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# Root fungi and absorptive fine root traits under low and high-water availability

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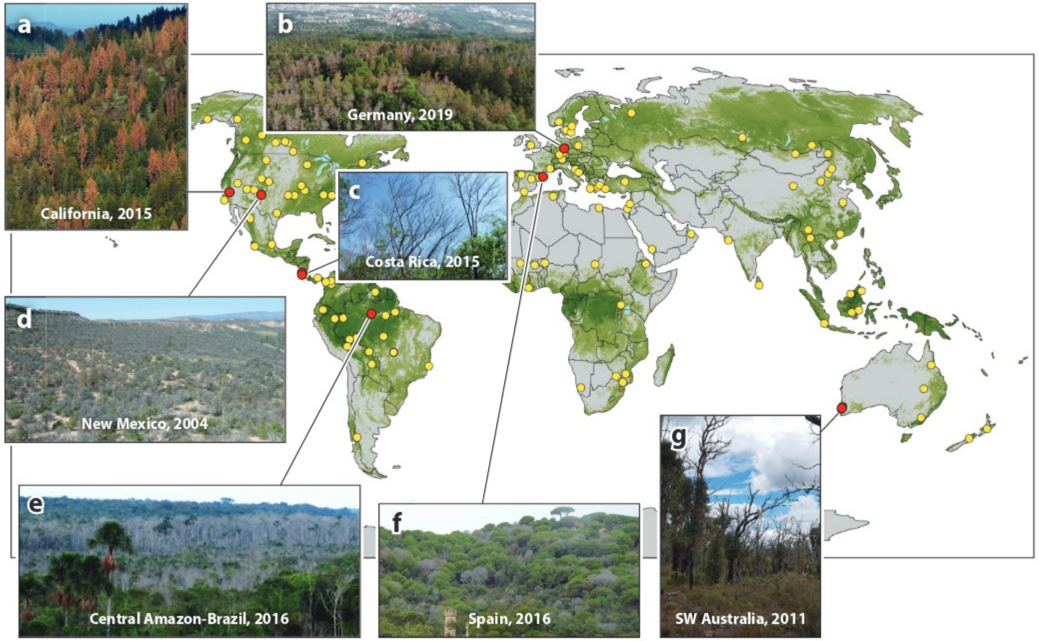
# Outline

1. Climate change → drought
2. Research questions & hypothesis
3. International Diversity Experiment Network with Trees (IDENT in Sault Ste. Marie, Ontario)
4. Root coring and sorting
5. Root traits & fungi

# Increased vulnerability of forests to future warming and drought related die-off




Source: Hartmann et al. (2022)

Article

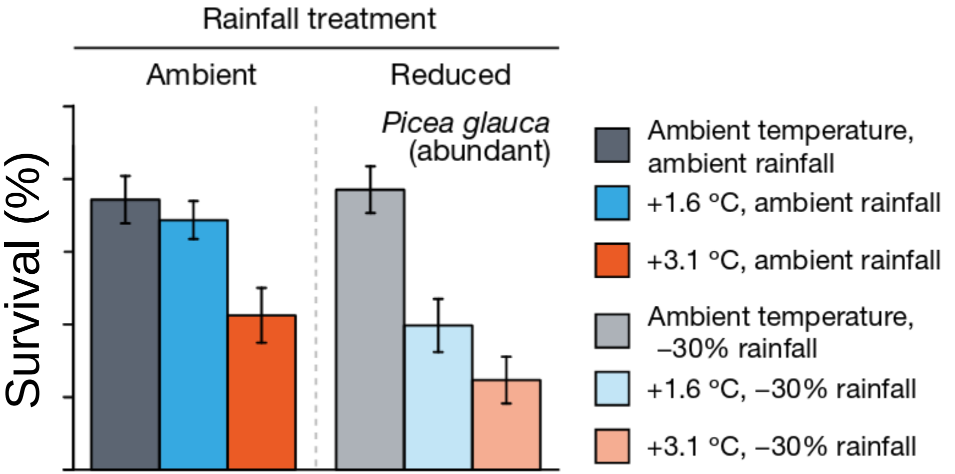
**Even modest climate change may lead to major transitions in boreal forests**


https://doi.org/10.1038/s41586-022-05076-3

Received: 10 May 2021



Peter B. Reich[1,2,3]✉, Raimundo Bermudez[1], Rebecca A. Montgomery[1], Roy L. Rich[1,4], Karen E. Rice[1], Sarah E. Hobbie[5] & Artur Stefanski[1]

# Questions and hypothesis root associated fungi:

1. How are fungal community abundance, richness, structure, and composition of pathogens, saprotrophs, and mutualists influenced by high and low $H_2O$?

- Mutualists abundance and richness higher under high $H_2O$, while pathogens and saprotrophs higher under low $H_2O$

2. How do root traits structure the root microbiome under low or high $H_2O$

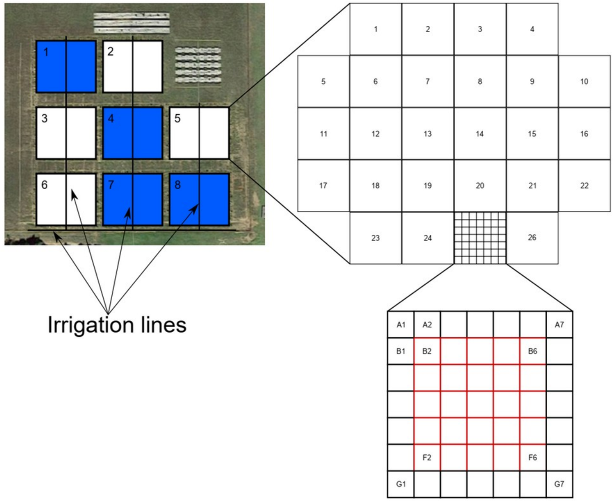
- Abundance of pathogenic and saprotrophic fungi higher under low $H_2O$ through high specific root length, specific root surface area, and root branching density

3. How is shoot mass affected through fungal functional groups, root traits, and $H_2O$

- (see structural equation model)

# International Diversity Experiment Network with Trees (IDENT), Sault Ste. Marie (Ontario)

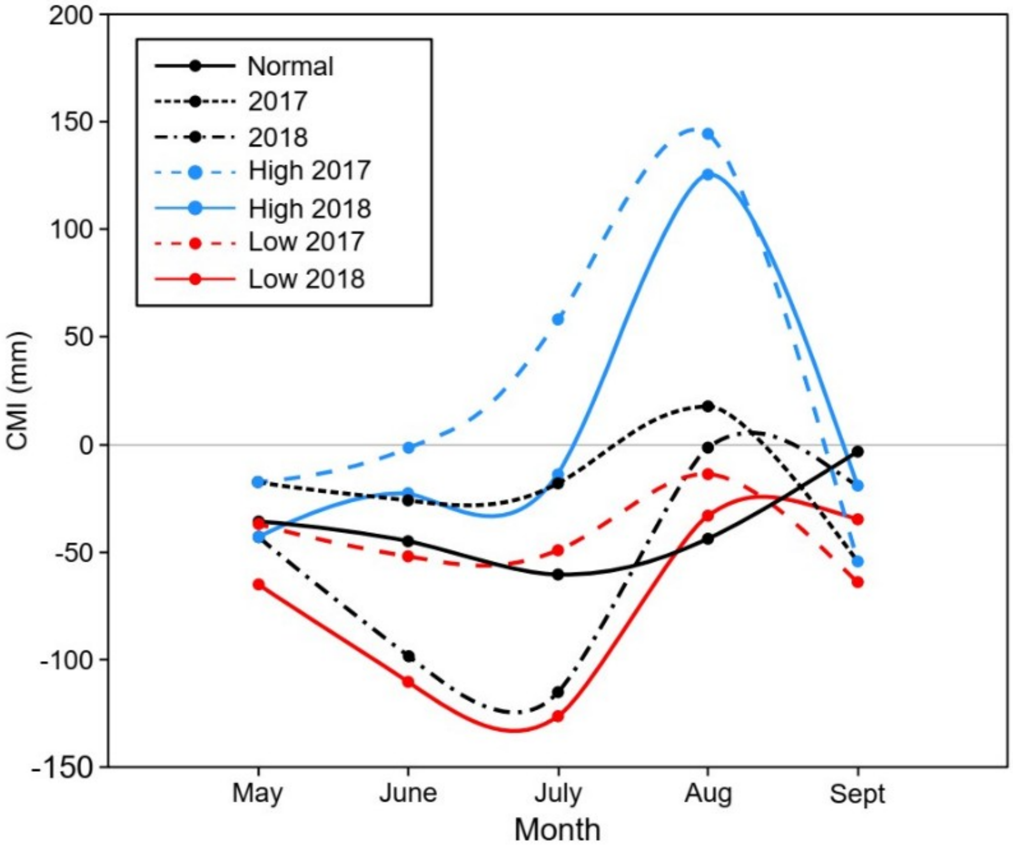
Source: https://treedivnet.ugent.be/ExpIDENT.html




Source: William C. Parker

Source: Florentin Jaeger

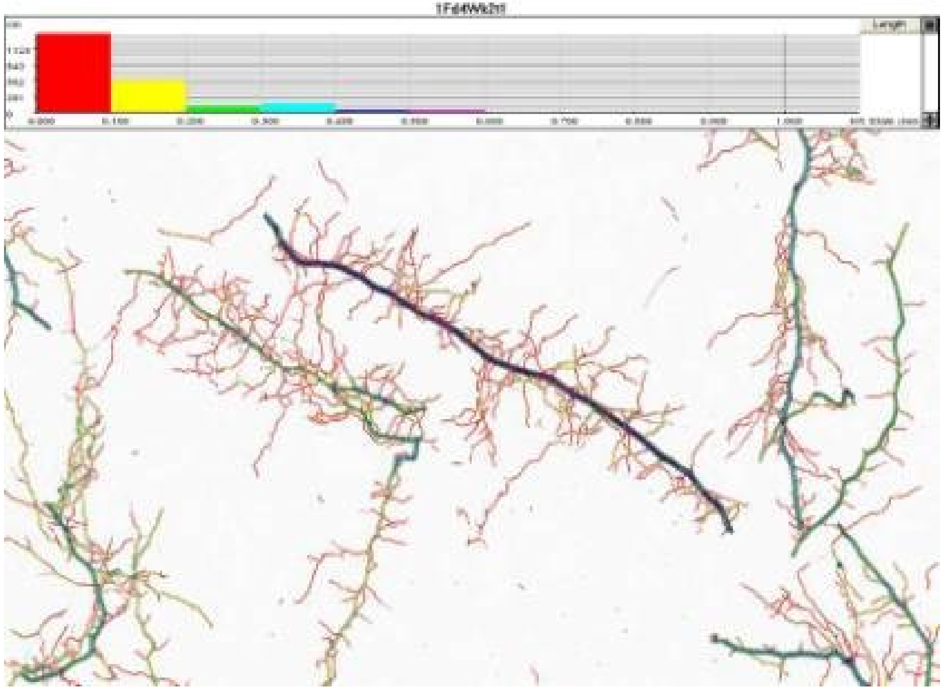
# 250 % moisture addition vs. 25 % moisture removal

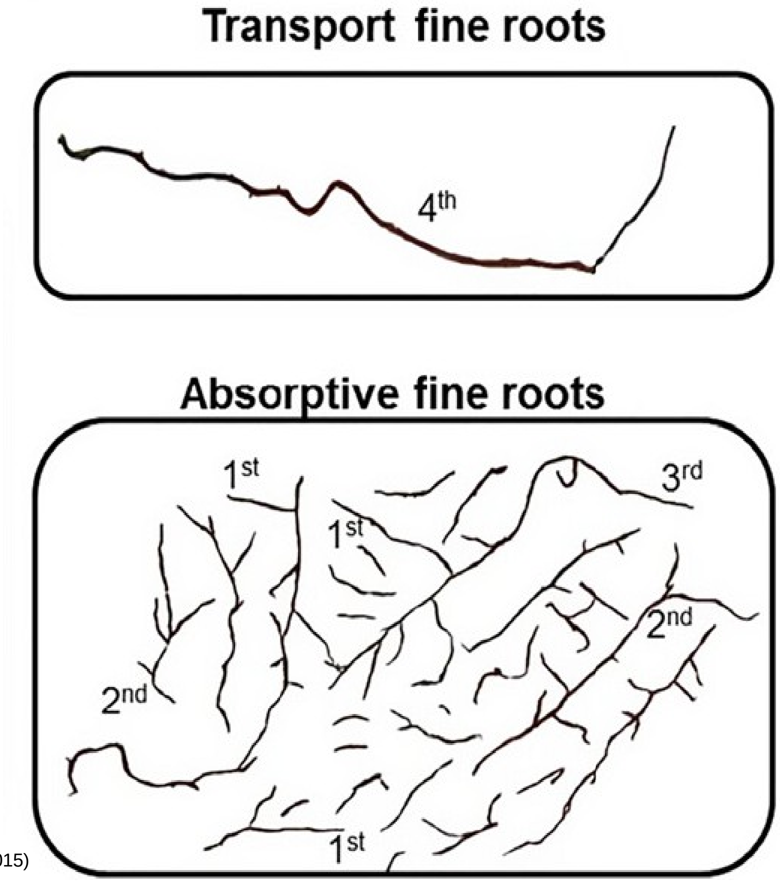



Source: Belluau et al. (2021) supp. info

# Root coring (August & September 2018)

# Root sorting and collection of molecular root samples





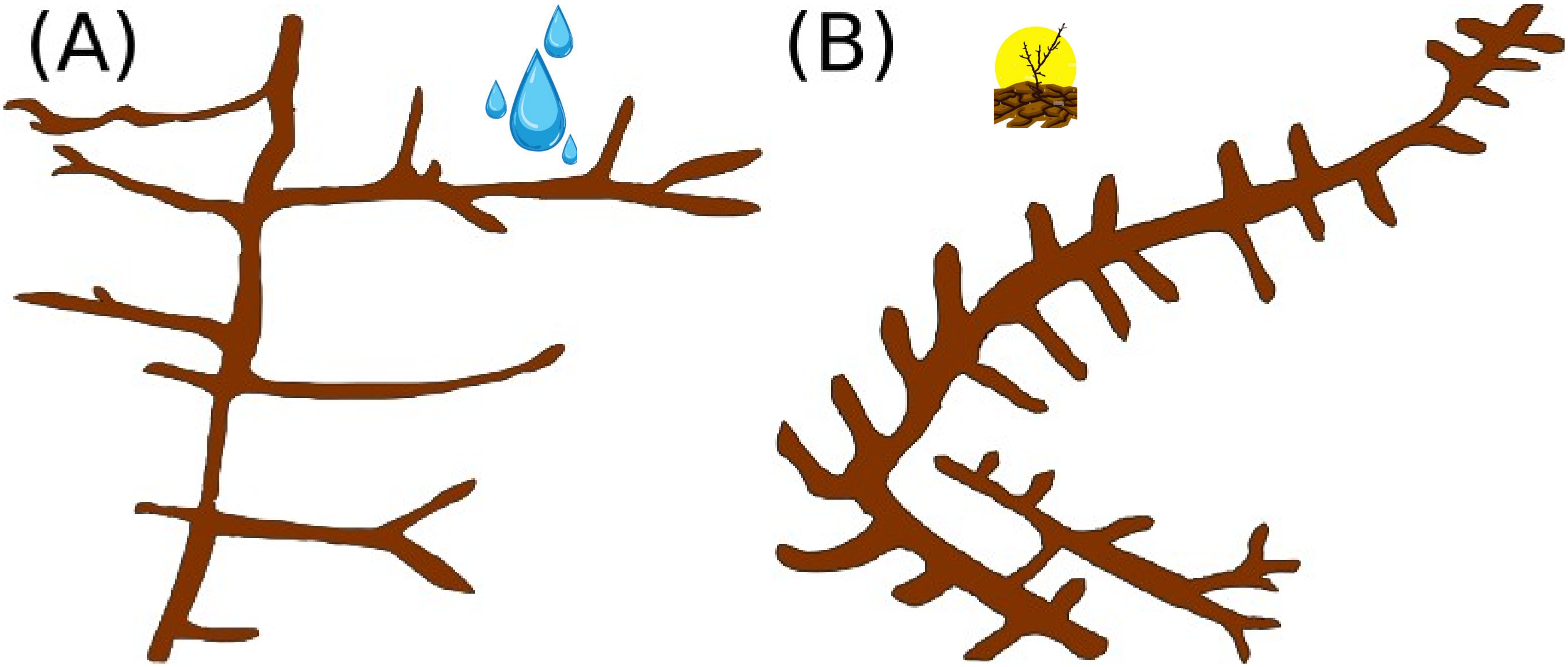

Source: Mc Cormack et al. (2015)

# Linear and generalized linear mixed effect models

- lme4::lmer(richness ~ species x $H_20$ + (1 | bloc), data = …, REML = T)

- adonis2(formula = vegdist(comm_rarfy, method = “bray”) ~ species x $H_20$, data = ...)

# Increase of absorptive capacity through higher root branching density rather than greater surface area *per se* (i.e. root length, SRL & RLD)

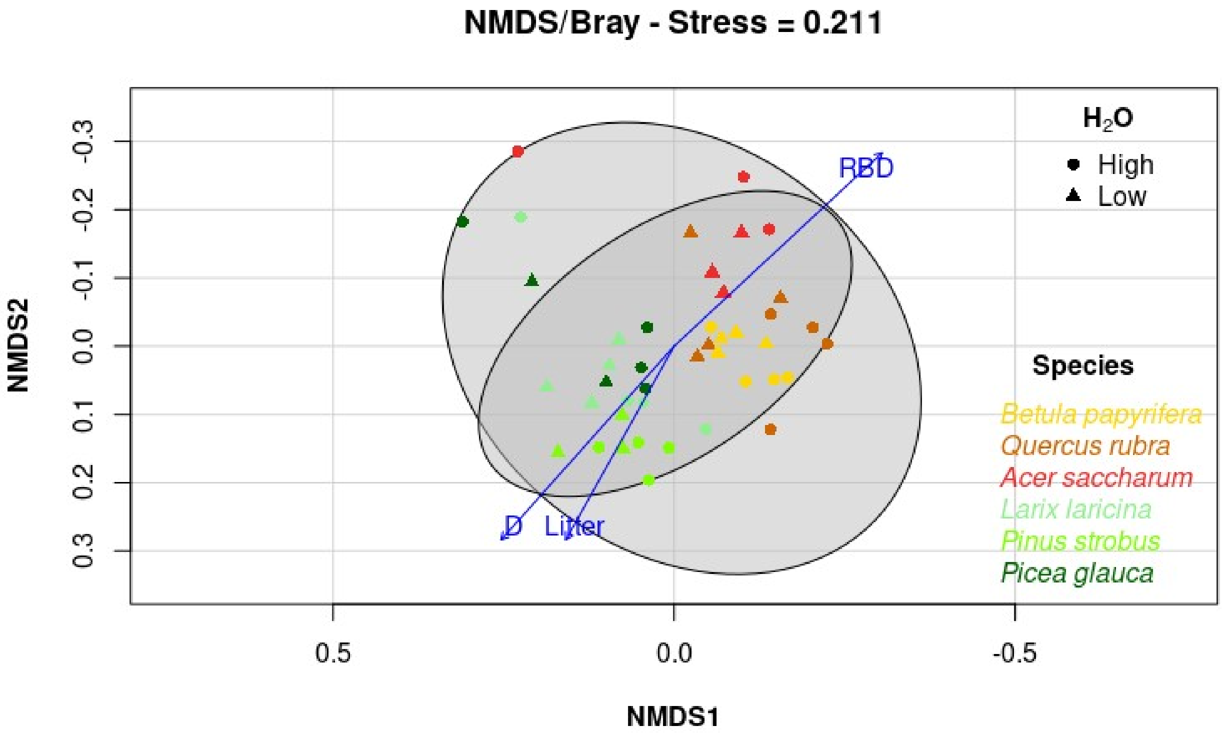



Source: https://www.creativefabrica.com/product/water-drops-2/

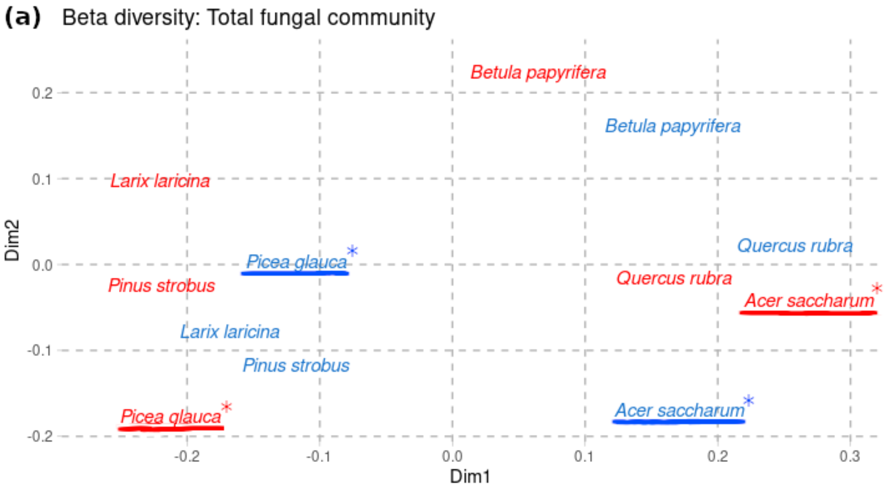
Source: https://www.alamy.com

| Fungal group | Attribute | Tree species (Sp) | $H_2O$ | Sp x $H_2O$ |
|---|---|---|---|---|
| Total community | Richness | **14.08 (<0.001)** | 0.11 (0.74) | **8.15 (<0.001)** |
| | Structure (PERMANOVA) | **2.83 (<0.001)** | **1.51 (<0.001)** | 1.07 (0.23) |
| | Composition (PCoA1) | **33.82 (<0.001)** | 1.45 (0.26) | 1.63 (0.18) |
| | Composition (PCoA2) | **4.09 (<0.01)** | 1.31 (0.29) | 1.14 (0.35) |
| Pathogens | Richness (GLM) | **15.84 (<0.01)** | **16.52 (<0.001)** | **27.93 (<0.001)** |
| | Structure (PERMANOVA) | **2.69 (<0.01)** | **0.82 (0.07)** | **2.08 (<0.05)** |
| | Composition (PCoA1) | 0.51 (0.72) | 0.03 (0.85) | 0.38 (0.81) |
| | Composition (PCoA2) | 1.61 (0.24) | 2.09 (0.19) | 0.62 (0.65) |
| | Abundance (GLM) | 3.92 (0.55) | **3.67 (0.055)** | 4.91 (0.42) |
| Saprotrophs | Richness | **3.70 (<0.05)** | 0.50 (0.50) | **4.91 (<0.01)** |
| | Structure (PERMANOVA) | **3.92 (<0.01)** | 0.92 (0.33) | 1.07 (0.45) |
| | Composition (PCoA1) | **10.99 (<0.001)** | 0.68 (0.44) | 1.96 (0.11) |
| | Composition (PCoA2) | **9.64 (<0.001)** | 1.28 (0.26) | 0.75 (0.59) |
| | Abundance | **6.52 (<0.001)** | 0.26 (0.62) | 0.90 (0.49) |
| Mutualists | Richness | **12.38 (<0.001)** | 1.36 (0.28) | **3.86 (<0.01)** |
| | Structure (PERMANOVA) | **15.51 (<0.001)** | **4.43 (<0.001)** | **4.00 (<0.05)** |
| | Composition (PCoA1) | **2.22 (0.08)** | 1.31 (0.29) | 1.12 (0.37) |
| | Composition (PCoA2) | **10.76 (<0.001)** | 0.92 (0.37) | 1.02 (0.42) |
| | Abundance | **26.97 (<0.001)** | 0.73 (0.43) | **2.22 (0.08)** |

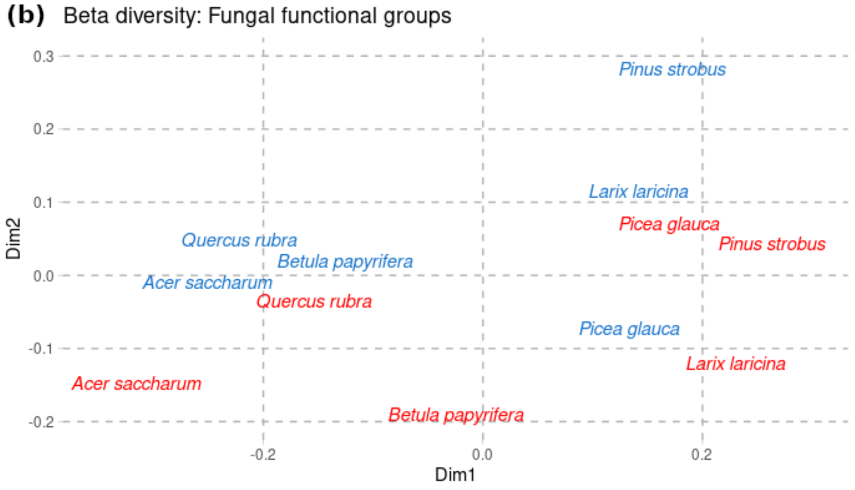
# Angio- vs. Gymnosperms separated fungal community and root traits



# Total fungal community --> *A. Saccharum* and *P. Glauca* are separated according to $H_2O$ (a), while fungal groups are only separated according to $H_2O$ on a global level (b)

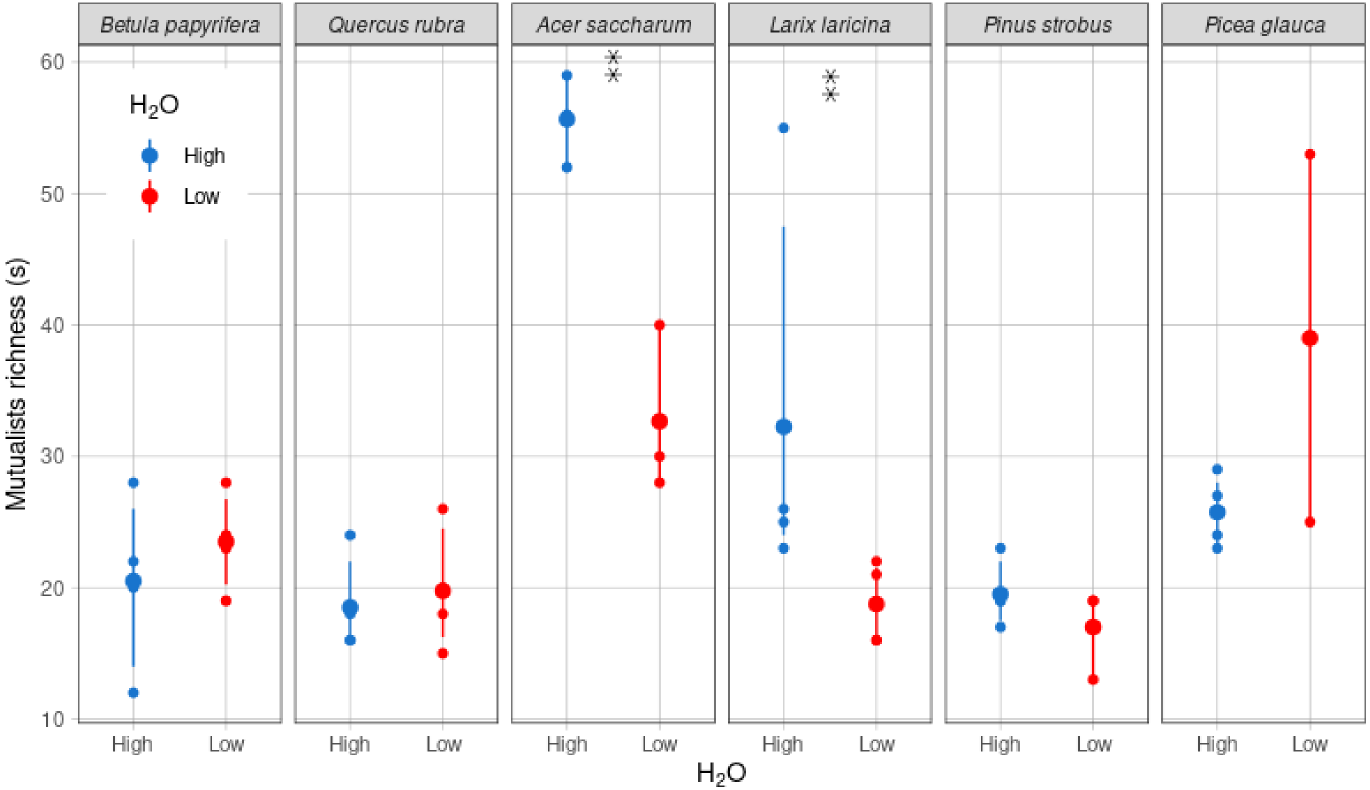



| Source of variation | Df | Sum of Squares | $R^2$ | $F$ | Pr(>$F$) |
|---|---|---|---|---|---|
| $H_2O$ Low | 1 | 0.5011 | 0.02872 | 1.4952 | **<0.05** |
| *Quercus rubra* | 1 | 0.9955 | 0.05706 | 2.9707 | **0.08333** |
| *Acer saccharum* | 1 | 1.1090 | 0.06356 | 3.3092 | **0.08333** |
| *Larix laricina* | 1 | 0.7320 | 0.04196 | 2.1844 | **0.08333** |
| *Pinus strobus* | 1 | 0.9931 | 0.05692 | 2.9635 | **<0.05** |
| *Picea glauca* | 1 | 0.9269 | 0.05313 | 2.7658 | **0.08333** |
| $H_2O$ Low x *Quercus rubra* | 1 | 0.4176 | 0.02394 | 1.2462 | 0.62500 |
| $H_2O$ Low x *Acer saccharum* | 1 | 0.4803 | 0.02753 | 1.4333 | **<0.05** |
| $H_2O$ Low x *Larix laricina* | 1 | 0.2520 | 0.01444 | 0.7519 | 0.95833 |
| $H_2O$ Low x *Pinus strobus* | 1 | 0.2790 | 0.01599 | 0.8324 | 0.29167 |
| $H_2O$ Low x *Picea glauca* | 1 | 0.3715 | 0.02129 | 1.1084 | **<0.05** |
| Residuals | 31 | 10.3885 | 0.59545 | - | - |

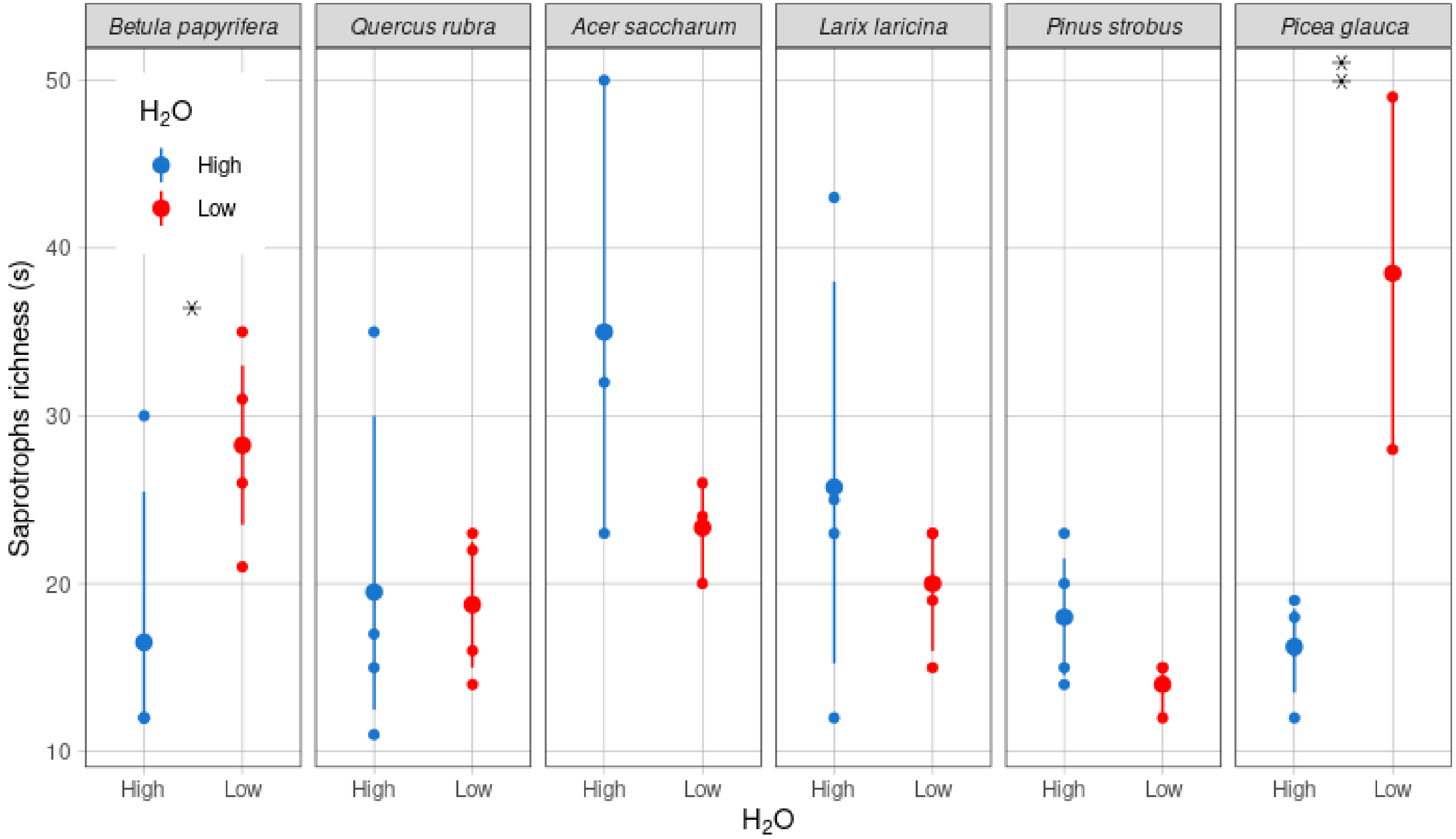



| Source of variation | Df | Sum of Squares | $R^2$ | $F$ | Pr(>$F$) |
|---|---|---|---|---|---|
| $H_2O$ Low | 1 | 0.5123 | 0.02971 | 1.5387 | **<0.05** |
| *Quercus rubra* | 1 | 0.9778 | 0.05670 | 2.9369 | **<0.05** |
| *Acer saccharum* | 1 | 1.2401 | 0.07191 | 3.7247 | **0.08333** |
| *Larix laricina* | 1 | 0.6492 | 0.03764 | 1.9499 | 0.12500 |
| *Pinus strobus* | 1 | 0.9657 | 0.05600 | 2.9007 | **0.08333** |
| *Picea glauca* | 1 | 0.8407 | 0.04875 | 2.5249 | **0.08333** |
| $H_2O$ Low x *Quercus rubra* | 1 | 0.5693 | 0.03301 | 1.7100 | 0.20833 |
| $H_2O$ Low x *Acer saccharum* | 1 | 0.3662 | 0.02123 | 1.0998 | 0.12500 |
| $H_2O$ Low x *Larix laricina* | 1 | 0.2326 | 0.01349 | 0.6986 | 0.95833 |
| $H_2O$ Low x *Pinus strobus* | 1 | 0.2329 | 0.01352 | 0.6996 | 0.75000 |
| $H_2O$ Low x *Picea glauca* | 1 | 0.3379 | 0.01960 | 1.0150 | 0.12500 |
| Residuals | 31 | 10.3211 | 0.59847 | - | - |

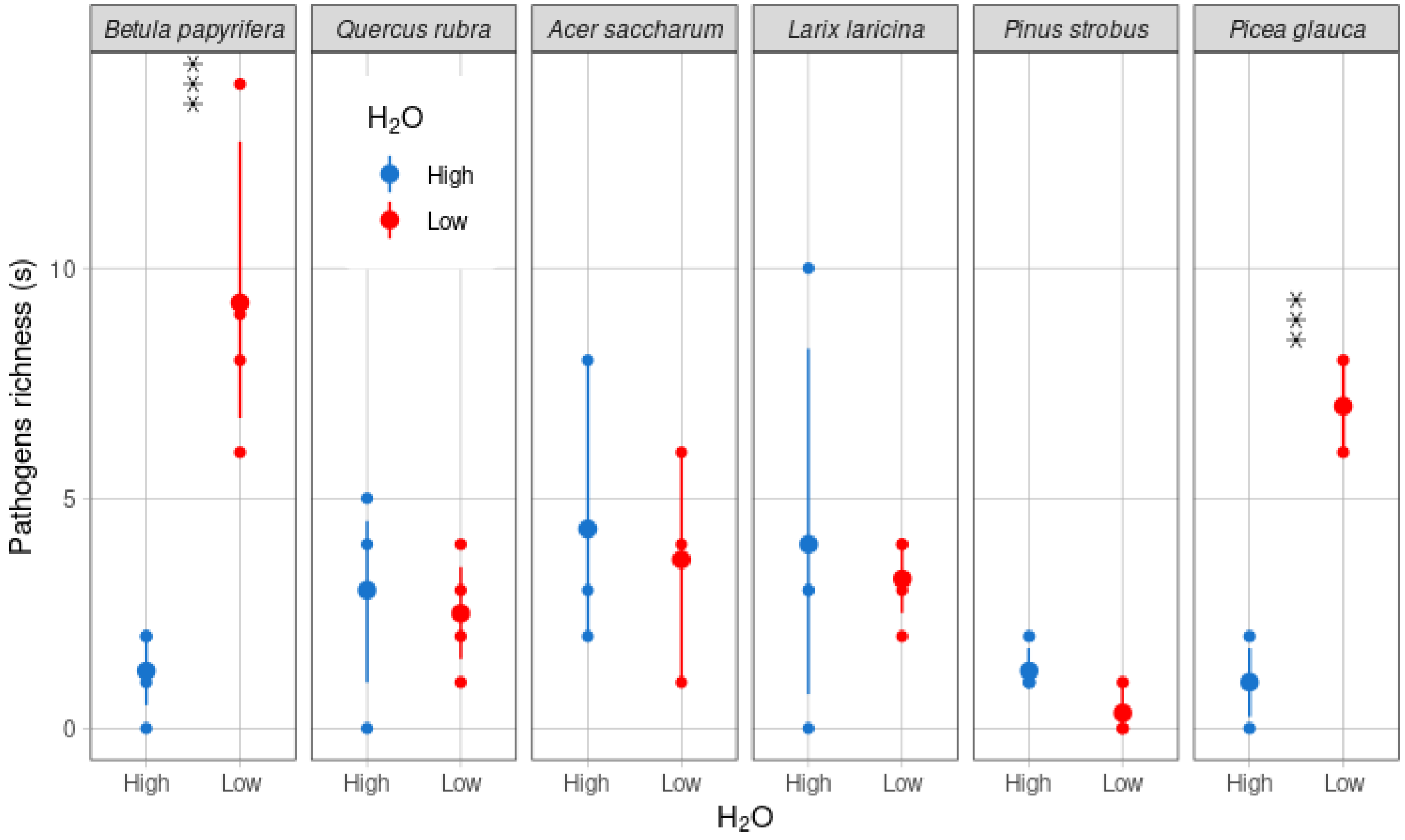
# Higher richness under more benign growing conditions ($H_2O$ high) for *A. Saccharum* & *L. laricina*



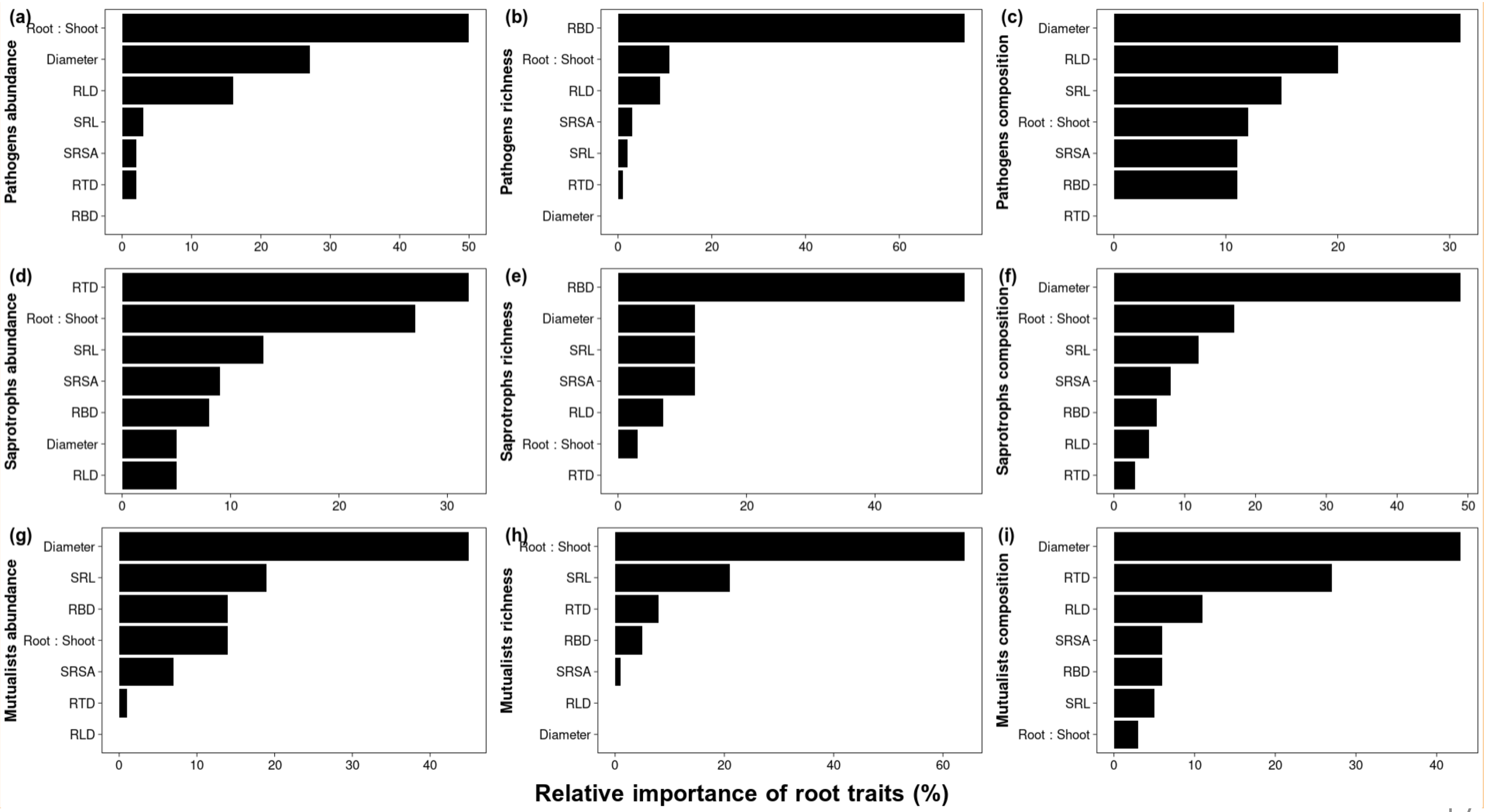
# Saprotroph richness increased under low $H_2O$ for *B. Papyrifera & P. Glauca*



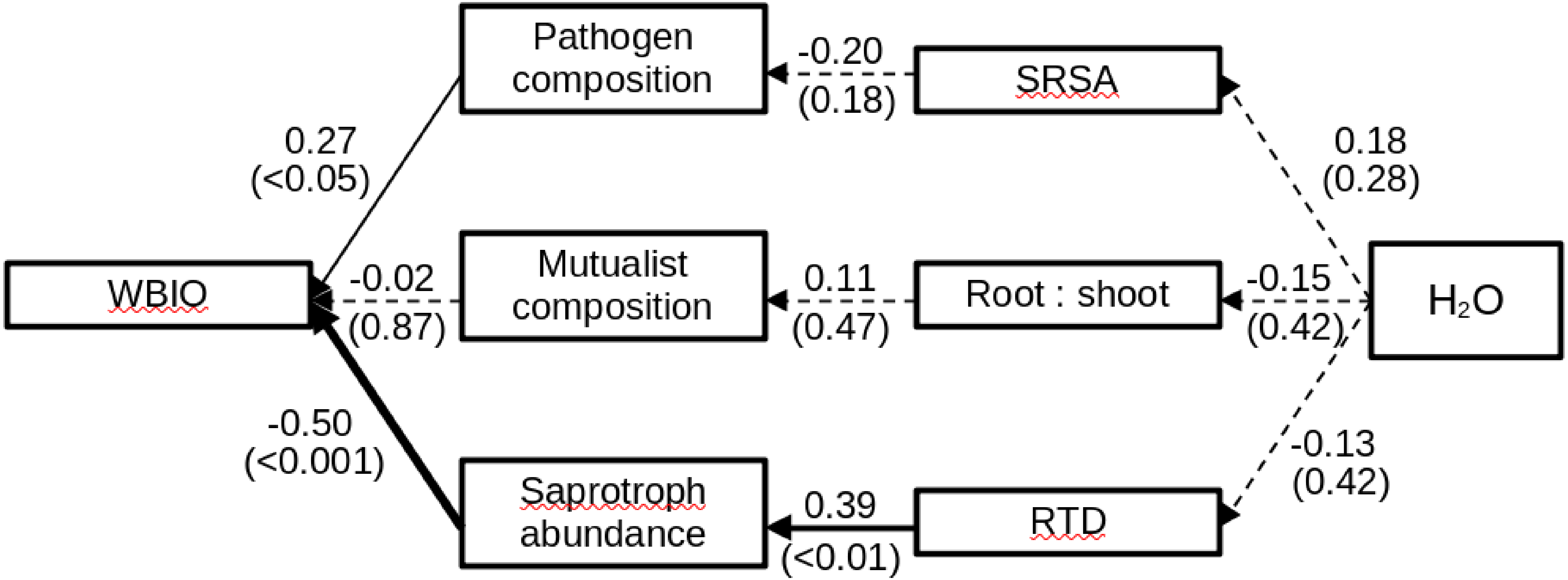
# Pathotrophs might take advantage of dryer roots (more root leasons?)



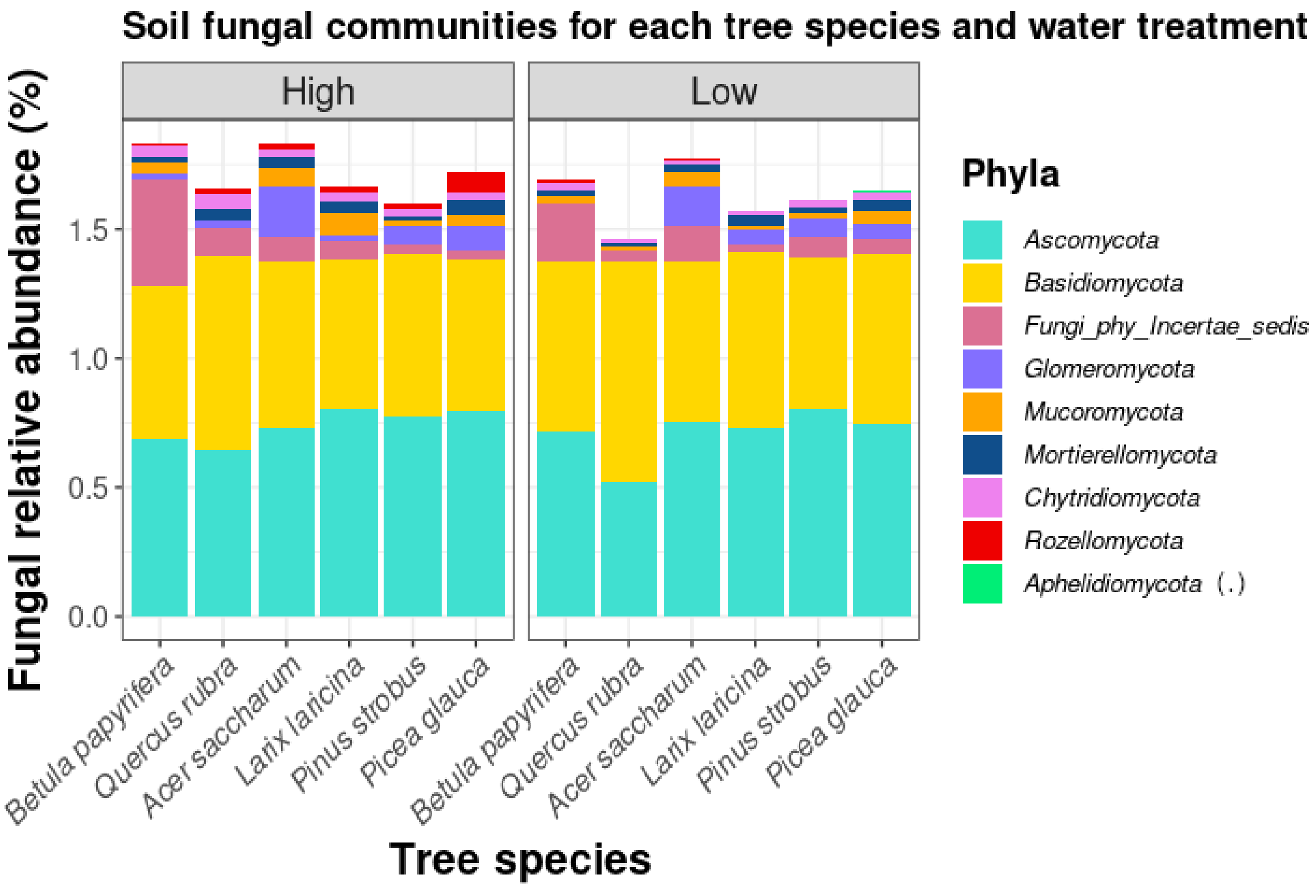
# Saprotroph and pathogen abundance not higher under low $H_2O$, and high root surface area not the primary driver of saprotroph and pathogen abundance.



# Fungal functional groups are more important than $H_2O$, and only RTD effects saprotroph abundance.



# Only *Aphelidiomycota* marginally shift with $H_2O$



# Conclusion

- Tree species-specific fungal response
- Slower growing species (*Acer saccharum* & *Picea glauca*) might be more vulnerable
- Root branching density more important for fungi than root surface area
- Fungal functional group influence on tree productivity stronger than root traits

# References

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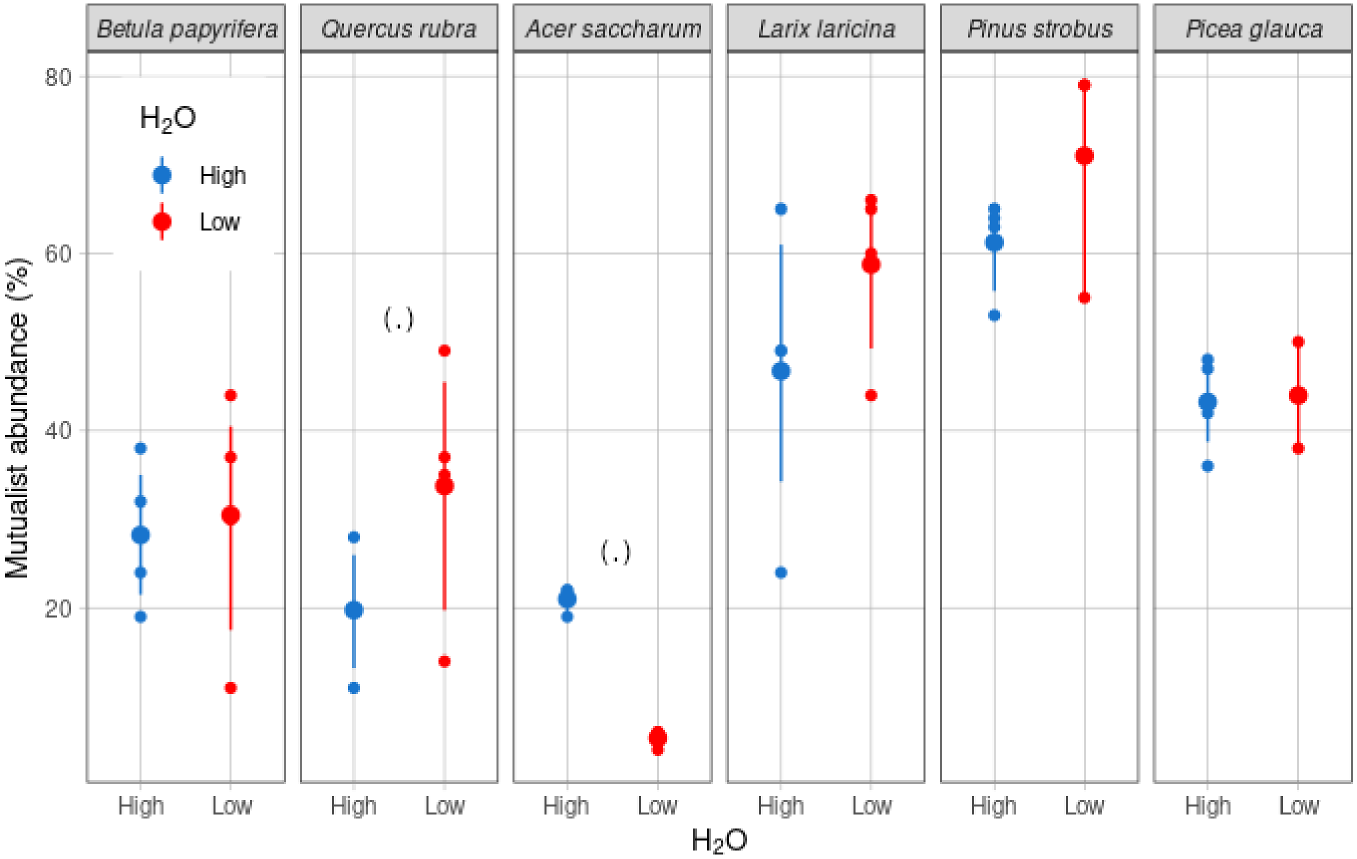
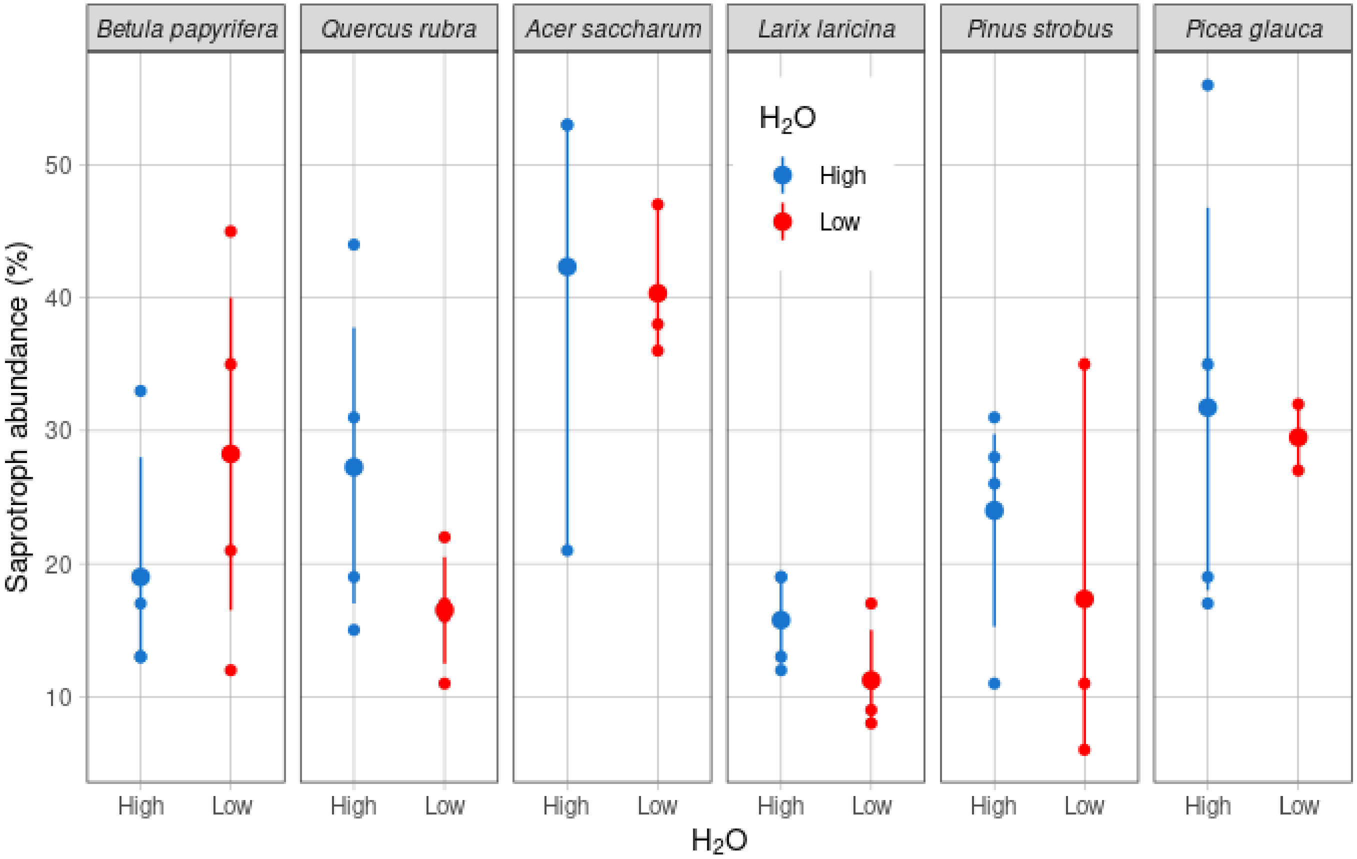
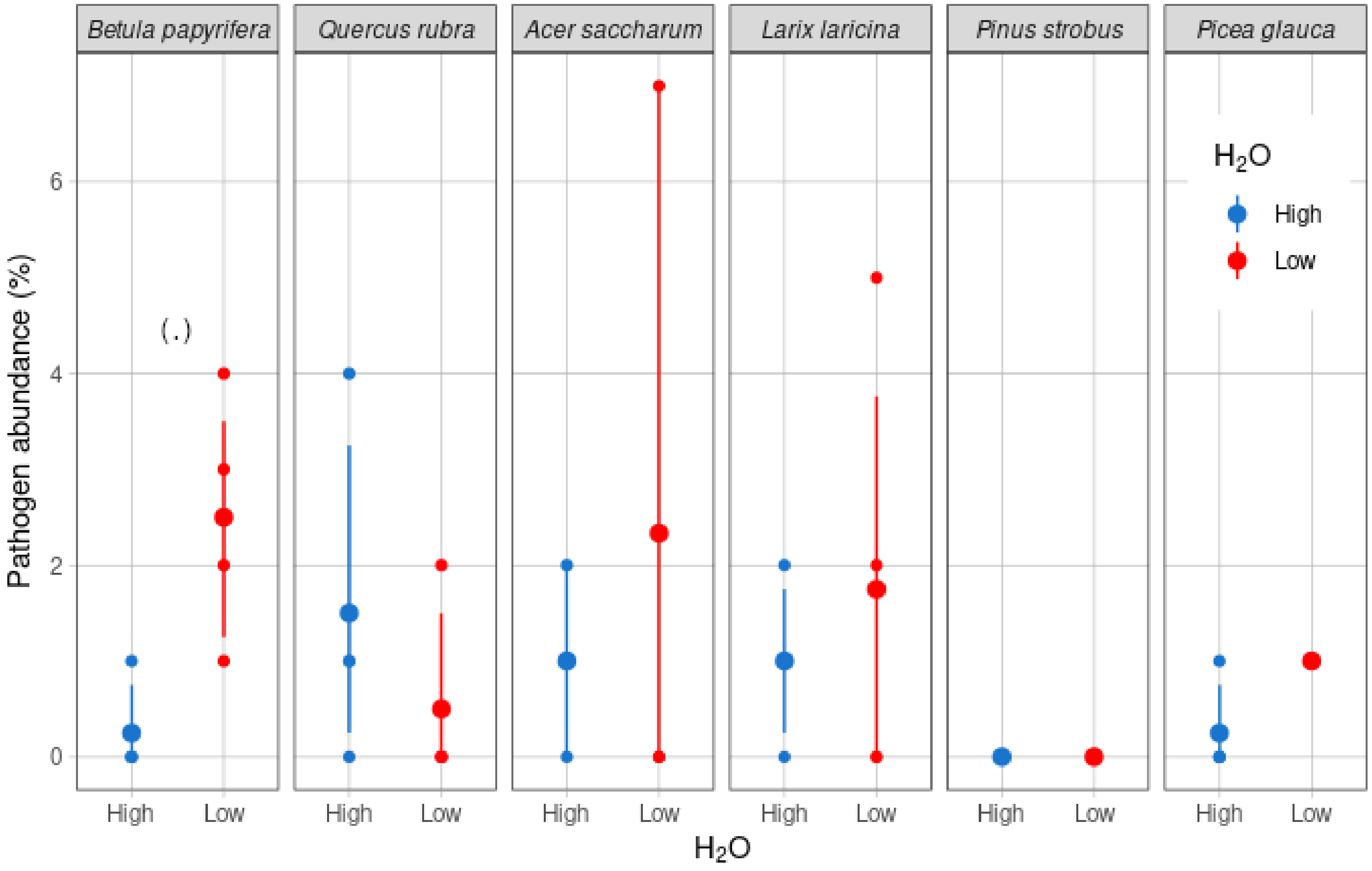


Betula papyrifera
Quercus rubra
Acer saccharum
Larix laricina
Pinus strobus
Picea glauca
80
60
40
20
Mutualist abundance (%)
$H_2O$
High
Low
(.)
(.)
High
Low
High
Low
High
Low
High
Low
High
Low
High
Low
$H_2O$



Betula papyrifera
Quercus rubra
Acer saccharum
Larix laricina
Pinus strobus
Picea glauca
Saprotroph abundance (%)
50
40
30
20
10
$H_2O$
High
Low
High
Low
High
Low
High
Low
High
Low
High
Low
High
Low
$H_2O$


Betula papyrifera
Quercus rubra
Acer saccharum
Larix laricina
Pinus strobus
Picea glauca
(.)
Pathogen abundance (%)
0
2
4
6
High
Low
$H_2O$
High
Low

# Root traits

| Traits | Hypothesized function | Predicted response to $H_2O$ |
| --- | --- | --- |
| *Architecture* | | |
| Root branching density (n $cm^{-1}$) | Absorptive capacity, foraging precision, resistance to and avoidance of drought | Increase under drought |
| *System and distribution* | | |
| Root length density (cm $cm^{-3}$) | Spatial coverage of a given soil volume, water acquisition and resistance to and avoidance of drought (exploitation intensity) | Decreased under drought |
| *Morphology* | | |
| Specific root length (m $g^{-1}$) | Length of roots exploring or exploiting the soil per unit root mass invested, water acquisition and plant resistance to and avoidance of drought | Varied response |
| Root tissue density (g $cm^{-3}$) | Recalcitrance and desiccation resistance | Predominantly no effect of drought, or increased under lower precipitation |