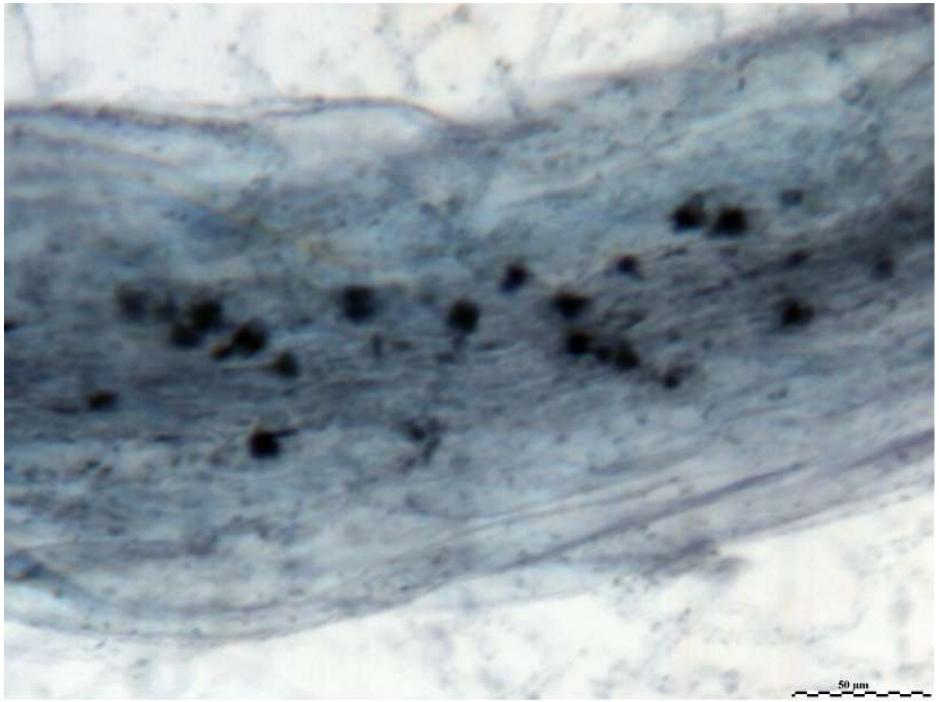
DSF have more colonization in *Helianthemum squamatum* in spring and in *Matthiola fruticulosa* in autumn





Dark septate hyphae of GyHi roots in fall. By: Estephania

Observational notes: Crystals and seasonality



Gypsophila hispanica have crystals in fall and not in spring. Other species do not have crystals.

Acknowledgments

Autumn 2017

Spring 2017

We are grateful to María Pérez-Serrano Serrano, Elena Lahoz and Sílvia Gutíerrez for help with soil analyses and to Beste Ozbey, Ebru Ozbeny, Laura de la Puente and Nate Heiden for help with field work and roots extraction.

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