Improving transplant success: algae extracts and mycorrhiza

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Ecosystem services

Green areas provide **ecosystem services = benefits arising from ecological processes which directly or indirectly increase human well-being**

CICES theme	*CICES class*	*TEEB categories*
Provisioning	• Nutrition	• Food, water
	• Materials	• Raw materials, genetic resources, medicinal resources, ornamental resources
	• Energy	
Regulating and maintenance	• Regulation of waste	• Air purification, waste treatment
	• Flow regulation	• Disturbance prevention, regulation of water flows, erosion prevention
	• Regulation of physical environment	• Climate regulation, maintaining soil fertility
	• Regulation of biotic environment	• Gene pool protection, lifecycle maintenance, pollination, biological control
Cultural	• Symbolic	• Information of cognitive development
	• Intellectual and experiential	• Aesthetic, inspiration for culture, art and design, spiritual experience, recreation and tourism

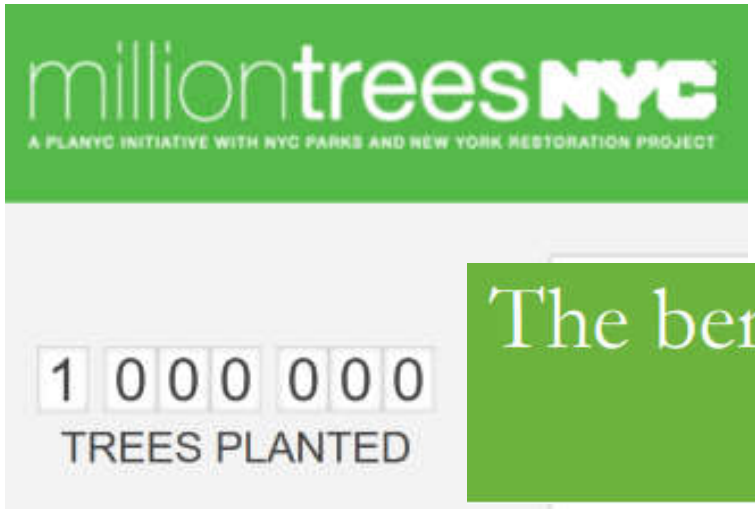
Cices, 2018

Provisioning of Food, water, energy

Regulation of the environmental processes and cycles (climate regulation, disturbance prevention)

Cultural

Tree planting programs



Forestami

The benefits of one Million Trees in LA

New EU Forest Strategy : planting three billion additional trees across Europe by 2030

ISPRA

As a flagship initiative of the **European Green Deal**, the European Commission has recently adopted the **New EU Forest Strategy for 2030.**

Tree planting programs: planting material

Tree planting programs: planting material

Tree mortality after transplant can range between 7 and 34% within 5 years from planting (Koeser et al., 2014; Roman et al., 2014).

Was planning carefully done?

- **Are there suitable locations to accommodate new plantings and resources for site amelioration?**
- Are selected species and cv. available in nurseries in adequate quantity and quality?
- Are there resources available for post-planting care?

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Nursery pre-conditioning

Includes a series of cultural techniques applied during nursery production with the aim of producing sturdy plants, with superior tools to recover from transplant shock (Franco et al., 2006):

- Container size and typology
- Nursery substrates
- Deficit irrigation
- Fertilization management
- Root pruning
- Inoculation with mycorrhizal fungi
- Application of biostimulants and plant-growth regulators

HortScience 45(12):1824–1829. 2010.

Effect of Container Design on Plant Growth and Root Deformation of Littleleaf Linden and Field Elm

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Effect of pot type and root structure on the establishment of *Tilia cordata* and *Ulmus minor* plants after transplanting

P. Frangi[1], G. Amoroso[1], R. Piatti[1], E. Robbiani[1], A. Fini[2] and F. Ferrini[2]

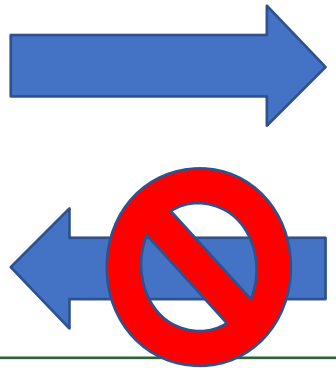
Nursery substrates

PNRR CN Biodiversity – National Biodiversity Future Centre (NBFC) – SPOKE 5: Urban biodiversity;
Task 1.4: Plant production (2023–2025)

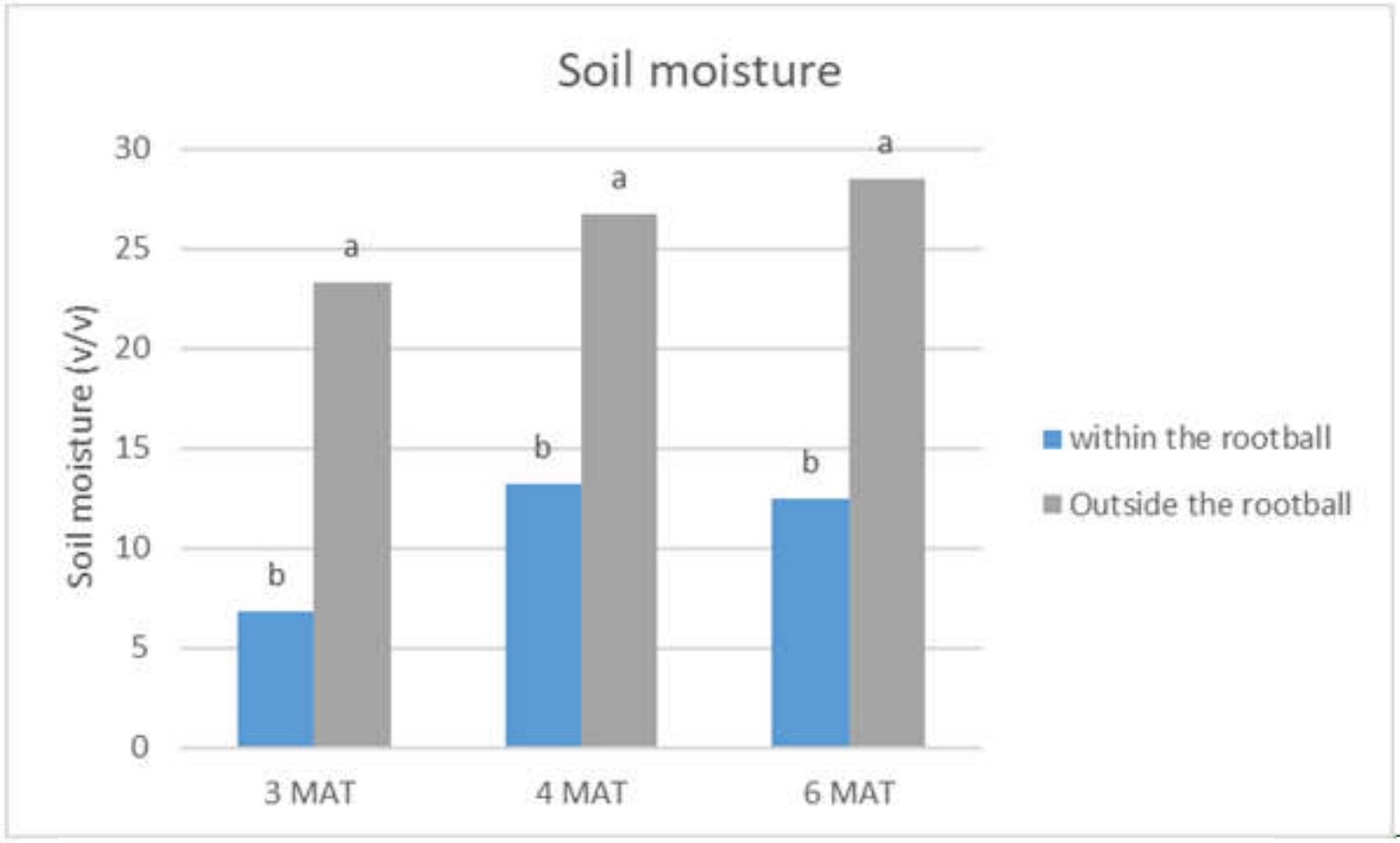
Aim: selection of environmentally friendly nursery substrate that:

1) Reduces the usage of peat
2) Shows similar performances as peat during nursery cultivation
3) Shows superior performances than peat after transplanting

Tested materials: wood fiber, zeolite, biochar, coconut



Rootball vs. soil moisture in newly transplanted trees from container



MAT = months after transplant. Transplant done at end February 2022

Biostimulants

A plant biostimulant is any substance or microorganism applied to plants with the aim to enhance nutrition efficiency, abiotic stress tolerance and/or crop quality traits, regardless of its nutrients content.

Diverse nature: single vs. mixed substances and microorganisms

Diverse physiological effects: improve nutrient efficiency and/or abiotic stress tolerance and/or crop quality traits

Humic and fulvic acids (31%; 450 M euro in 2016)

Beneficial fungi and bacteria (9,7%; 141 M euro in 2016)

Inorganic compounds (9,6%; 140 M euro in 2016)

Chitosan and other biopolymers (6%; 87 M euro in 2016)

Seaweed extracts (33,3%; 483 M euro in 2016)

Protein hydrolysates and other N-containing compounds (10,2%; 148 M euro in 2016)

Du Jardin, 2015
Critchley et al., 2021

Seaweed extracts

Algae, especially brown-algae have been applied for agricultural purposes. *Ascophyllum nodosum* is most widely studied (Khan et al., 2009)

About 15 millions metric tons of algae-based products are manufactured annually (FAO, 2006)

Algae-extracts contain several bio-active ingredients:

Laminarin (glucan)

Triggers plant defences

Fucoidan (sufurated polysaccharide)

Biological activity in mammals

Polyphenols

Trigger plant defences

Plant hormones (cytokinins, auxins)

Modulate biosynthetic pathways

Arginin

(N source)

Mannitol (sugar alchool)

Osmotic adjustment

Alginic acid

Soil and rooting improvements, mycorrhiza

Inorganic ions

(Na, Mg, K, Cl e SO4)

Organic acids (D-mannuronic; L-guluronic)

Water and nutrient uptake

Aims of experiment 1

1- Test the hypothesis that a seaweed extract can improve seedling growth, therefore fastening plant production process.

2- Test the hypothesis that a seaweed extract improves root morphological traits and root:shoot ratio, so that transplant success can be improved

3- Identify optimal dose of application

Experimental site

The experiment was carried out at ERSAF, in a regional forest nursery (Curno, BG, Italy), under a Cfb (Koppen-Geiger classification) climate.

Average temperature = 11.5 °C

Average rainfall = 1420 mm/year

The seaweed extract tested

Ascophyllum nodosum is a brown-algae which grows in coasts of Northern Europe, Iceland, Eastern Canada and Greenland with possible applications for horticulture

We used a pure extract (Agrofertil, France) made by grinding the algae at low temperatures. The extract was a powder

The extract was mixed with the nursery substrate at different rates

D0: no extract (control)

D1: 1 kg/m^3 (label dose)

D2: 2 kg/m^3 (2x label dose)

D3: 3 kg/m^3 (3x label dose)

COMPOSIZIONE MEDIA			
Umidità	12-15%	Carboidrati	45-60%
Proteine grezze	5-8%	Acido alginico	20-26%
Grassi grezzi	2-4%	Mannitolo	5-8%
Fibre grezze	>8%	Laminarina	2-6%
Materia minerale	40-55%	Fucoidano	8-10%
Sabbia	>0,5%		
MACROELEMENTI		**MICROELEMENTI**	
Azoto (N)	0,8-1,3%	Iodio (I)	500-1200 ppm
Fosforo (P)	0,05-0,15%	Rame (Cu)	1-10 ppm
Potassio (K)	1-3%	Ferro (Fe)	150-1000 ppm
Calcio (Ca)	1-3%	Manganese (Mn)	0-50 ppm
Zolfo (S)	2-5%	Boro (B)	20-100 ppm
Magnesio (Mg)	0,5-0,9%	Molibdeno (Mo)	1-5 ppm
Cloro (Cl)	2-5%	Zinco (Zn)	40-200 ppm
Sodio (Na)	2-4%	Arsenico (As)	20-45 ppm
VITAMINE presenti in quantità approssimative			
Carotene (A)	20-60 ppm	Tocoferolo (E)	50-200 ppm
Acido ascorbico (C)	2000-1000 ppm	Niacina (B3)	10-30 ppm
Riboflavina (B2)	5-10 ppm	B12 ca. (M)	0,004 ppm
Tiamina (B1)	1-5 ppm	Acido folico (B9)	0,2 ppm
Biotina (B)	0,1-0,4 ppm	Acido folinico	0,2 ppm

Tabella 4 – Composizione media del biostimolante a base di Ascophyllum nodosum usato nella sperimentazione (agrofertil.fr).

Plant material and growing conditions

- Seeds of *Carpinus betulus, Crataegus monogyna, Fagus sylvatica* were obtain from local certified seed forests.
- Seeds were cleaned using sodium hypochlorite and stratified in moist sand at 4 °C to overcome dormancy
- In Feb. 2021, seeds were seeded in 0.4 L plastic trays, according to a randomized block design with 10 blocks (32 plants per species and seaweed treatment per block, 1280 plants per species; 3840 plants in total)
- A commercial substrate specifically developed for seedlings (Hochmoor, Teflor, Italy). The substrate contains with 1 kg/m3 of soluble fertilizer and 1 kg/m3 a controlled release fertilizer, was used.

Substrate component or trait	Amount (v/v) or value
Brown peat + montmorillonite	30%
Blond peat (10-20 mm)	50%
Coconut fiber	20%
pH	6.0
EC	0.3 dS/m
Density	100 kg/m^3
Porosity	95%

Plant material and growing conditions

In Jan. 2022, plants were re-potted into 1.7 L containers and grown under a tunnel under full sunlight for one additional growing season.

<u>Algae extracts were not applied at repotting</u>

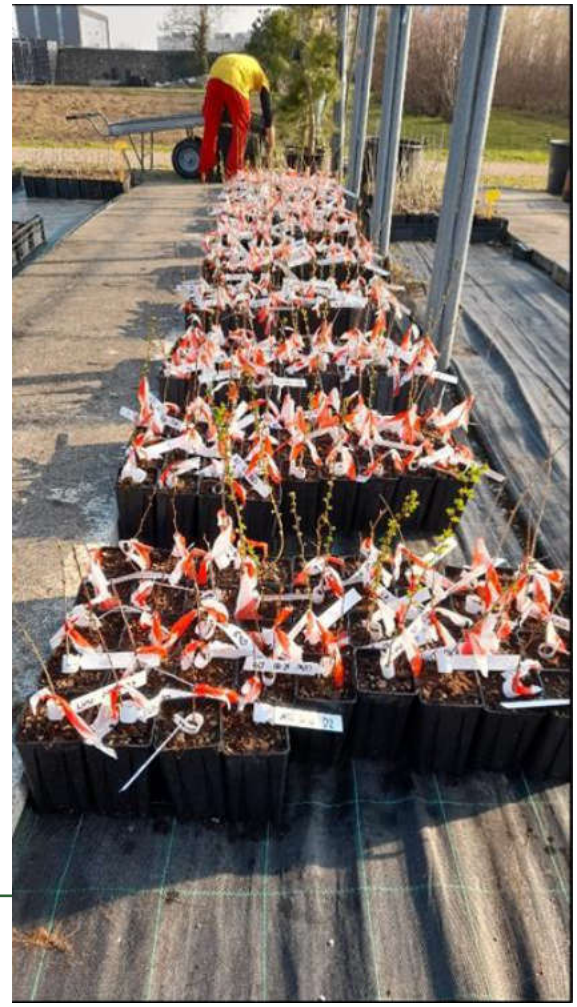
After repotting, plants were arranged according to a randomized block design with 10 blocks (2 plants per treatment and species in each block; 240 plants in total)

Irrigation was carried out daily (10-15 minutes during nighttime)

No additional fertilization other than that included in the substrate was done

Weeding was conducted manually, twice per month

No pesticide was applied



Measurements

Growth traits (measured on 2, 6, 12, 24, 48 and 72 weeks after emergence):

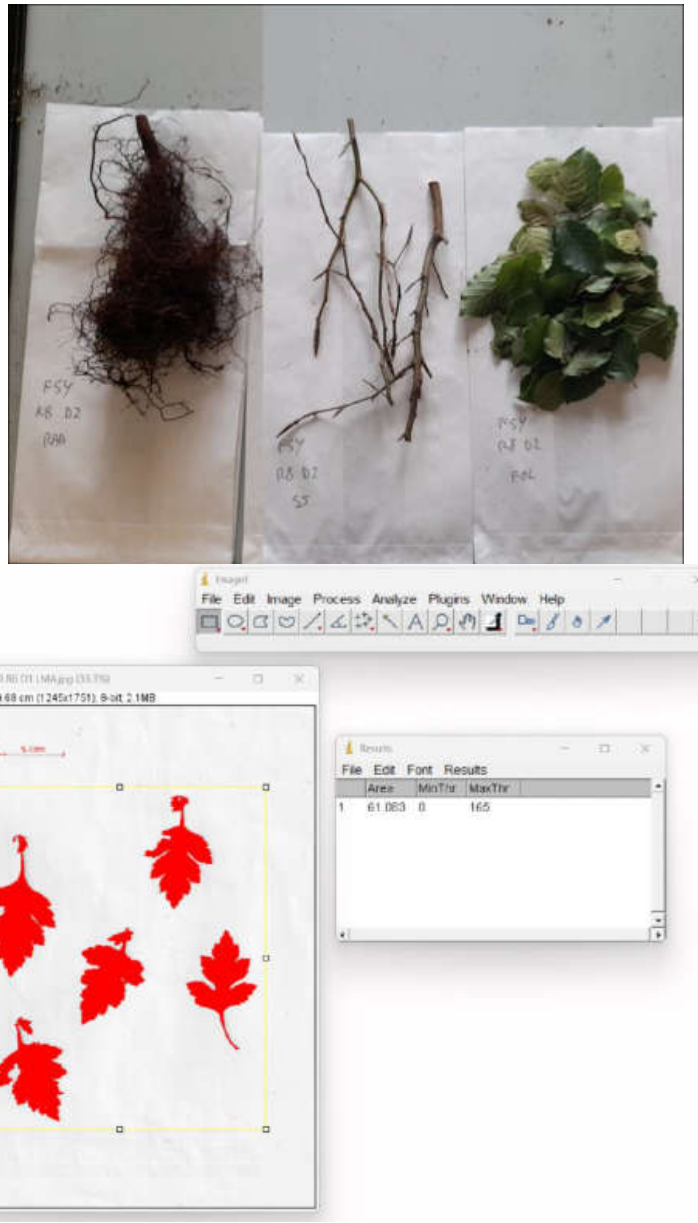
1- **plant height** (cm): measured from the flare to the base of the apical bud

2- **leaf, stem, and root dry weights** (g): measured after cutting the stem at the flare, separating the leaves, cleaning the roots with a flush of air, and oven-drying leaves, stems, and roots separately at 70°C until constant weight

3- **Average and Total leaf area** (cm^2): measured scanning all plant leaves with an A3-scanner

4- **Root:shoot**: calculated as DWroots/(DWstem + DWleaves)

5- **Relative Growth Rate of the plant and of roots**: calculated as (lnDWt1 - lnDWt0)/(t1-t0)



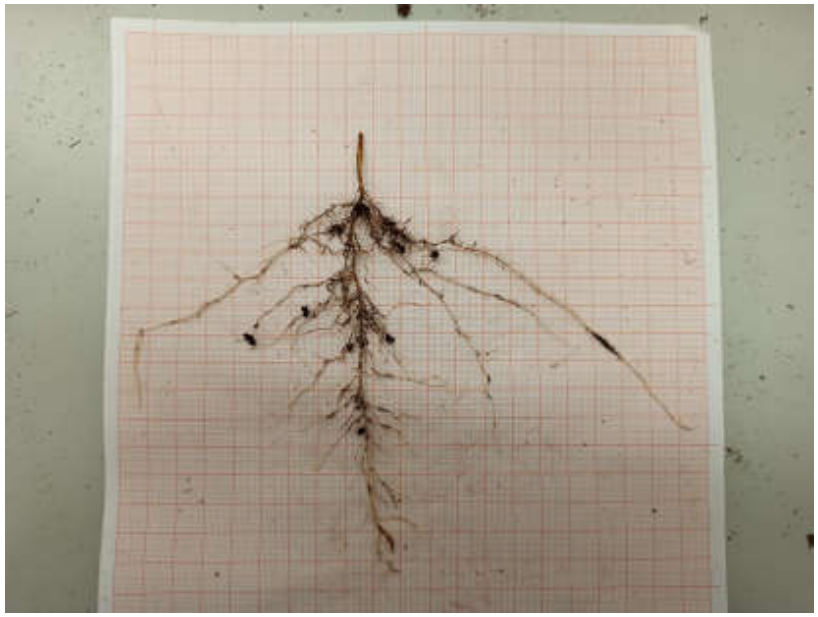
Measurements

Root traits (measured on 8, 13, 23, 58, and 70 weeks after emergence):

1- **Total root length** (cm): measured using the root-line intersect method (Tennant, 1975)

2- **Root density** (cm/dm3): calculated as total root length/effective container volume

3- **Specific root length** (cm/g): root length per unit weight.



Physiology (measured on 2, 6, 12, 24, and 72 weeks after emergence):

1- **Net CO_2 assimilation** (μmol m^{-2} s^{-1})

2- **Stomatal conductance** (mmol m^{-2} s^{-1})

3- **Sub-stomatal and chloroplastic CO2 concentration** (ppm)

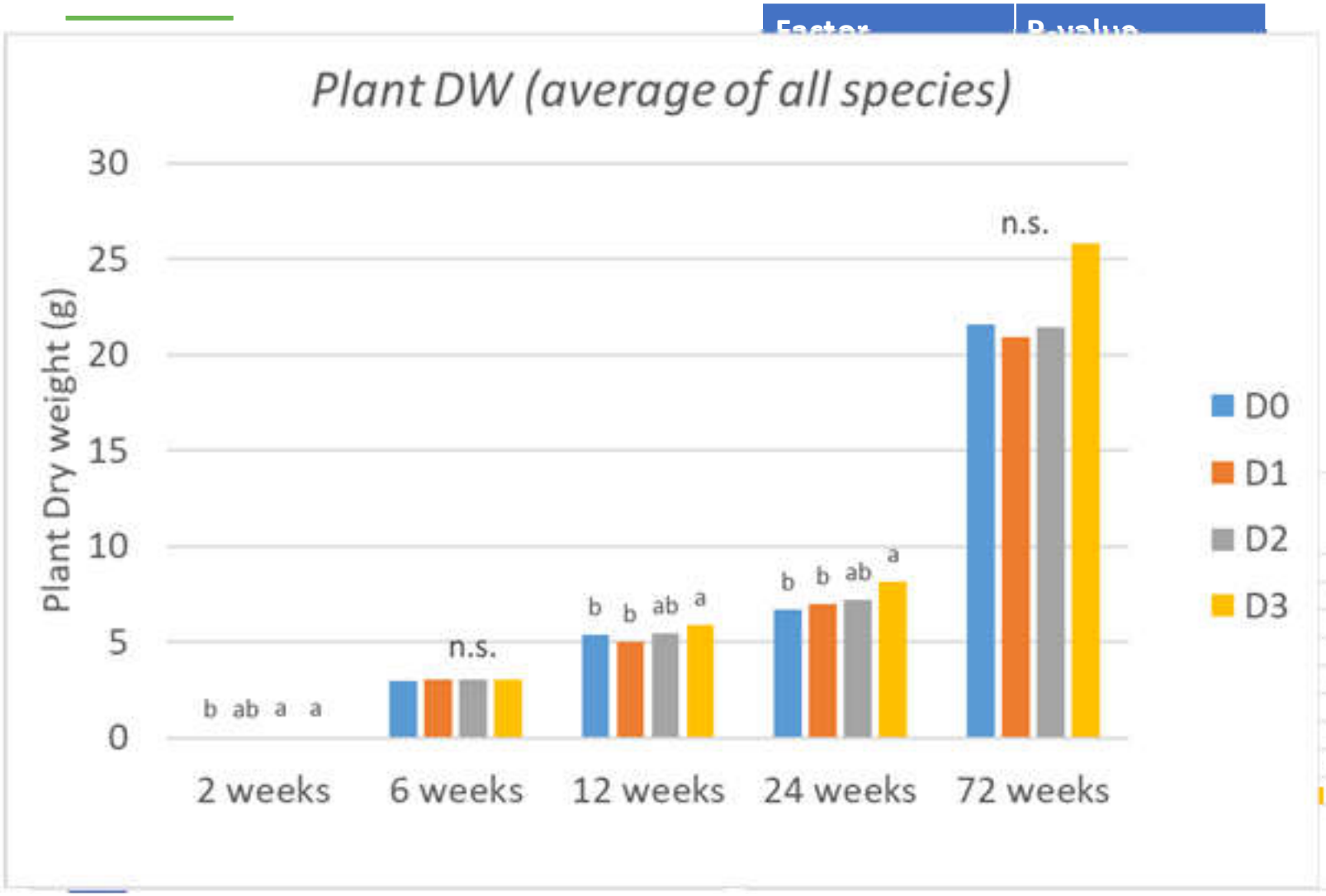
4- **Water use efficiency**: calculated as A/E

5- **Leaf greenness index**: measured using a SPAD-meter

Results

All data were analysed using mixed models tool in SPSS. Homogeneous subsets were separated using Sidak test

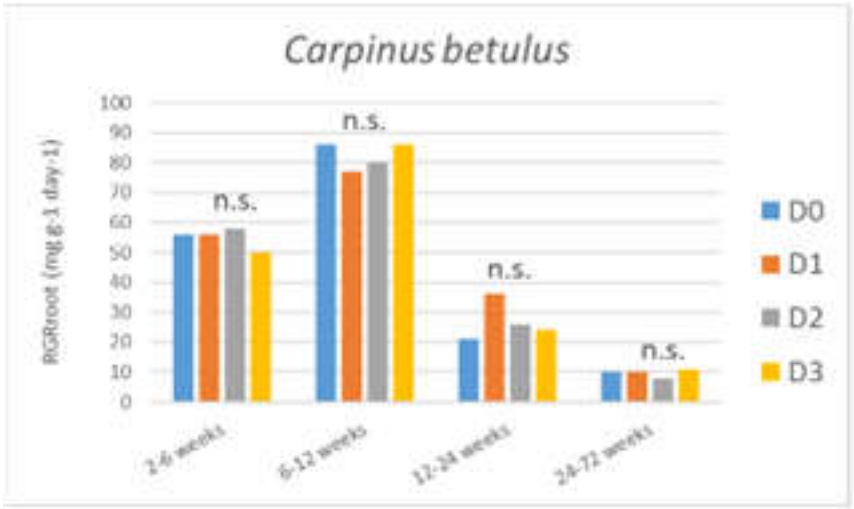
Relative growth rate: whole plant



- It indicates the amount of dry biomass produced per unit existing g DW per day

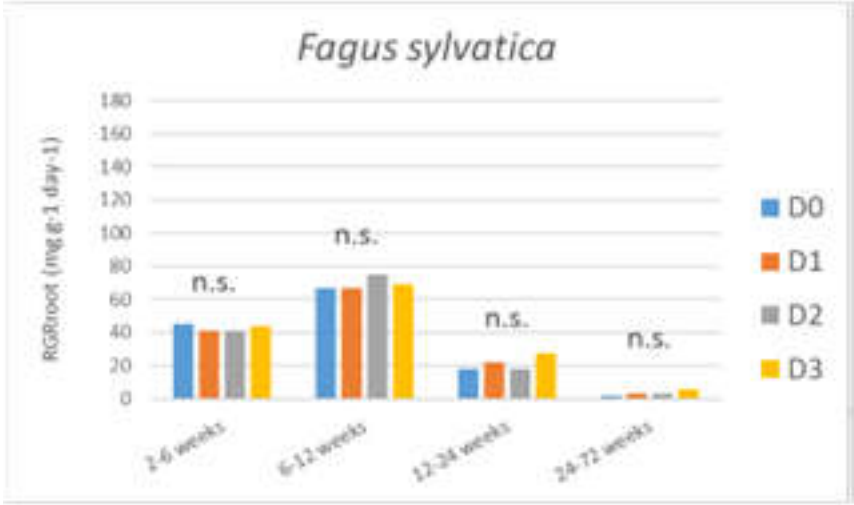
Higher RGRplant was observed in the 2 weeks after emergence in all species
RGRplant <u>transiently</u> increased when biostimulants werea applied at 2x or 3x label doses, compared to control
Larger effect in *F. sylvatica*

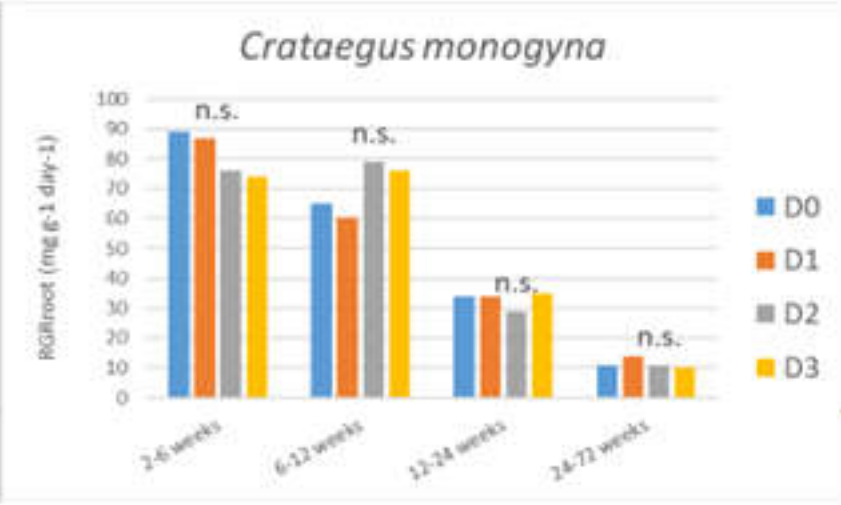
Relative growth rate: roots



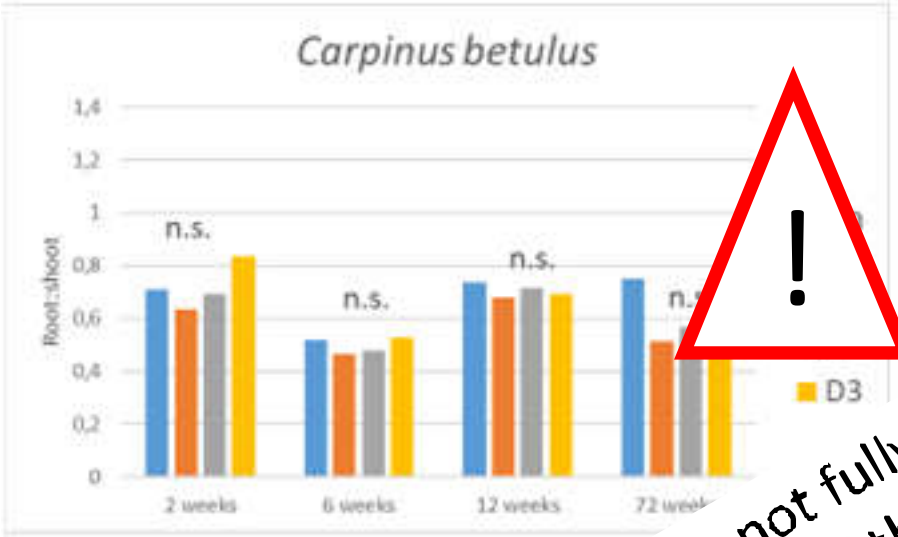
Factor	P-value
Pspecies	**
Pdose	n.s.
Ptime	**
PspeciesXdose	n.s.
PspeciesXtime	**
PdoseXtime	n.s.
PspXdoseXtime	n.s.

- It indicates the amount of root dry biomass produced per unit existing g DW per day
- Root RGR could not be calculated in between germination and 2 weeks
- Biostimulant application did not promote root RGR





Root:Shoot



Factor	P-value
Pspecies	**
Pdose	n.s.
Ptime	**
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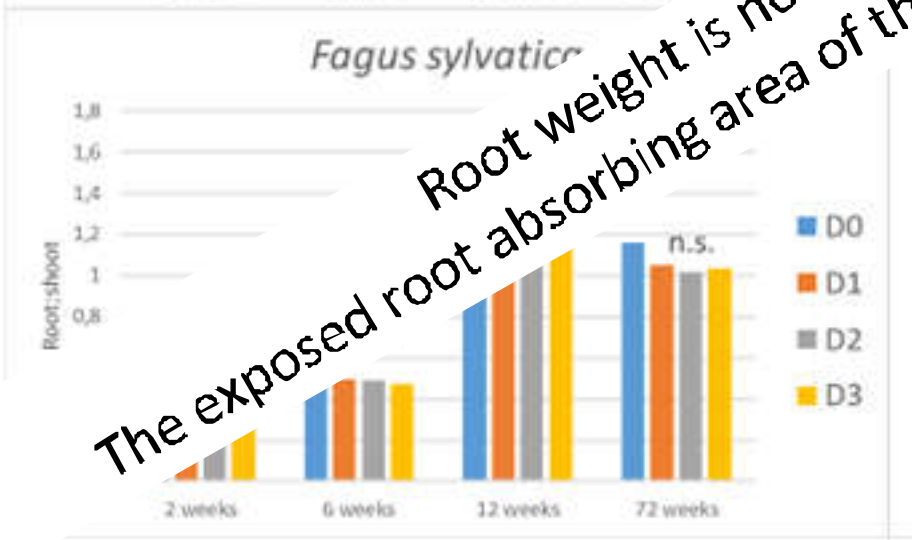
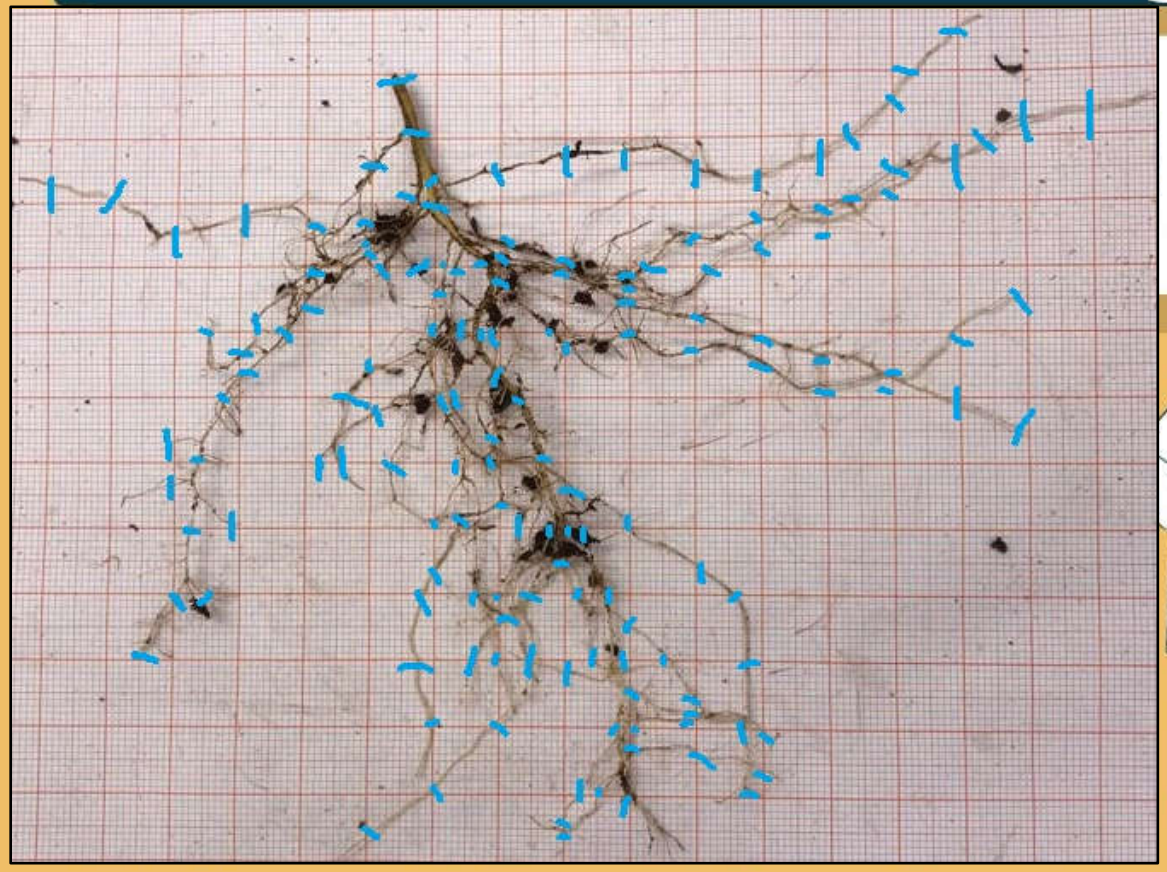
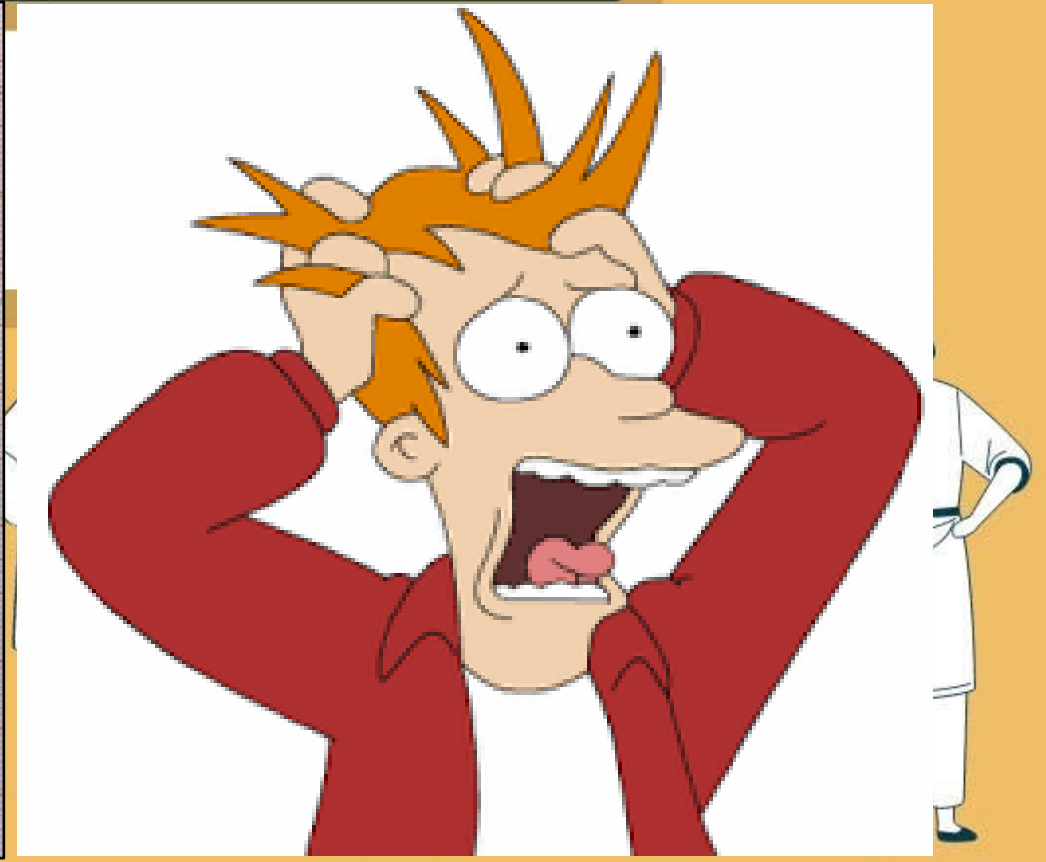


Root weight is not fully informative about root systems.
The exposed root absorbing area of the unit root biomass can differ largely among plants

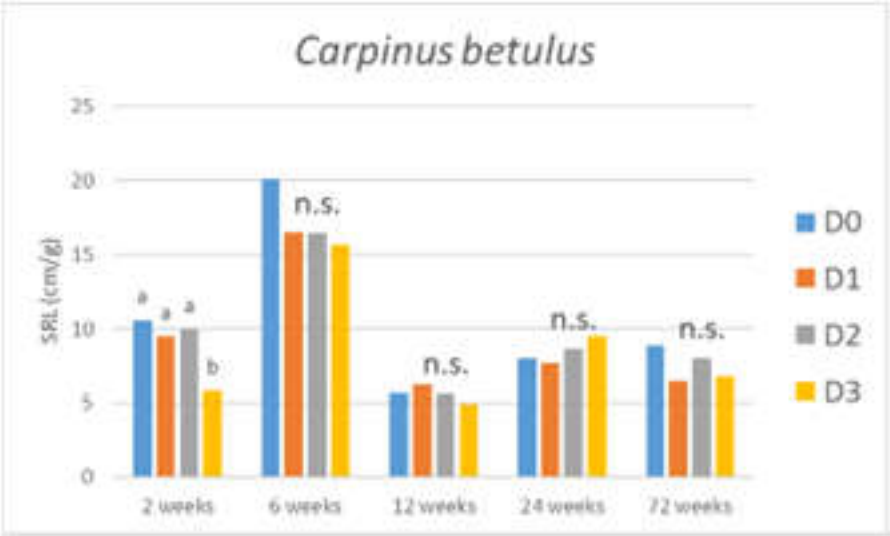
- R arly
  . *betulus* and
  gyna (around 0.5-
  ), while it increased over time in *F. sylvatica* (0.35 to 1.0-1.2)
- Biostimulants did not increase root:shoot at any dose, compared to control

Going beyond root weight

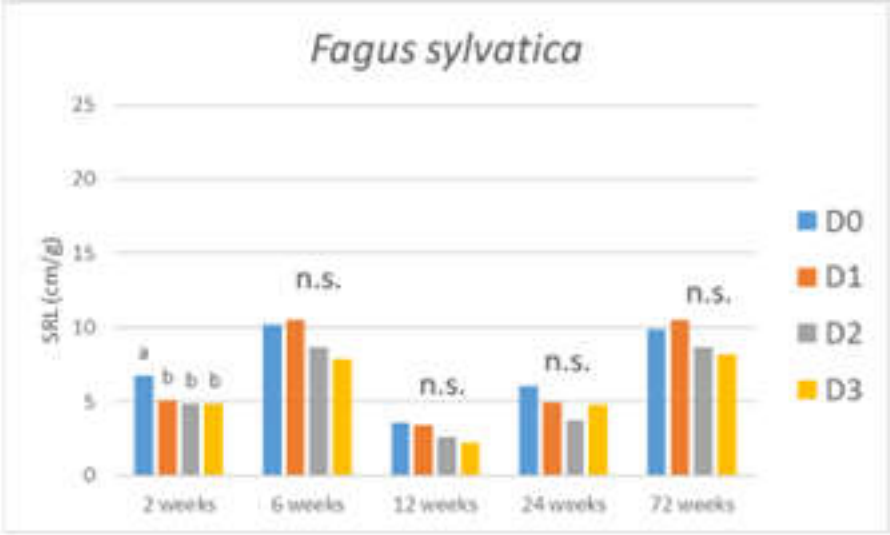


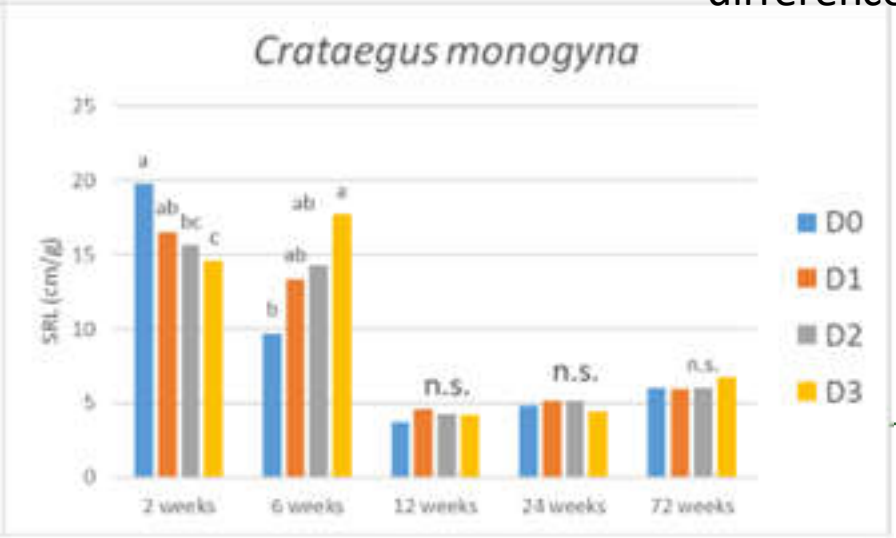


Specific root length



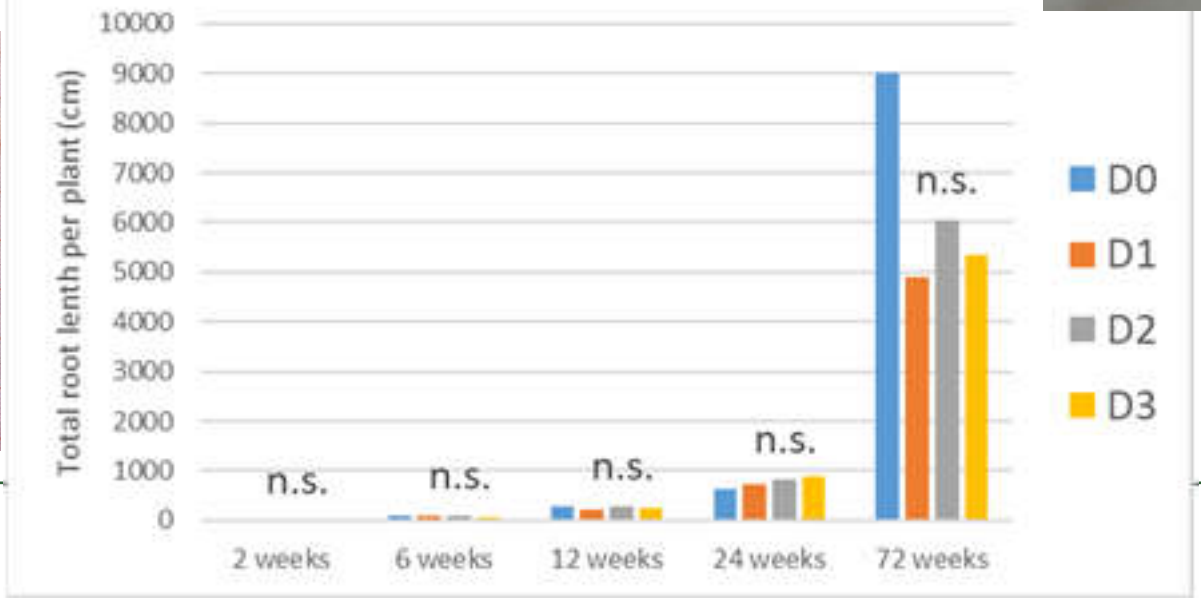
Factor	P-value
Pspecies	**
Pdose	n.s.
Ptime	**
PspeciesXdose	n.s.
PspeciesXtime	**
PdoseXtime	*
PspXdoseXtime	n.s.





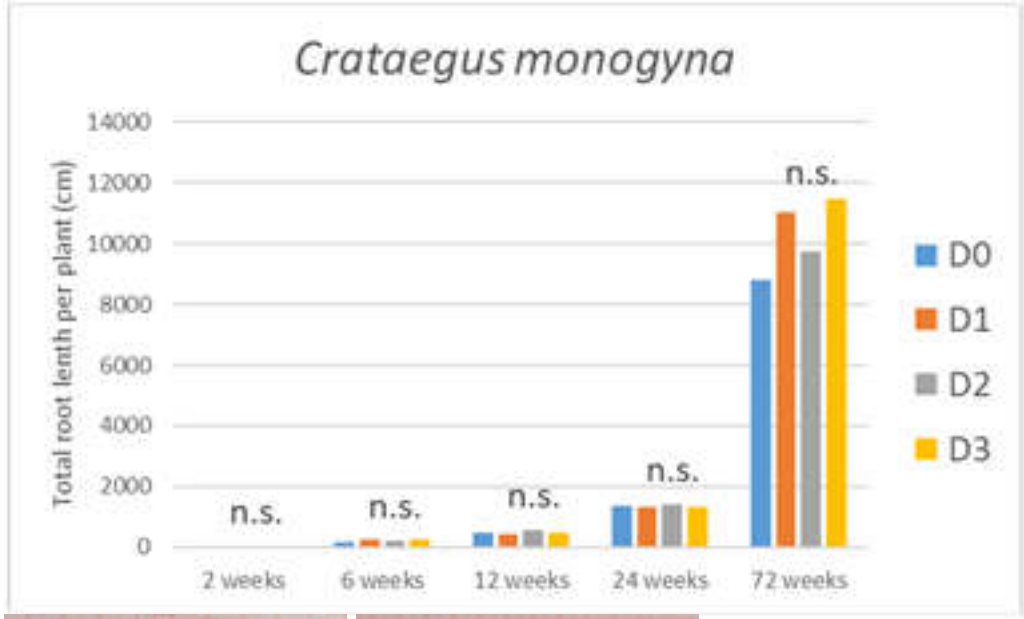
- It indicates the total length of 1 g of root dry biomass
- SRL decreased in all species from 6 to 12 weeks (root secondary growth)
- *Fagus* had shorter roots per unit root diameter than other species
- Algae reduced SRL 2 weeks after emergence, then differences disappeared

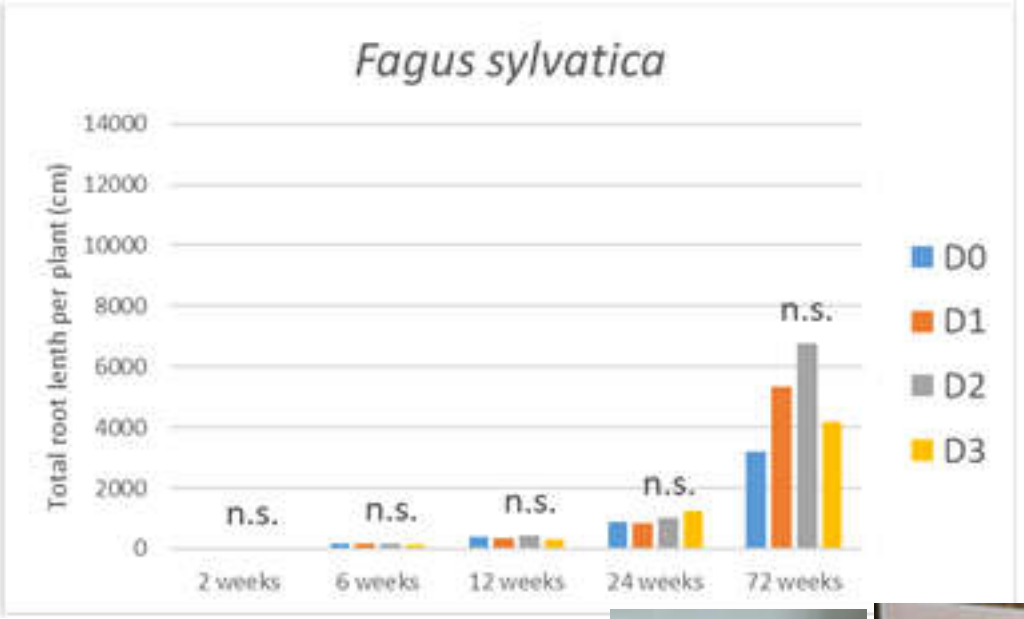
Total root length – Carpinus

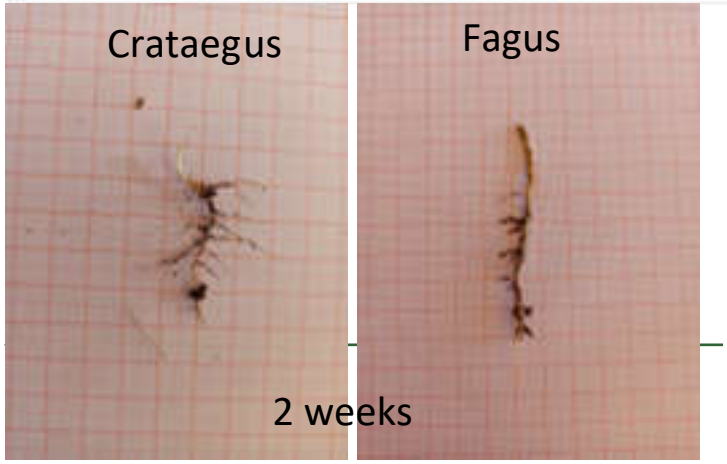


72 weeks: circling

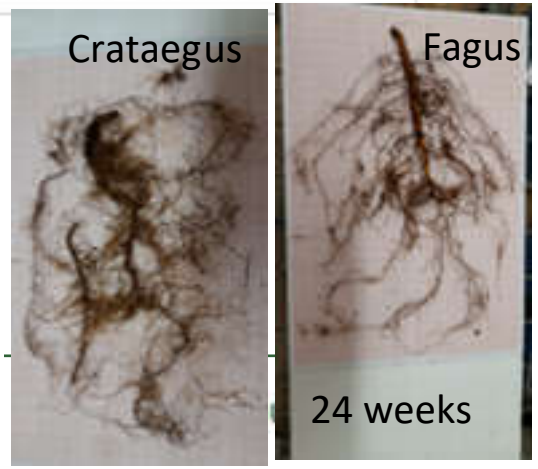
Total root length



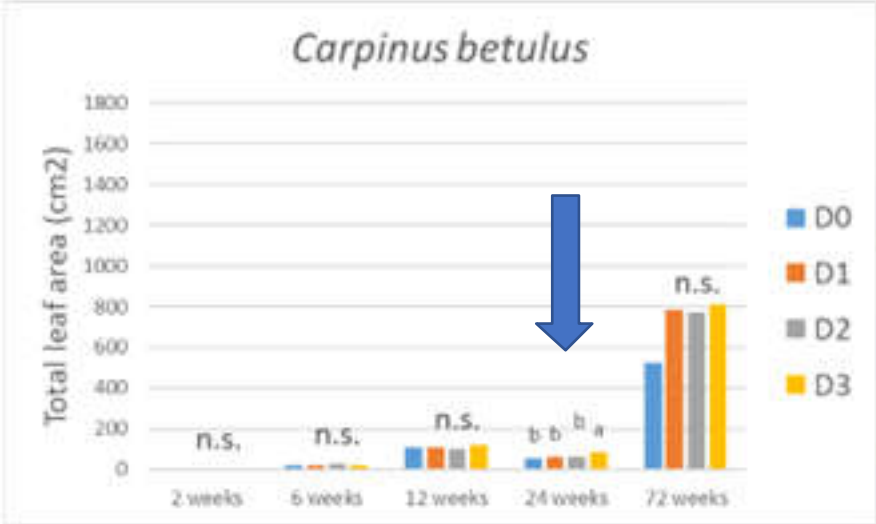




- Total root length increased with species' sunlight requirements (*Crataegus* > *Carpinus* ≥ *Fagus*)
- Biostimulants did not consistently affect total root length per plant



A look above-ground: Leaf Area



Factor	P-value
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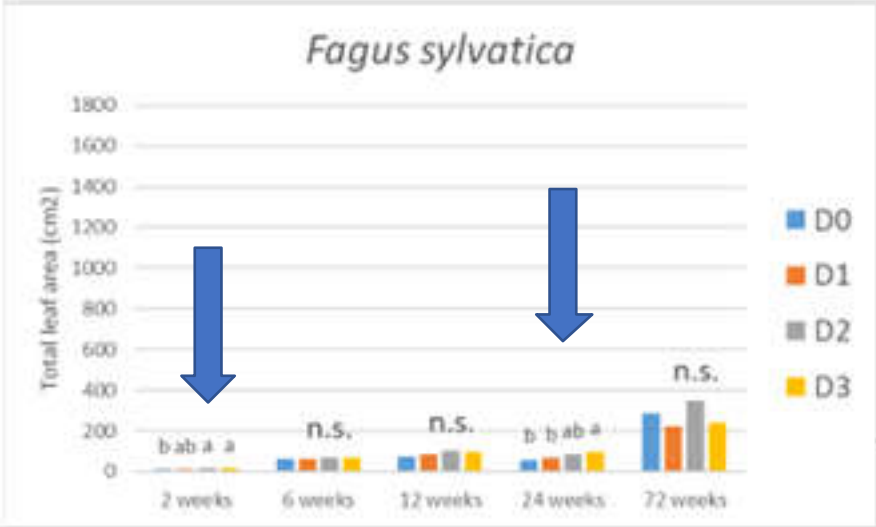
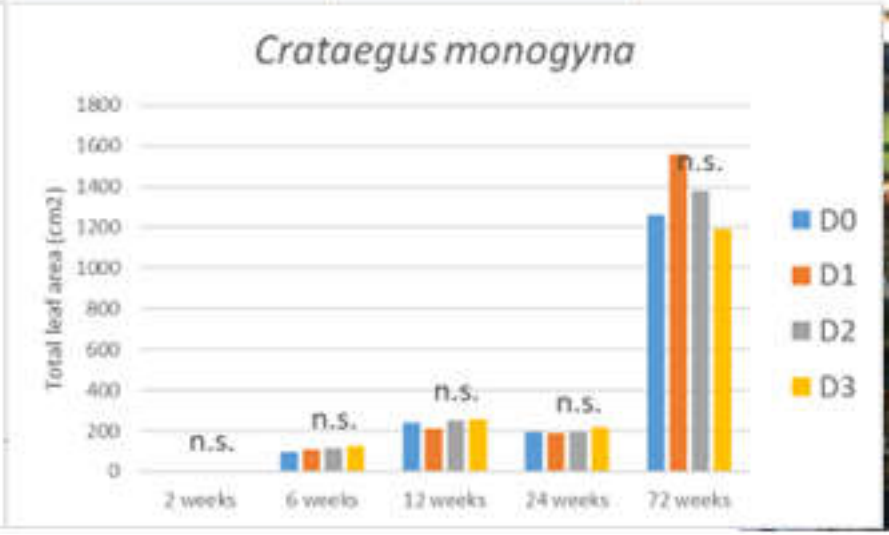
Pdose	n.s.
Ptime	**
PspeciesXdose	n.s.
PspeciesXtime	**
PdoseXtime	n.s.
PspXdoseXtime	n.s.





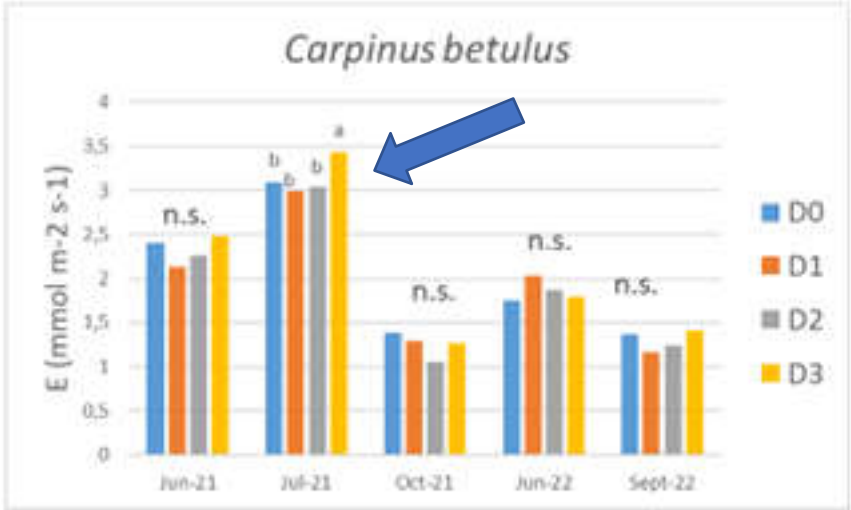
- *F. Sylvatica* had higher TLA than other species 2 weeks after emergence. Thereafter, *C. monogyna* had higher leaf area than other species
- Biostimulants transiently increased TLA when applied at 3x label dose
- Effects were mostly apparent in fall and may be due to enhanced tolerance to summer heat or delayed stress-induced leaf senescence (polyphenols?)

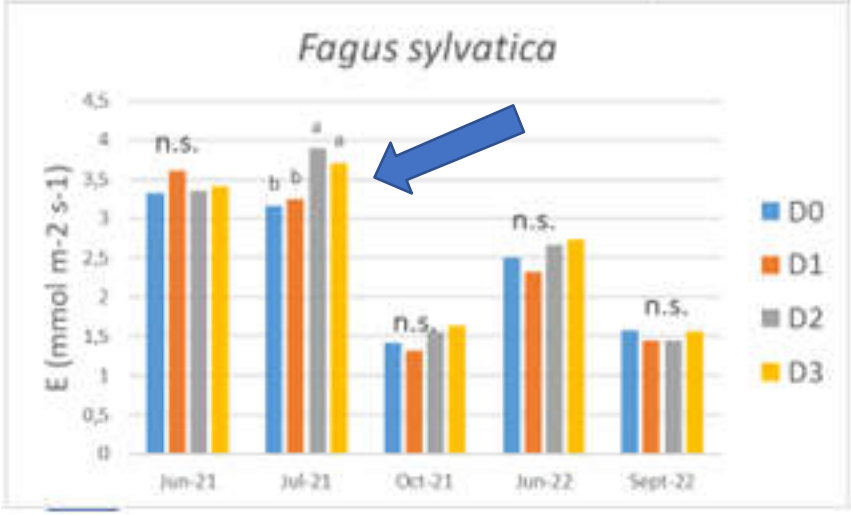
Leaf gas exchange

Sometimes measuring leaf gas exchange is pleasant…

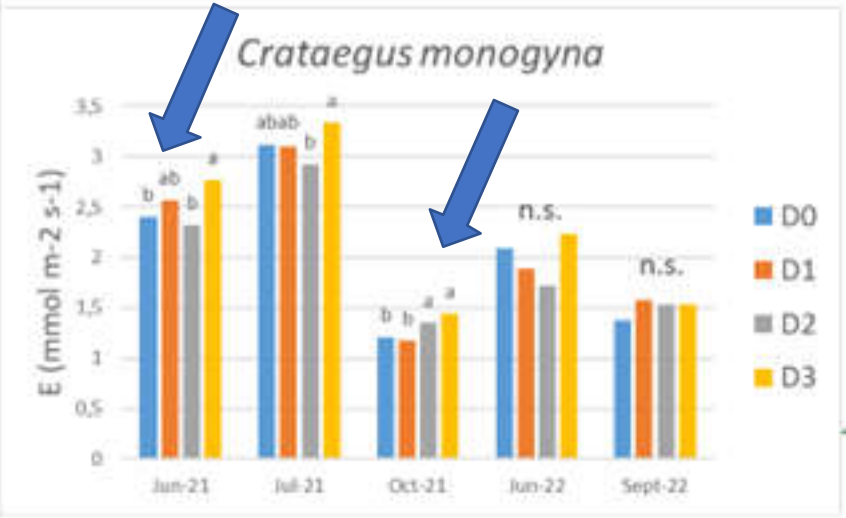
…not this time!

Leaf gas exchange: transpiration



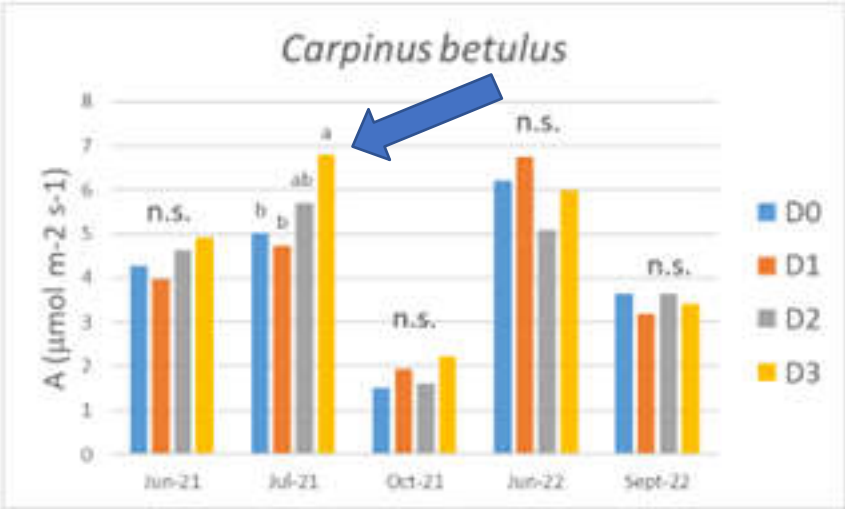


Factor	P-value
Pspecies	**
Pdose	**
Ptime	**
PspeciesXdose	n.s.
PspeciesXtime	**
PdoseXtime	n.s.
PspXdoseXtime	*

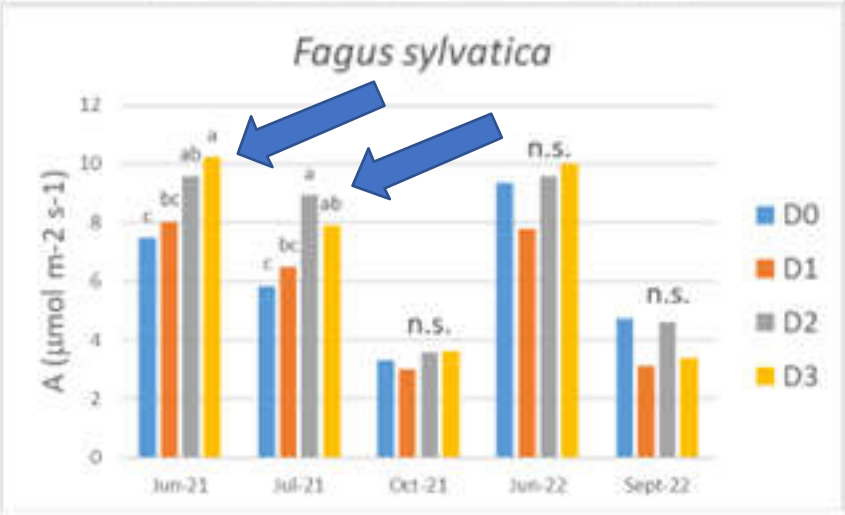


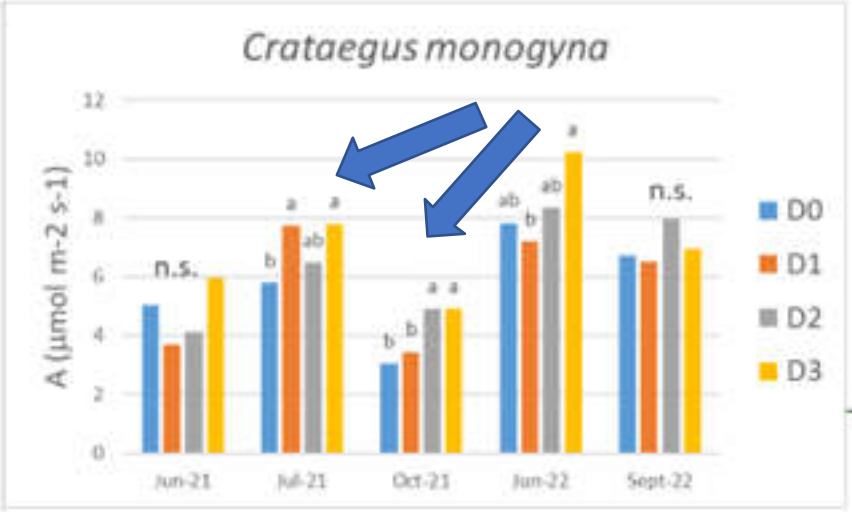
- Mannitol in algae-extracts may have improved osmotic adjustment and water uptake.
- Seaweed extracts transiently increased the amount of water transpired per unit leaf area compared to control.
- The effect was significant only in the 1st year and only when algae were applied a 3x label dose

Leaf gas exchange: net CO2 assimilation



Factor	P-value
Pspecies	**
Pdose	**
Ptime	**
PspeciesXdose	*
PspeciesXtime	**
PdoseXtime	*
PspXdoseXtime	n.s.





- The amount of CO2 assimilated by 1 m2 leaf area was increased when seaweed extracts were applied at 3x label dose, compared to control.
- Such effect was observed within 1 year since biostimulant application

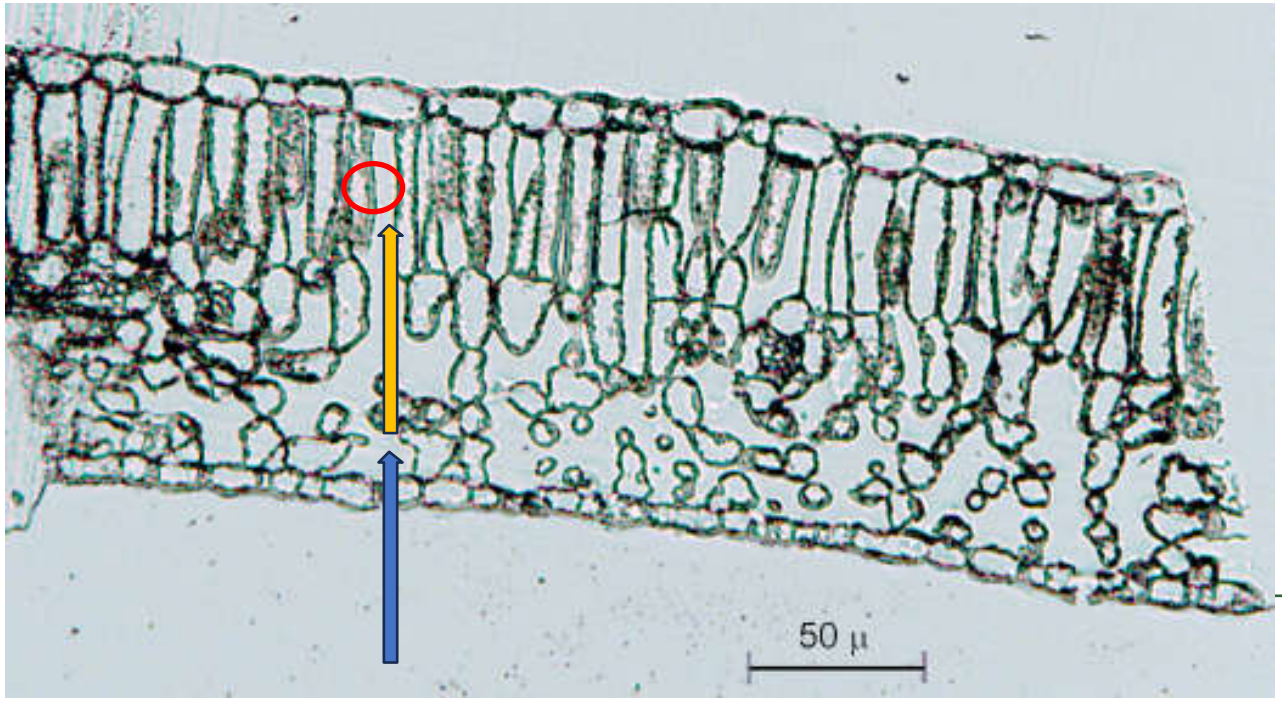
Leaf gas exchange: photosynthetic limitations

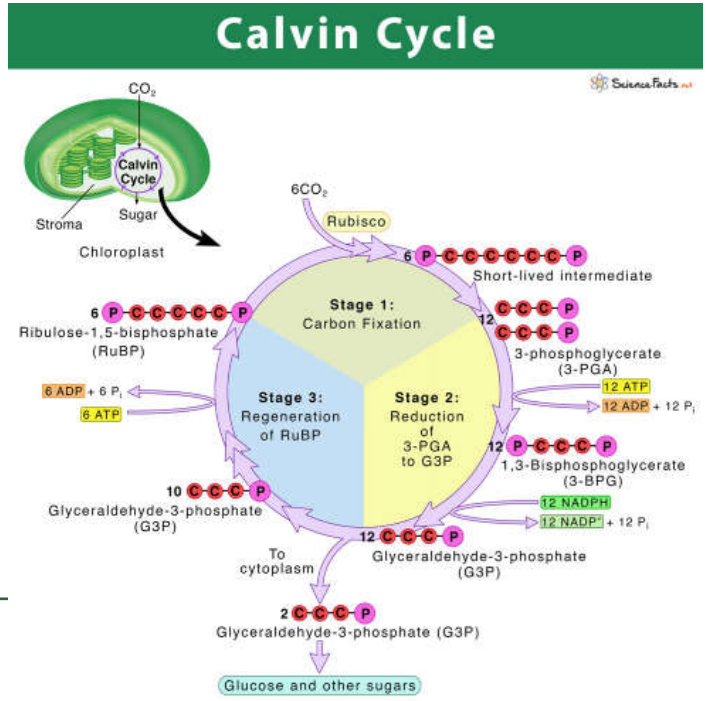
To be converted into carbohydrates, CO_2 must:

1- diffuse from the outer air to the leaf (stomata, blue arrow)

2- diffuse from the substomatal chamber to the chloroplast (mesophyll, orange arrow)

3- be carboxylated (Rubisco and Ribulose, red dot)

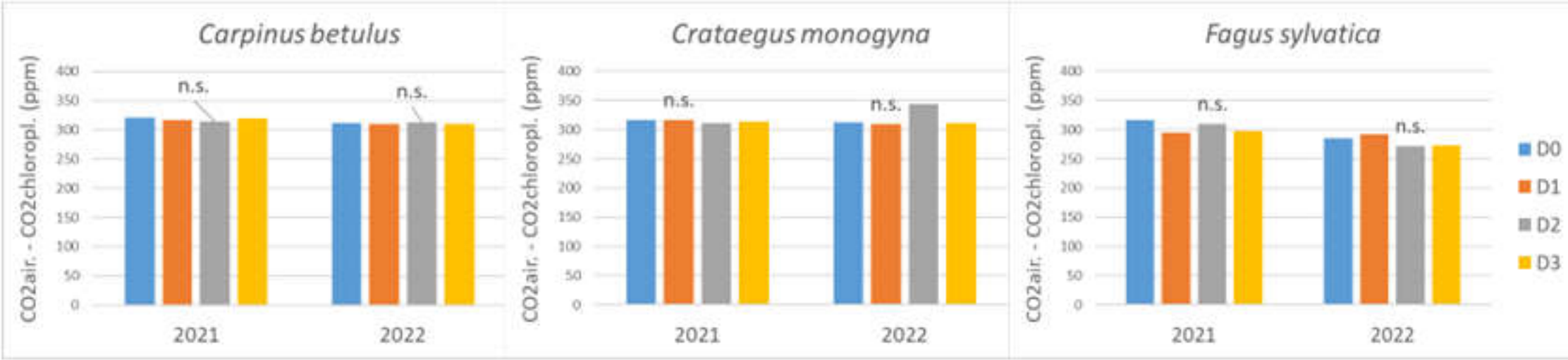




Leaf gas exchange: diffusive limitations (stomata + mesophyll)

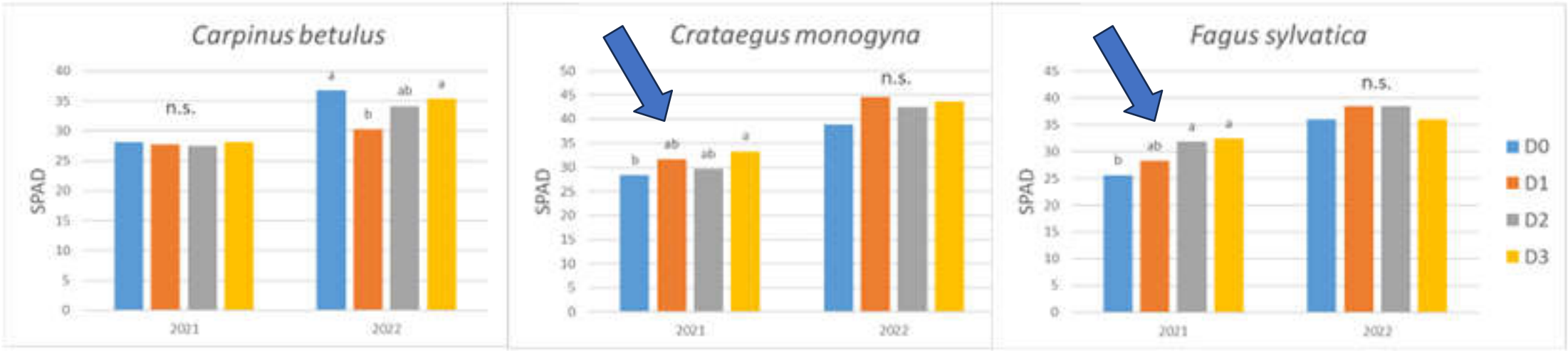
Stomatal and mesophyll factors determine diffusive limitations to photosynthesis, which can be estimated as (Loreto et al., 1994):

- Diffusive limitations = CO2 air – CO2 chloroplasts (the lower it is, the easier the diffusion)



- Diffusive limitation were not affected by seaweed extracts

Leaf gas exchange: leaf greenness index



- Biostimulants at 3x label dose increased leaf greenness index in 2 of the 3 species, during the 1st year
- Short-term effect.
- Nitrogen involved? (A. nodosum has up to 1.3% N which can yield about 40 g N/m3 substrate when it is applied at 3x label dose; comparable to several organic fertilizers, e.g. compost, horse and bone meal manure)

Experiment 1: take home message

- *A. nodosum* improved growth in the short-run during nursery cultivation. This was partly due to higher chlorophyll content in plants treated with algae at high doses which determined a short-term increase in photosynthetic rate

- Annual applications of *A. nodosum* may fasten plant production process

- The optimal dose of application was 3x label dose = 3 kg/m3

- Little evidences were found that its application may have long-term effects that promote tolerance to transplanting shock.

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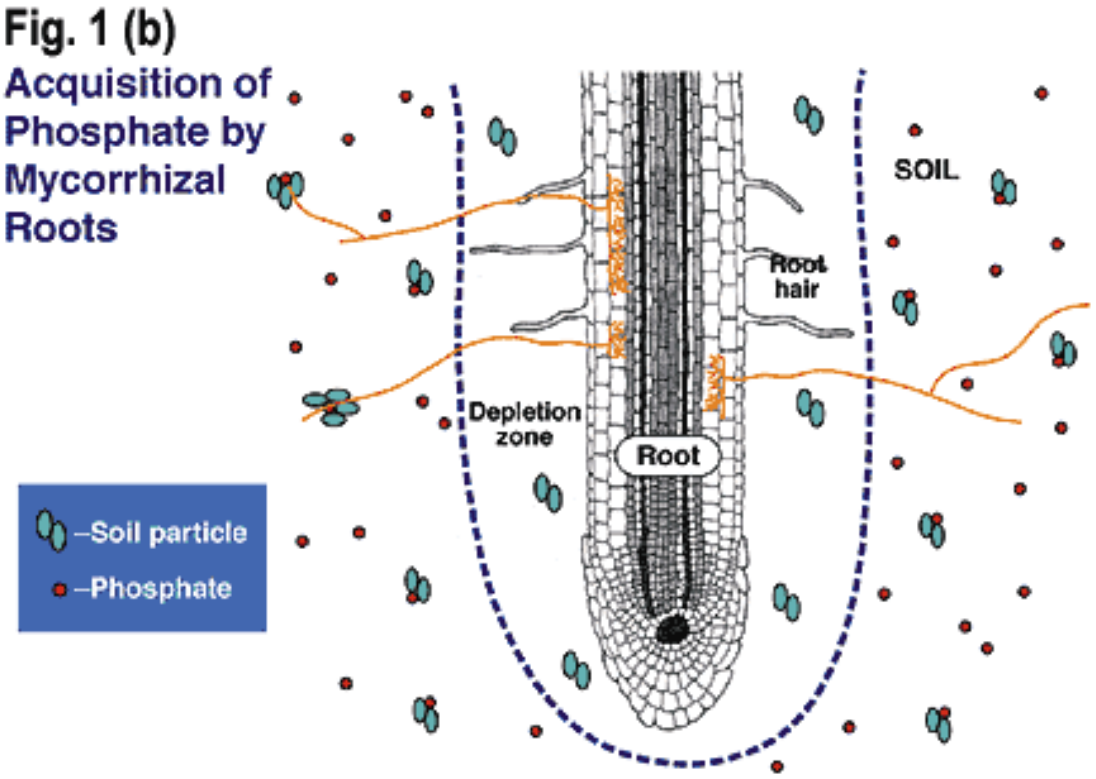
Regione Lombardia

DiSAA
DIPARTIMENTO di SCIENZE AGRARIE e AMBIENTALI

Mycorrhizae-forming fungi are ecologically significant because they form relationships in and on the roots of a host plant in a mutualistic association

- Improved P-uptake (with GvPT and GiPT, specific AMF trasporters and down-regulation of direct uptake by plant) and ability to absorb P outside of the depletion zone (*Karandashov and Bucher, 2005, Trends in plant Science*)
- Protection against drought and salinity (*Augè, 2000*, *Mycorrhiza*)
- Protection against pathogens (*Tygensen et al., 2004, Eur. J. Plant Pathol.)*



Mycorrhizal inoculation of young plants in the nursery requires little inoculum (25-50 ml per tree; up to 20 plants per L inoculum) but:

1- Inocula must survive standard nusery cultivation practices and substrates

2- Inocula must keep functionality after transplanting (competition with native soil microbiota)

The aim of experiment 2 was:

- To evaluate if inoculation with specific mycorrhizal strains in the nursery can build a long-term mutualism which enhances tolerance to transplanting stress.
- 160 2-year-old *Acer campestre* and *Tilia cordata* plants were used.

Fondazione Minoprio

Inoculation

Transplant

Nursery cultivation

Standard management but no use of fungicides

Field cultivation

No irrigation and fertilization. Only weeding

Year 0

Year 2

Year 5

Selection of the inoculum

Instead of using commercial products, a controlled mycorrhization approach was used (overall, it took about 8 months to get the inoculum)

1a) Excavation around healthy trees in a selected environment

1b) Roots+soil samples harvest

2) Analysis (e.g. Hartig net, alkaline phosphatase) and multiplication

3) Preparation

4) Distribution*

* The inoculum was composed by colonized root pieces, fungal mycelium, montorillonite and a hydrogel to avoid dehydration

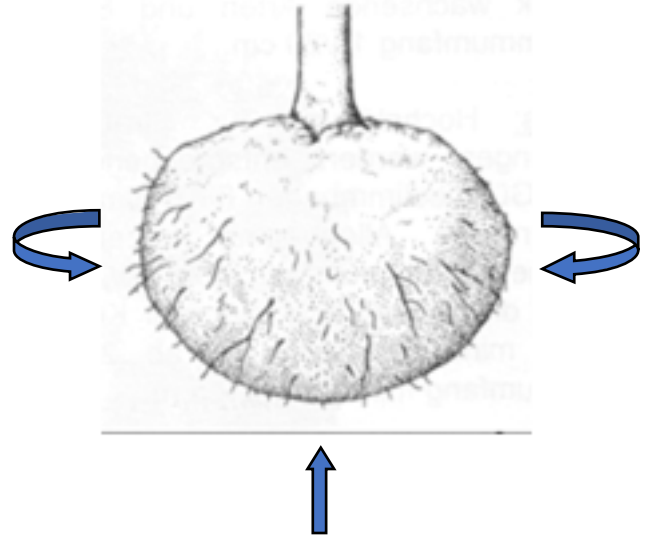
Selection and distribution of the inoculum

STEP 2: Selection

Based on laboratory analyses, strains of the following species were selected:

A. campestre: native strains of *Glomus geosporum, G. mossae*, and *G. clarum* (all VAM)

T. cordata: native strains of *Boletus edulis* (ECM) and *Glomus mossae* (VAM).



STEP 4: Distribution

It was done at potting, in March 2008 on half of the plants (+I), while the other half was not inoculated (-I).

Every 10 cm of stem diameter correspond to 450 -500 ml of inoculum.

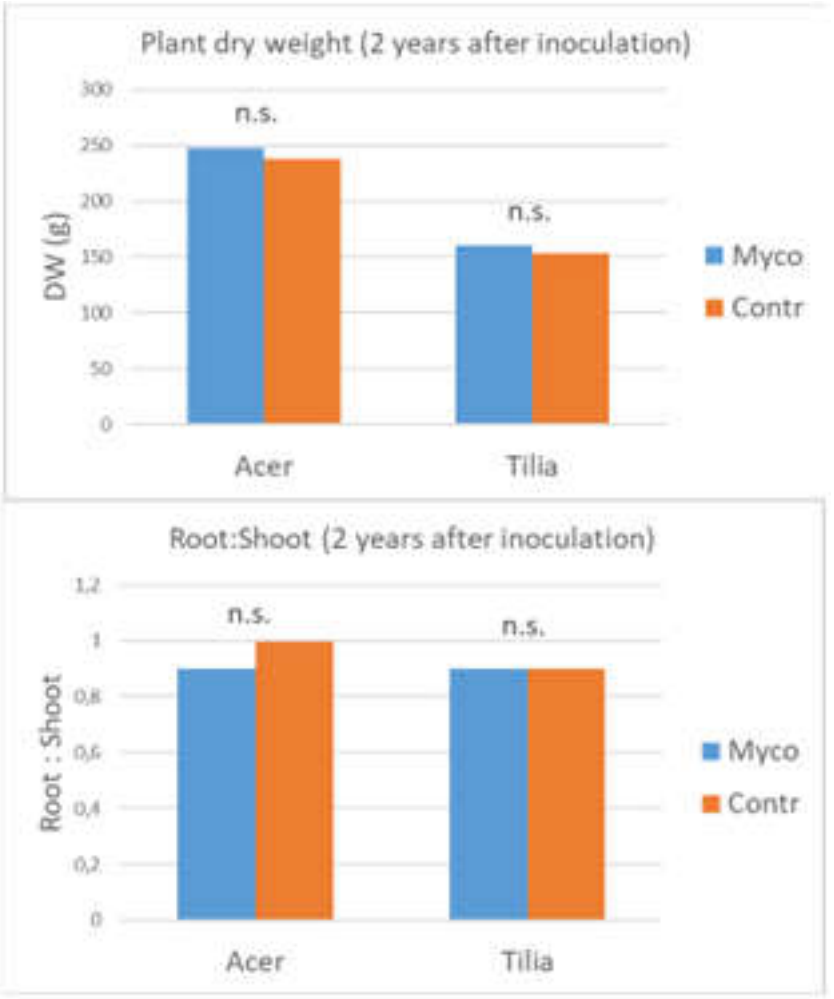
- **2/3 spreading on the sides**
- **1/3 putting into bottom**

Phase 1: nursery cultivation

Percentage of mycorrhizal root tips (ECM) and root colonization after staining (AMF) measured using a stereomicroscope after 7 months of cultivation in inoculated (+I) and non-inoculated plants. Different letters denote significant differences between +I and –I plants at p<0,05

Species	Inoculation (I)	
	+I (%)	–I (%)
Maple	53 a	24 b
Linden (ECM)	81 a	59 b
Linden (AMF)	17 a	10 b

- -I plants were also mycorrhizal
- Inoculation increased mycorrhizal root colonization



Growth of woody organs and root:shoot were not affected by inoculation

Phase 1: nursery cultivation

Vcmax and Jmax are photosynthetic parameters obtained from A/Ci curves which represent Rubisco and electron transport activity in the photosystems.
Different letters denote significant differences between +I and –I plants at p<0,05

Species	Parameter	Inoculation (I)	
		+I	–I
Maple	V_{cmax}	29.1 a	16.0 b
	J_{max}	72.5 a	36.5 b
Linden	V_{cmax}	43.0 a	24.4 b
	J_{max}	68.8 a	40.7 b

Ksp, Ksx, and Kl denote whole plant, soil to xylem, and leaf conductivity to water. They are crucial parameters to understand the hydraulic functionality of the plant.
Different letters denote significant differences between +I and –I plants at p<0,05

Species	Parameter	Inoculation (I)	
		+I	–I
Maple	$K_{sp} \times 10^{-7}$ (m s^{-1} MPa^{-1})	78.9 a	84.1 a
	$K_{sx} \times 10^{-7}$ (m s^{-1} MPa^{-1})	169.0 a	164.1 a
	$K_l \times 10^{-7}$ (m s^{-1} MPa^{-1})	178.2 a	140.5 a
Linden	$K_{sp} \times 10^{-7}$ (m s^{-1} MPa^{-1})	155.0 a	115.6 b
	$K_{sx} \times 10^{-7}$ (m s^{-1} MPa^{-1})	402.9 a	351.0 a
	$K_l \times 10^{-7}$ (m s^{-1} MPa^{-1})	327.1 a	195.9 b

Fini et al., 2011

- Activity of photosynthetic enzymes was higher in +I than in -I plants of both species
- Inoculation increased plant conductivity in linden

Then, transplant!

- Plants were arranged according to a randomized block design with 6 blocks and 6 plants per species and mycorrhizal treatment in each block (144 plants in total)
- Plants were planted into hand-dug planting holes (as deep as the rootball and 1.5 times the width of the rootball) following a 3 x 3 m planting design
- Soil of the experimental site is a loam (51% sand, 40% silt and 9% clay) and sub-acid (pH 6.41), with high levels of gravel (16%) and available phosphorus (317 mg kg^{-1}), a normal content of organic matter (18 g kg^{-1}) and total N (1.30 g kg^{-1}) and a low CEC (5 meq 100 g^{-1})

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Measurements after transplant

- **Root colonization**: assessed 34 months after transplanting (MAT).
- **Growth and mortality**: both plant dry weight (measured 34 MAT) and shoot extension (measured 11, 23, and 34 MAT) were used to quantify the effects on inoculation on growth. Mortality was assessed as the frequency of dead plants
- **Leaf gas exchange**: measured 4, 5, 14, 16, 18, 27, 28 and 30 MAT using an infrared gas analyzer (Ciras-2, PP-System)
- **Water relations and leaf soluble carbohydrates**: measured 5, 14, and 28 MAT. A pressure bomb was used to measure pre-dawn, xylem, and midday water potentials. HPLC-RI was used to quantify individual carbohydrates

Detailed methods are reported in

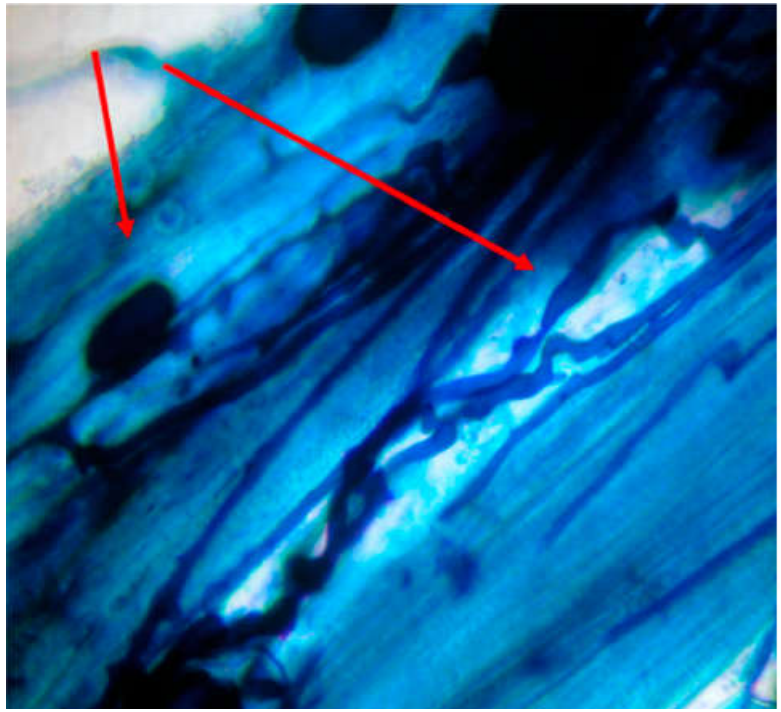
Results

- Species were independently analyzed for all the measured parameters because of the different tested inoculants applied to species
- Dendrometric and physiological parameters were analyzed on each individual sampling date using General Linear Model (GLM; SPSS 16.0, SPSS Inc.)

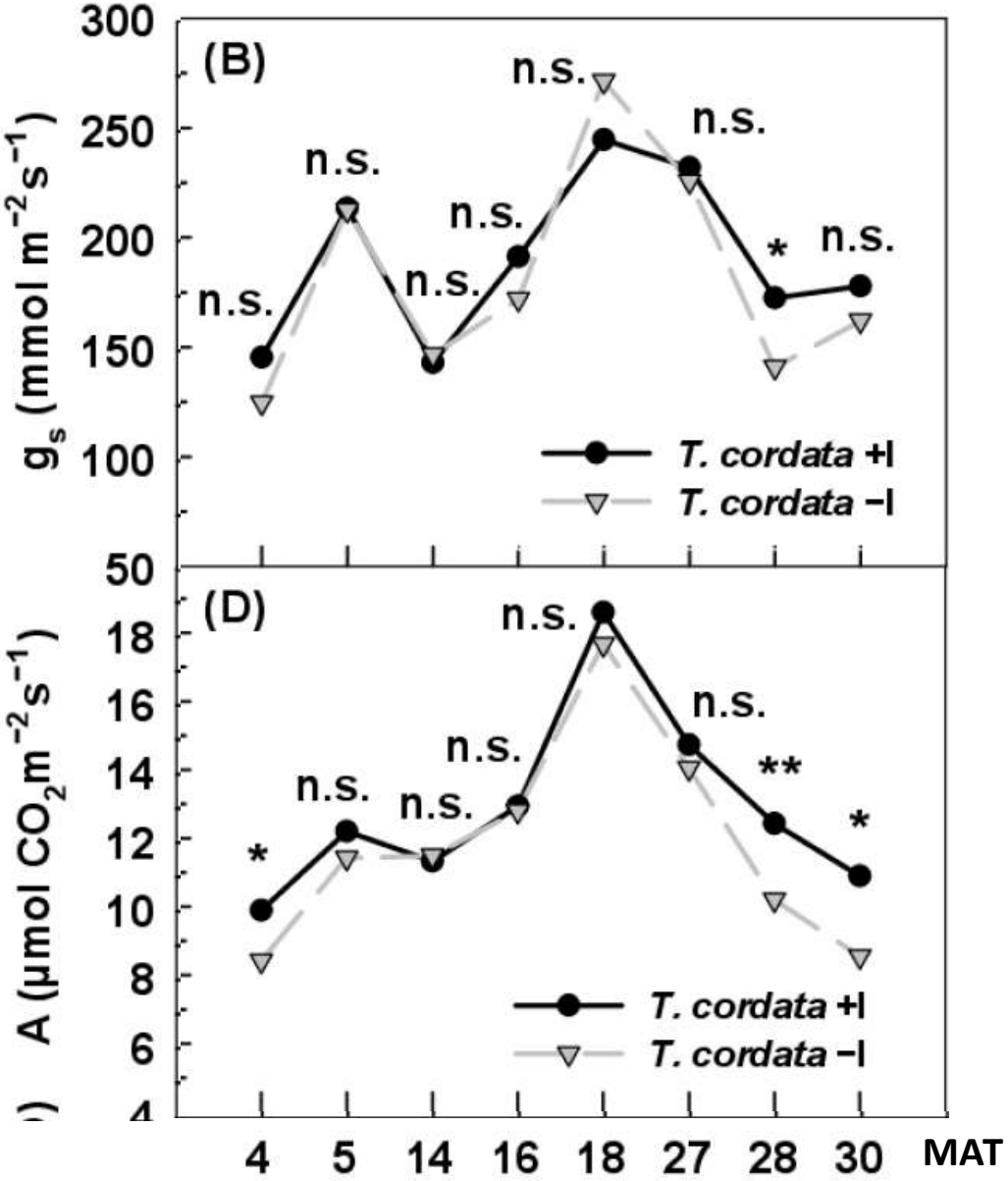
Root colonization (34 months after transplanting)

Percentage of mycorrhizal root tips (ECM) and root colonization after staining (AMF) measured using the magnified intersection method in inoculated (+I) and non-inoculated plants. Different letters denote significant differences between +I and –I plants at $p<0,05$

Species	Inoculation (I)	
	+I (%)	–I (%)
Acer campestre (AMF)	70.6 a	63.0 b
Tilia cordata (AMF)	38.6 a	33.5 a
Tilia cordata (ECM)	87.7 a	91.7 a



- Inoculated *A. campestre* still had higher root colonization then non-inoculated plants
- No difference in root colonization was found between +I and –I plants in linden, both for ECM and VAM



Leaf gas exchange

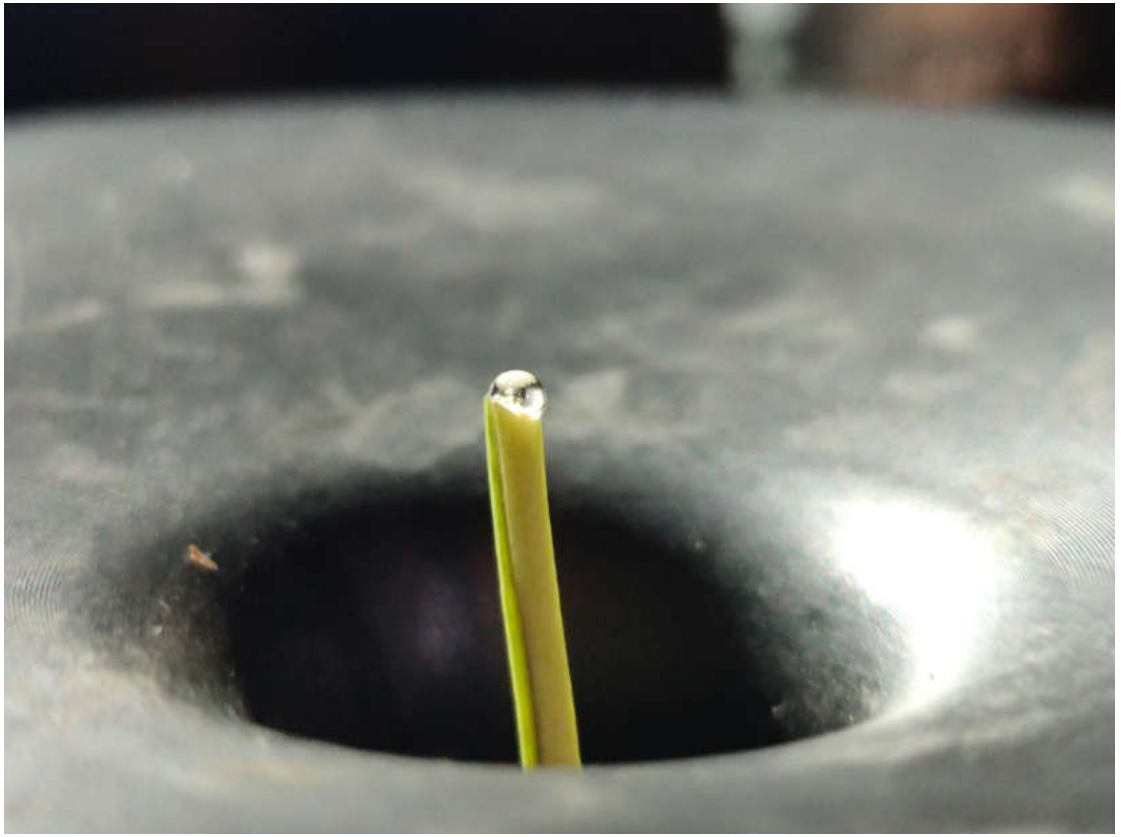
- In *Acer*, both stomatal conductance (gs) and net photosynthesis (A) were consistently increased by inoculation in the 30 months after transplanting
- In *Tilia*, gs and A were not consistently affected by inoculation

- gs is a measure of stomatal opening
- A is the net quantity of atmospheric CO_2 converted into carbohydrates by photosynthesis

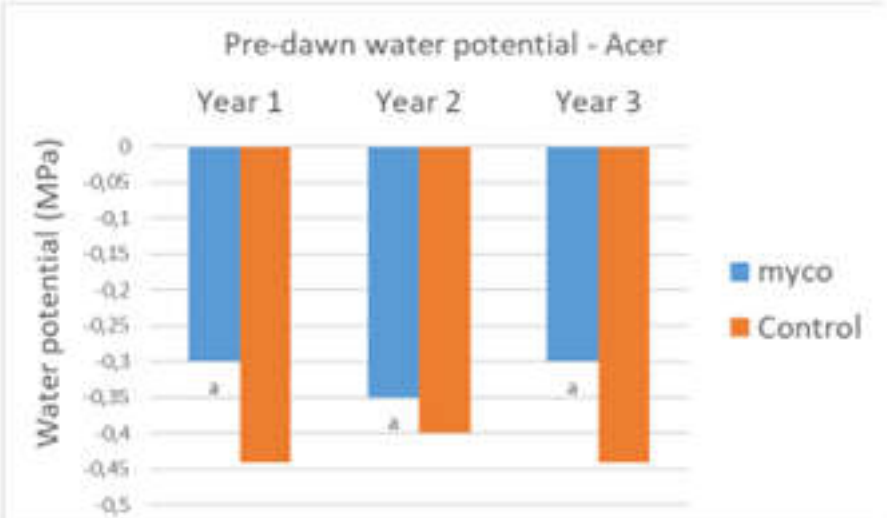
Water relations

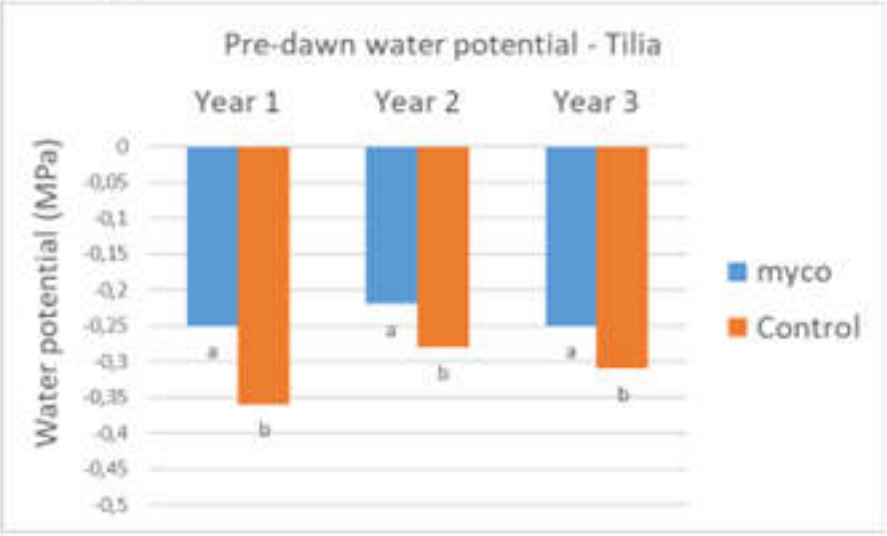
- **Pre-dawn water potential** is major index of plant hydration.
- It is a tension (negative pressure)
- The closer to 0, the better the hydration
- It is made by two components: **osmotic** (negative) and **turgor** (positive)
- The **turgor pressure** is exerted by the plasmalemma on the cell wall, if it declines below a critical threshold, leaves wilt.
- The **osmotic component** is due to compatible solutes (e.g. soluble solids) within the cell. Lowering OP can help maintaining turgor at decreasing water potential (osmotic adjustment)

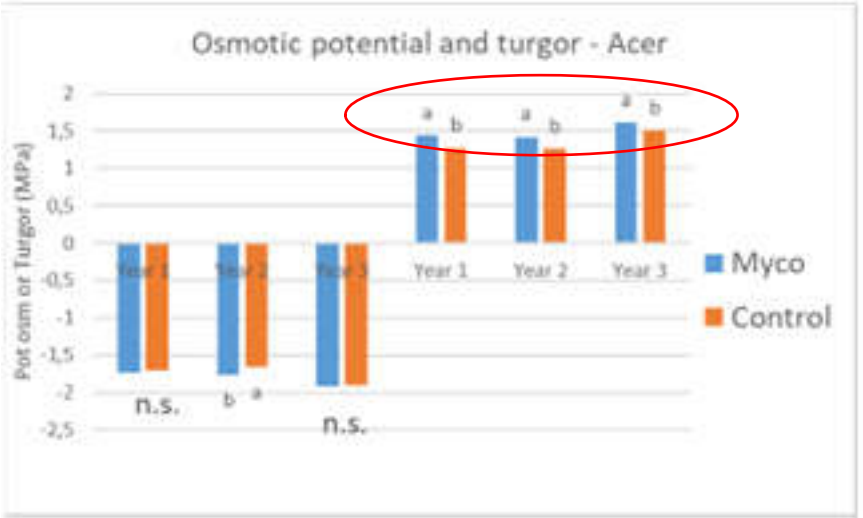
Water potential = Osmotic + Turgor

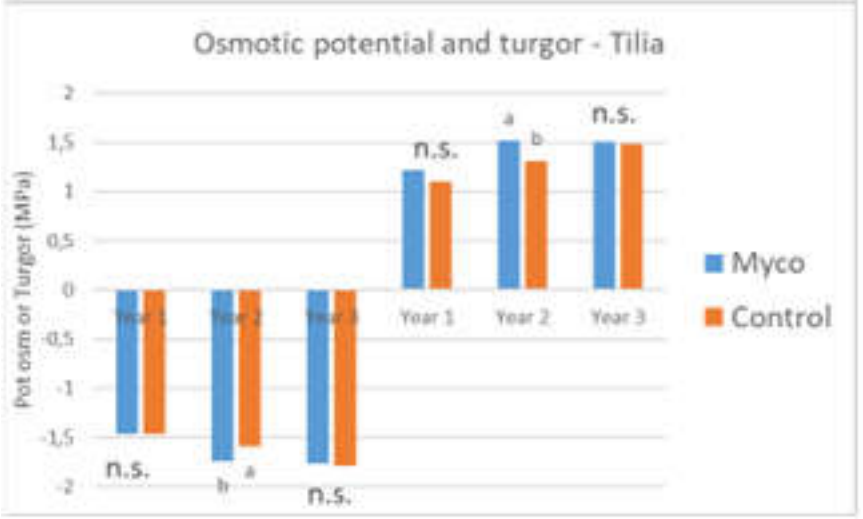


Water potential and its constituents









Water potential and soluble carbohydrates

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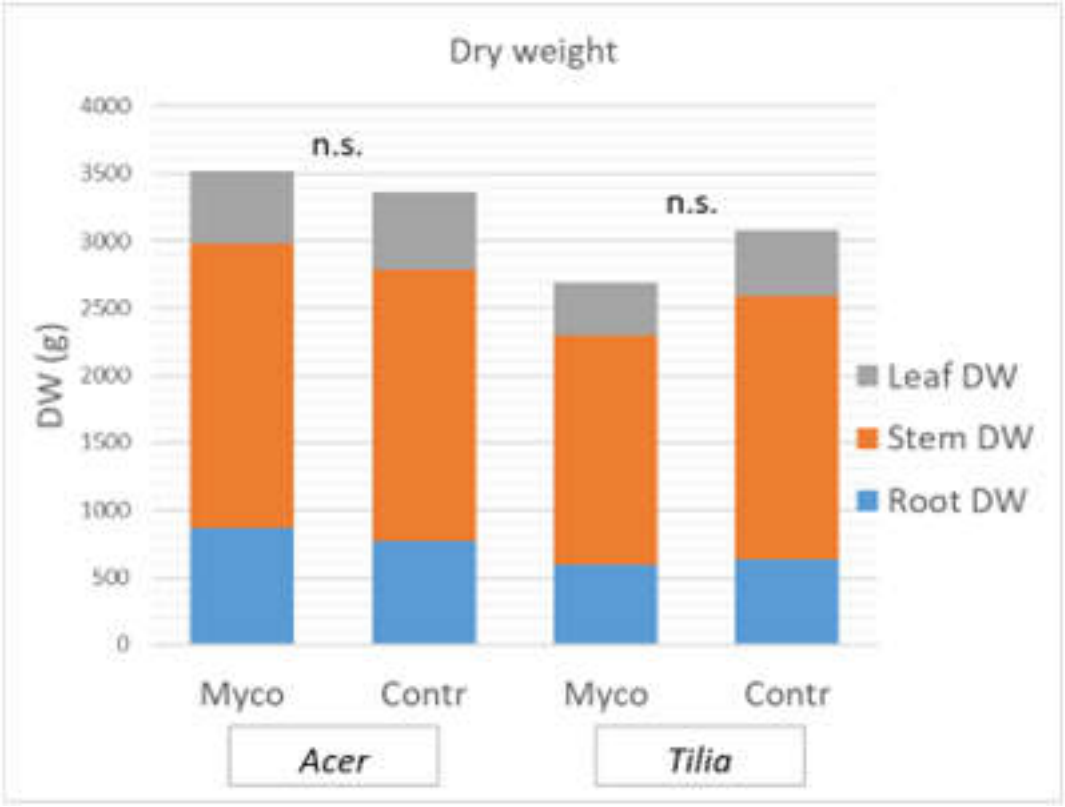
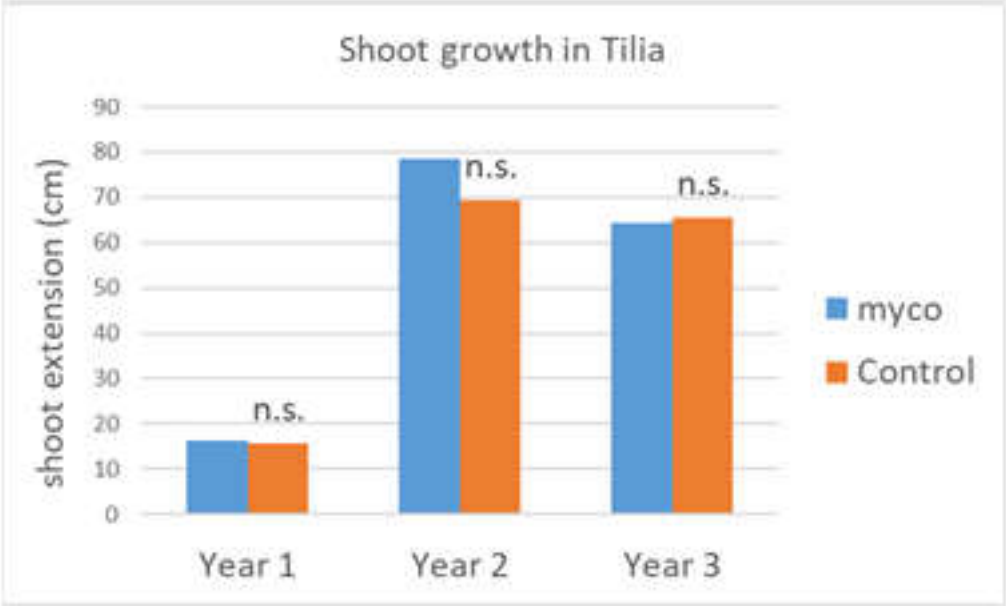
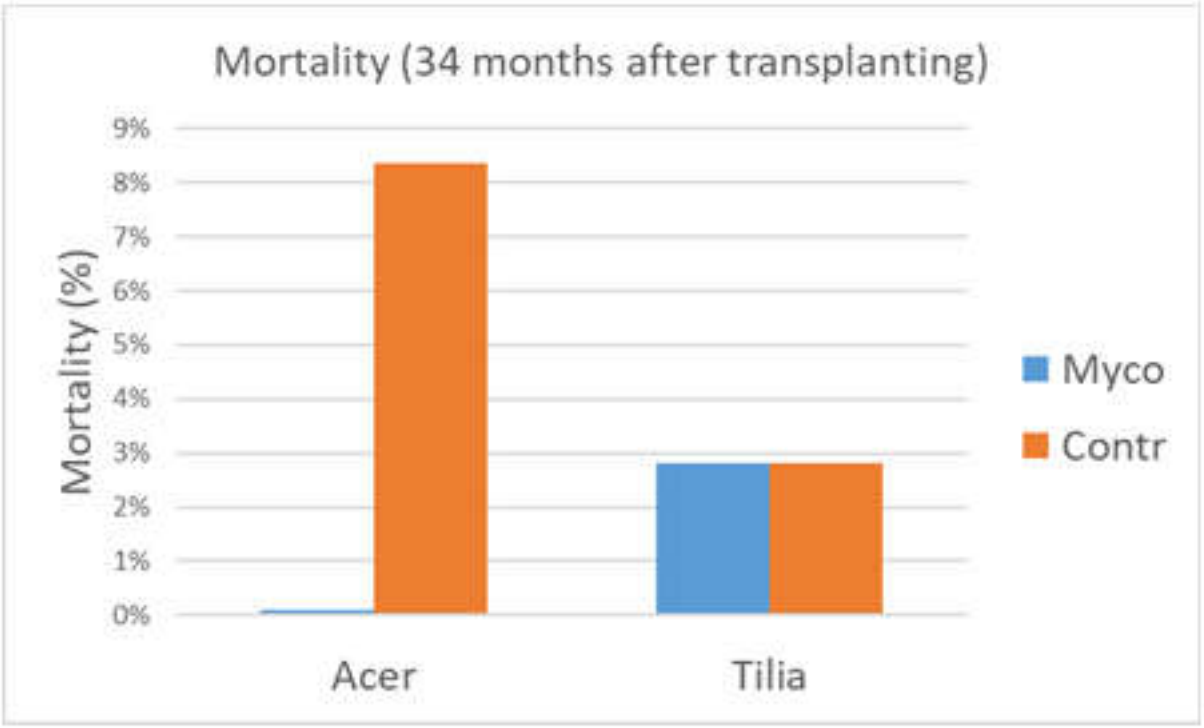
Growth after transplanting

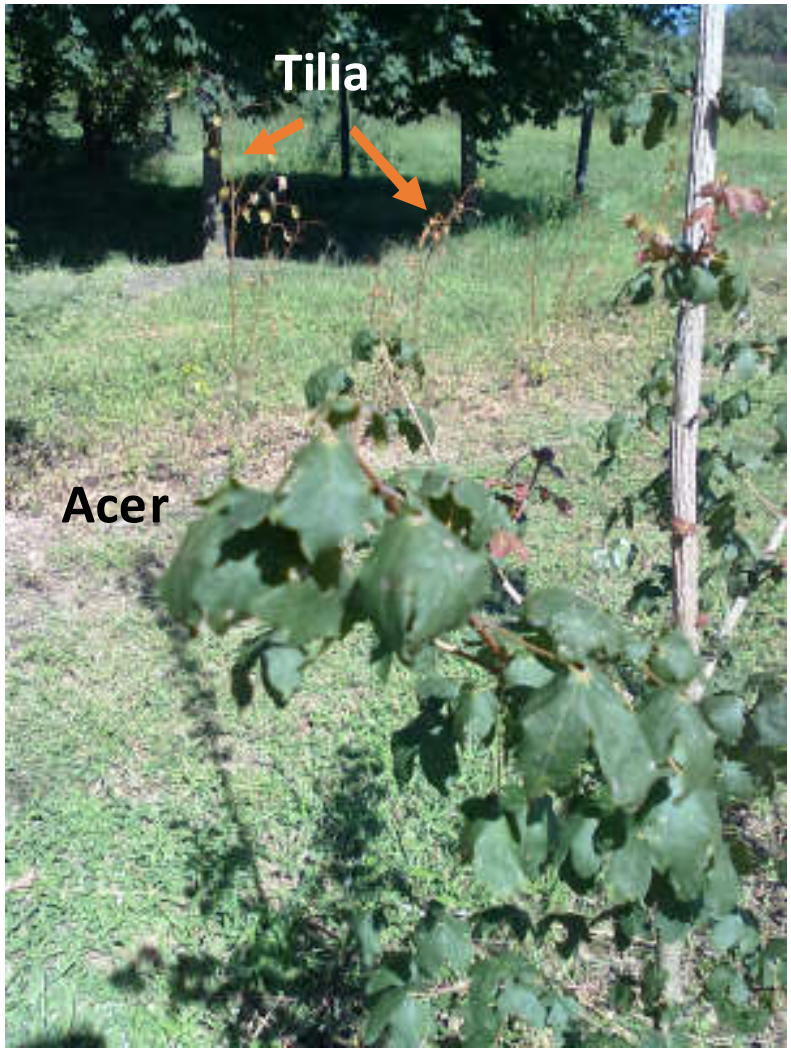


- Dry biomass on 34 MAT was not affected by inoculation
- Shoot growth increased in +I maple on year 2 and 3.



Mortality after transplanting



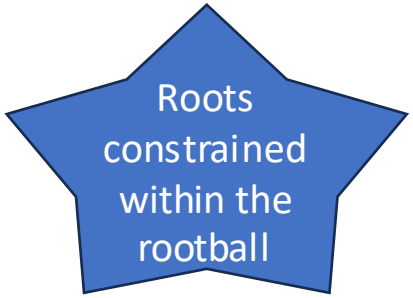


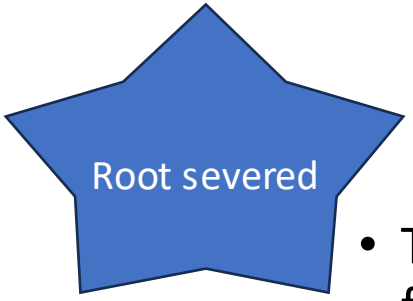
- Inoculated *A. campestre* showed no mortality after transplanting, whereas it was around 8% for non-inoculated maples
- Inoculation did not improve survival in *T. cordata*

Mycorrhiza – take home message

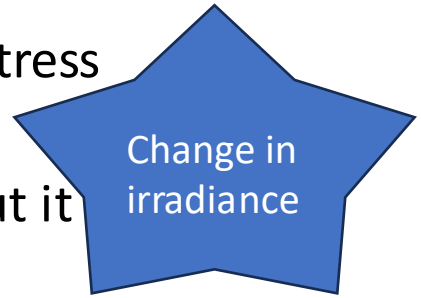
- Plants inoculated in the nursery with specific symbionts sustained higher CO2 assimilation and more favorable water relations after transplanting. The effectiveness of inoculation may be lower in species such as Tilia cordata which commonly establish generalist mycorrhizal symbioses in the open field
- Controlled inoculation in the nursery is technically feasible and may be more cost-effective than inoculation at transplanting (don’t use systemic fungicides!)
- Need for a better understanding of plant species–fungal strain interactions, which might be achieved by sequencing the specific fungal communities in nurseries and at urban sites.

Conclusions





- Transplanting shock is complex and due to multiple stress factors acting together on a root constrained plants
- Nursery pre-conditioning may help establishment, but it not a Panacea
- Quality tree + Quality site + Quality care
- Do not overplant, rather plant the trees you can manage



Thanks to

The biostimulant research was not funded, but falls under the umbrella of PNRR Biodiversity, SPOKE 5, Task 1.4

The mycorrhiza research was funded by Regione Lombardia—Agricultural Department (Research Project no. 1749-dgr 1180/2010), according to the Plan of Research and Development, as a part of the research project "Metodologie produttive e gestionali per migliorare la qualità del verde ornamentale—METAVERDE". Authors are also grateful to Floricoltura San Donato for contributing to the research.