Leaf and tree water-use efficiency of *Populus deltoides* × *P. nigra* in mixed forest and agroforestry plantations

Anaïs Thomas, Nicolas Marron, Damien Bonal,

Séverine Piutti, Erwin Dallé and Pierrick Priault

UNIVERSITÉ DE LORRAINE

INRAE

- Water becomes a scarce resource under temperate latitudes
- Mixture plantations have the potential to optimize the quantitative use of this resource
- Water may be used more efficiently by the trees (to produce biomass) as compared to a monoculture because of niche complementarity
- This potential has seldom been demonstrated



To determine if species mixing has an impact on poplar WUE and if the potentially highlighted differences could be found independently of scale, spatial (leaf and tree level) and temporal (instantaneous, leaf lifetime, growing season)

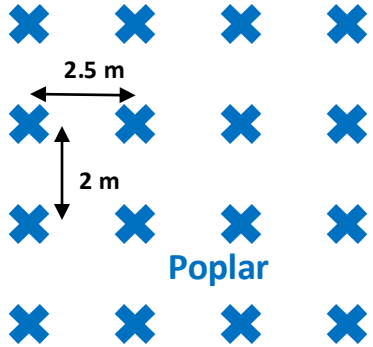
Hypotheses

The species interactions will allow the poplars in the mixtures to increase WUE compared to the poplars in monoculture thanks to:

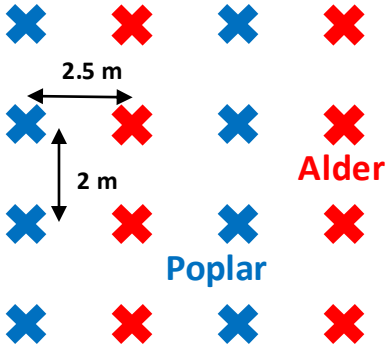
(1) a reduction in competition

(2) and / or a facilitation effect due to the presence of the N_2-fixing species in mixtures

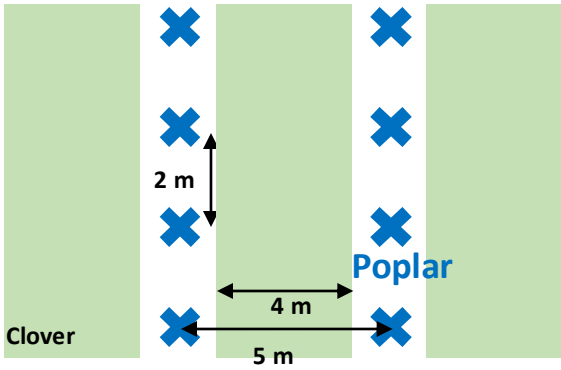
- Three ha plantation in northeastern France, installed in 2014
- Three treatments:



Monoculture plot detail



Forest mixture plot detail



Agroforestry plot detail

- Twelve poplar trees per treatment




Instantaneous

Intrinsic water-use efficiency (WUE_i) = Leaf gas exchanges: Light-saturated net CO_2 assimilation / Stomatal conductance

Leaf life span

Mass spectrometry

Carbon isotope discrimination (Δ, ‰)

Known to be inversely proportional to WUE_i




Growing season

Transpiration water-use efficiency (WUE_T) = $\frac{\text{Biomass increment}}{\text{Transpiration}}$

Allometric equations

Sap flow measurements

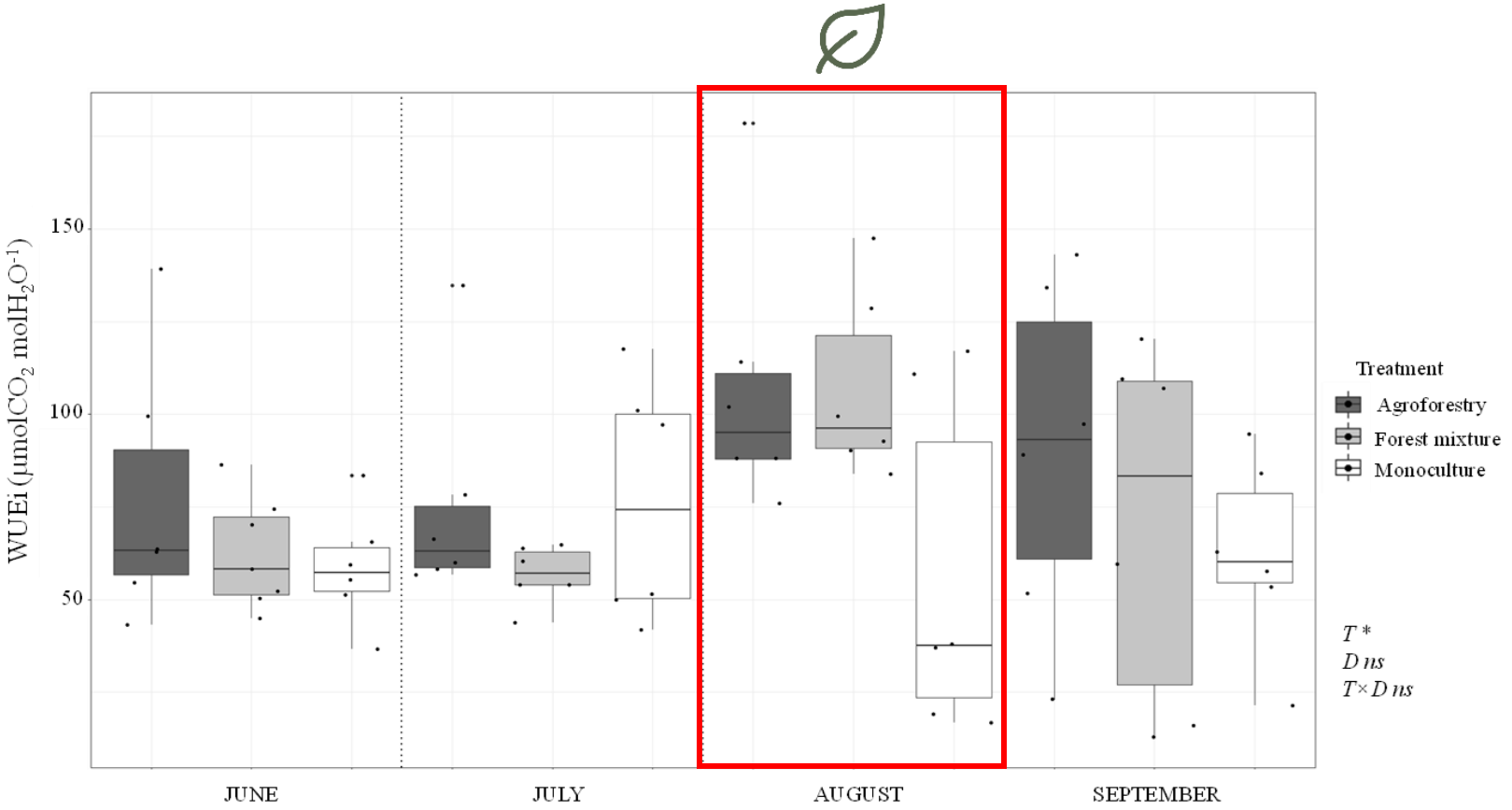
Stem microcores ➔ Mass spectrometry

Ring carbon isotope discrimination (Δ_{wood}, ‰)

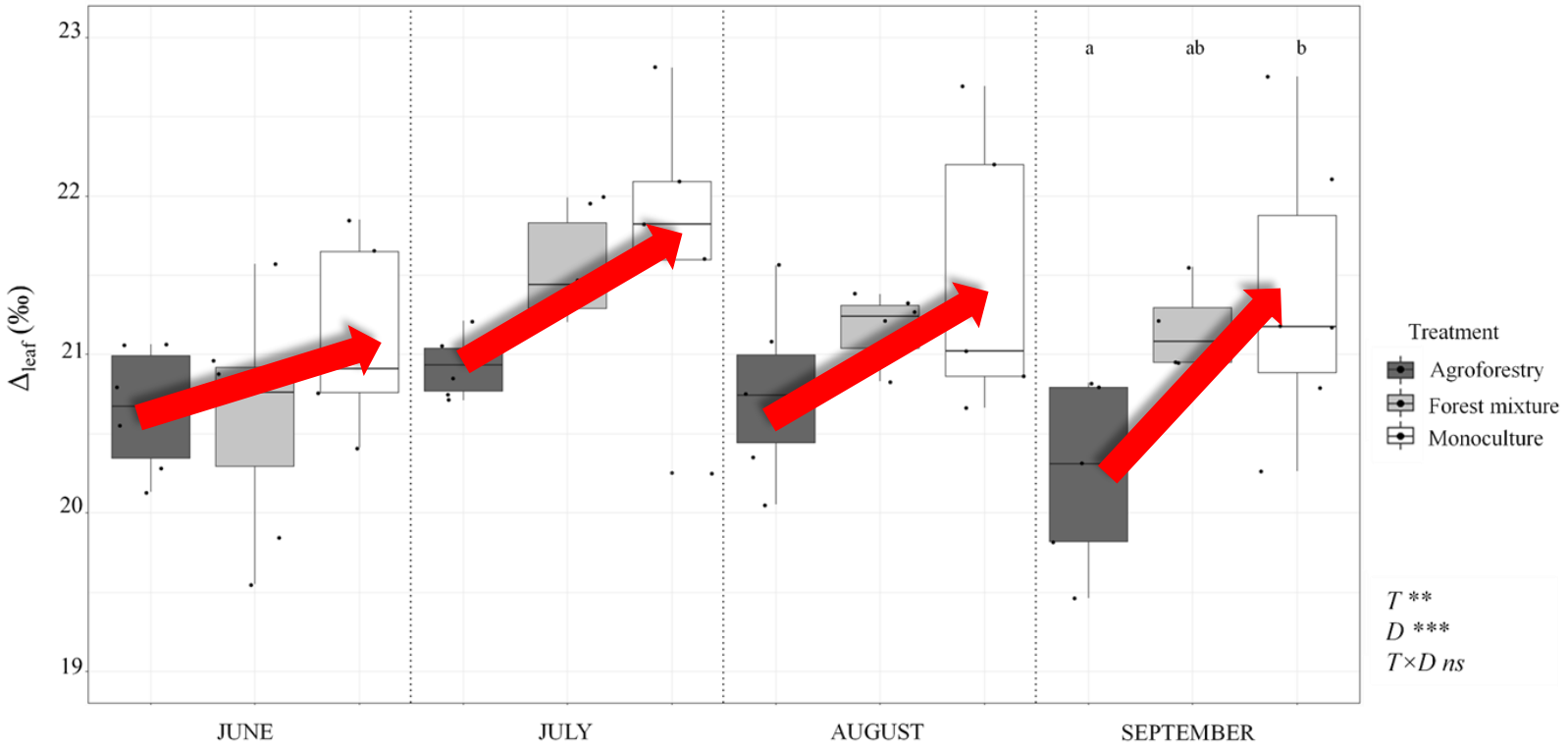
Known to be inversely proportional to WUE_T

Growing season

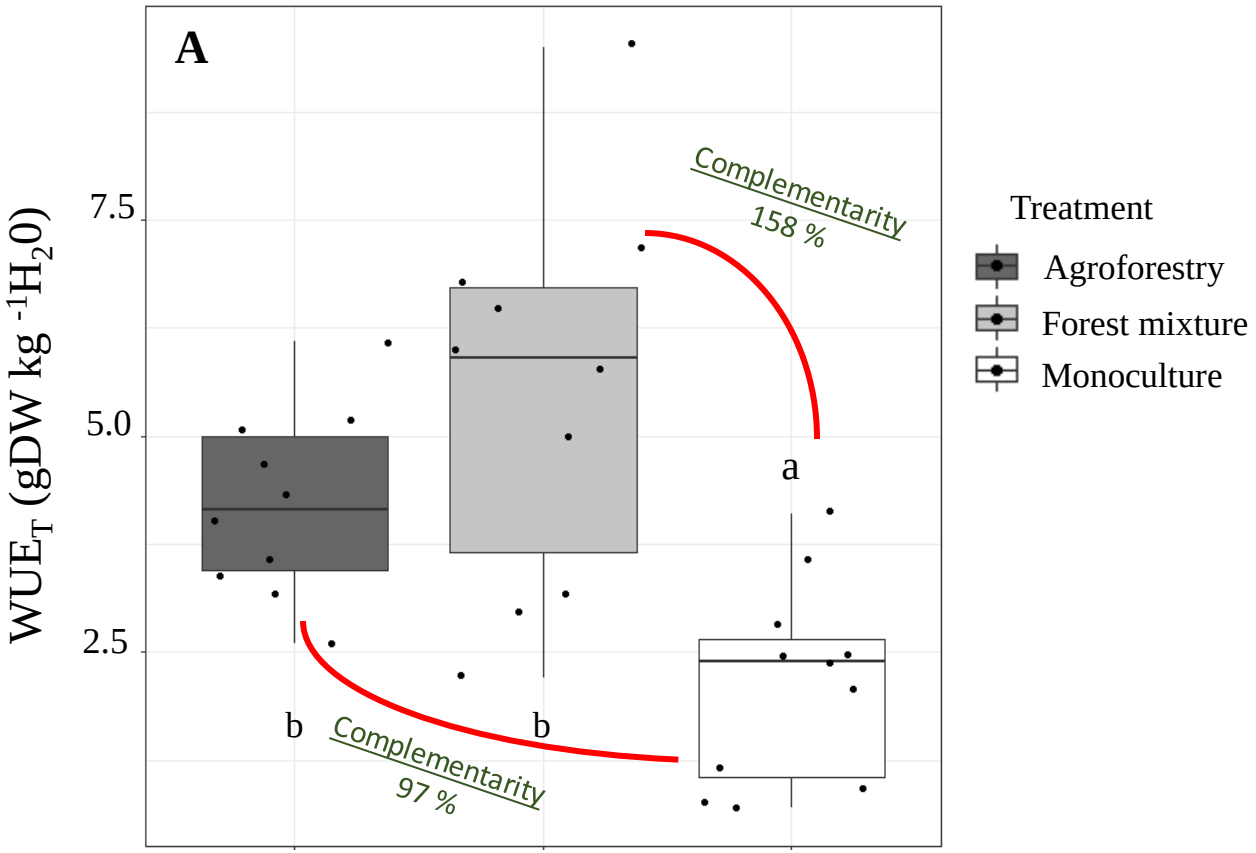


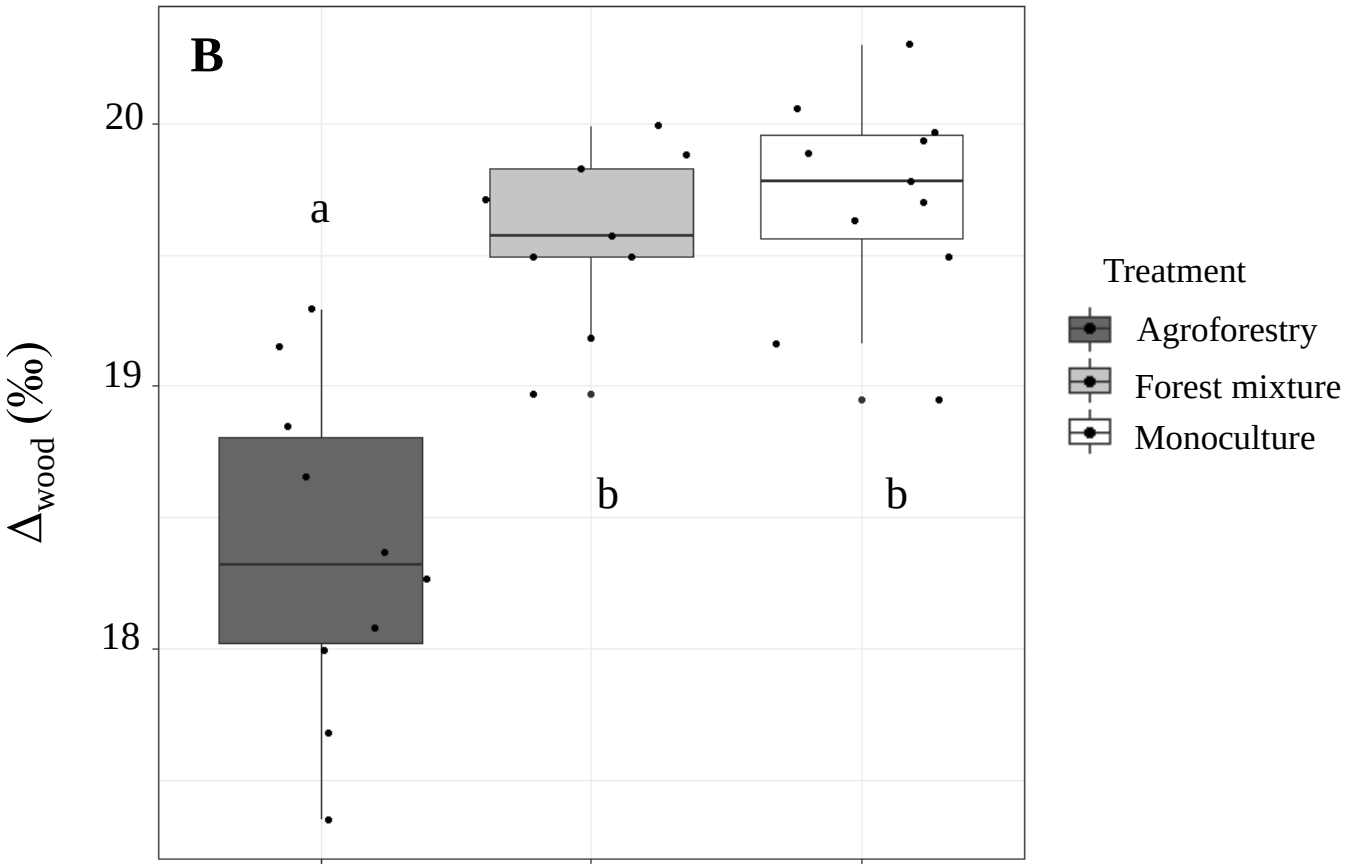
- WUE_i higher in the agroforestry than in the monoculture
- August: WUE_i ↗ in the agroforestry and ↘ in the monoculture (gap increase)



- Identical trends as for WUE_i: Lower values in agroforestry (higher WUE)
  Gap increase at the end of the season



➢ WUE_T forest mixture > WUE_T agroforestry > WUE_T monoculture



➢ Similar trend as for WUE_T: Agroforestry > Forest mixture = Monoculture

- Poplars in both mixture types showed higher WUE compared to the monoculture
- An ↗ of WUE has been commonly observed in response to a decrease in water availability

Bonhomme et al. 2008, Fichot et al. 2009, 2010, Cocozza et al. 2011

	JUNE			JULY			AUGUST		
	AF	FM	Mono	AF	FM	Mono	AF	FM	Mono
$\Psi_{predawn}$ (MPa)	-0.15 ± 0.01 [a]	-0.19 ± 0.01 [ab]	-0.25 ± 0.02 [b]	-0.18 ± 0.02 [a]	-0.15 ± 0.01 [a]	-0.35 ± 0.02 [b]	-0.29 ± 0.02 [a]	-0.32 ± 0.01 [a]	-0.34 ± 0.01 [a]

… but there was not water limitation

- A higher N supply in mixtures than in monoculture can ↗ increase WUE in poplars

Ripullone et al. 2004

… but there was no difference in leaf [N] between poplars in mixtures and monoculture

- Difference in agroforestry probably associated to higher light availability due to lower tree planting density than in the forest plots

- Agroforestry *vs.* Monoculture:

  differences were associated to differences in g_{400} and A_{sat} … and transpiration

- Forest mixture *vs.* Monoculture:

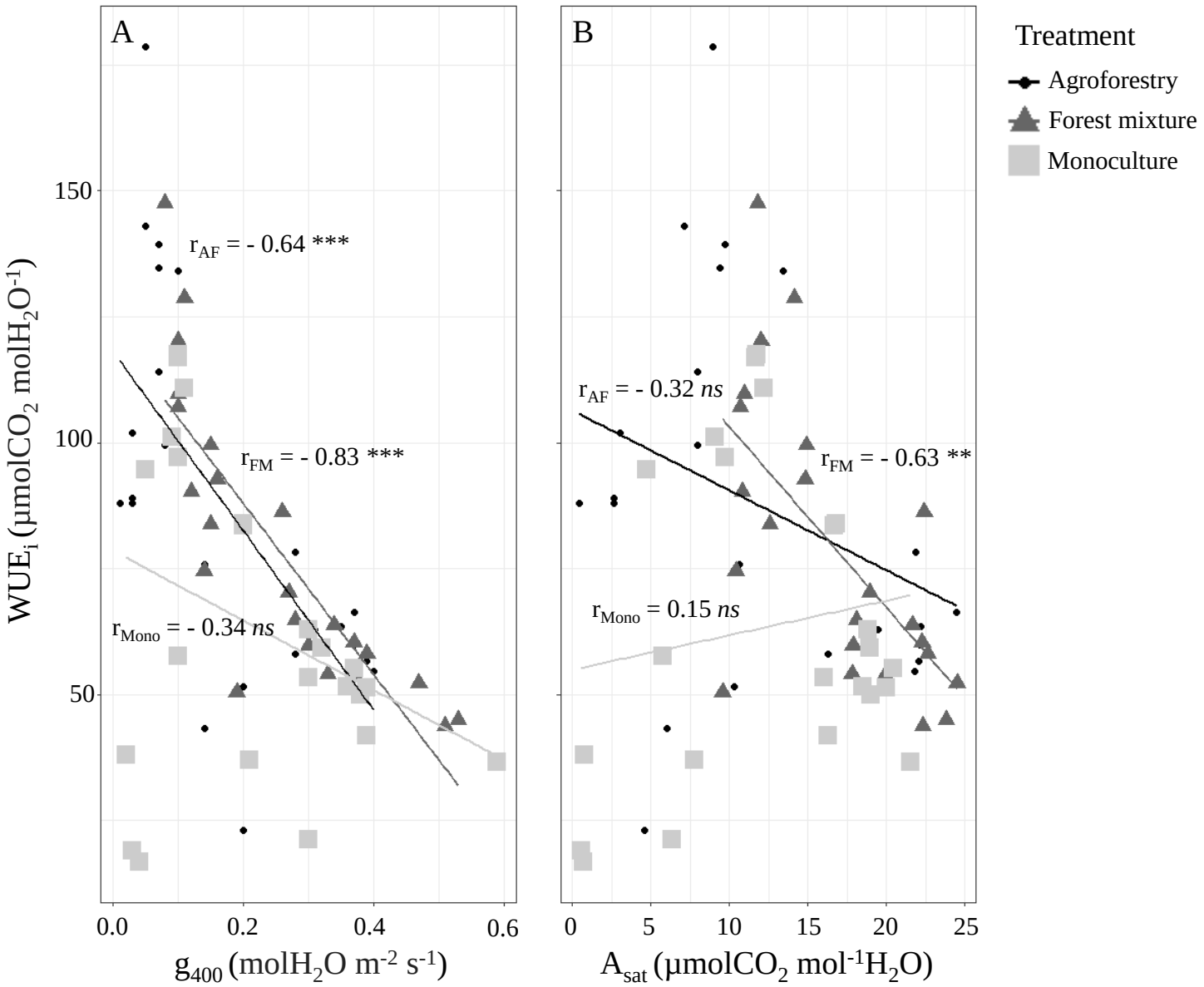
  differences were associated to differences in g_{400} … and both transpiration and biomass accumulation

Poplar trees are more productive (Thomas et al. 2021) and use water more efficiently (Thomas et al. 2022, in press) in agroforestry than in monoculture !

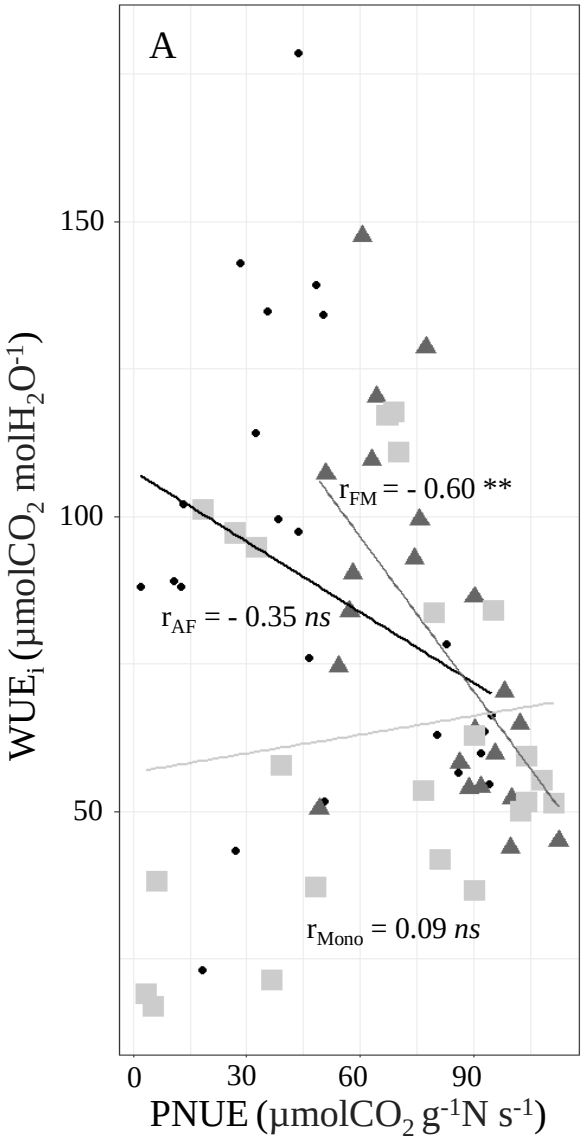
UNIVERSITÉ DE LORRAINE

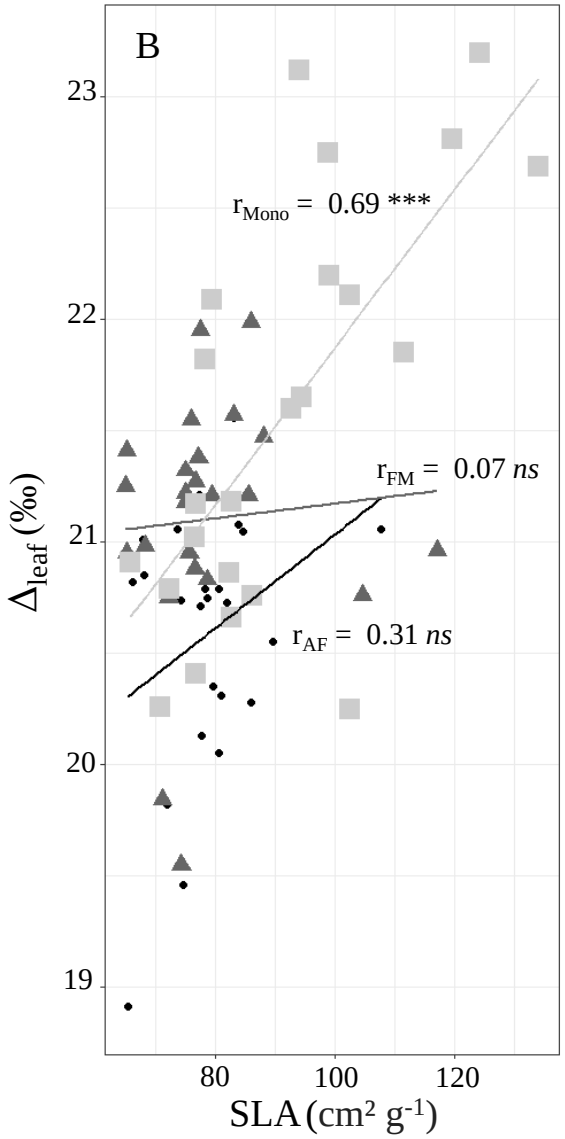
INRAE

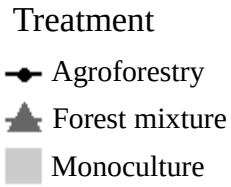
WUE drivers at leaf level



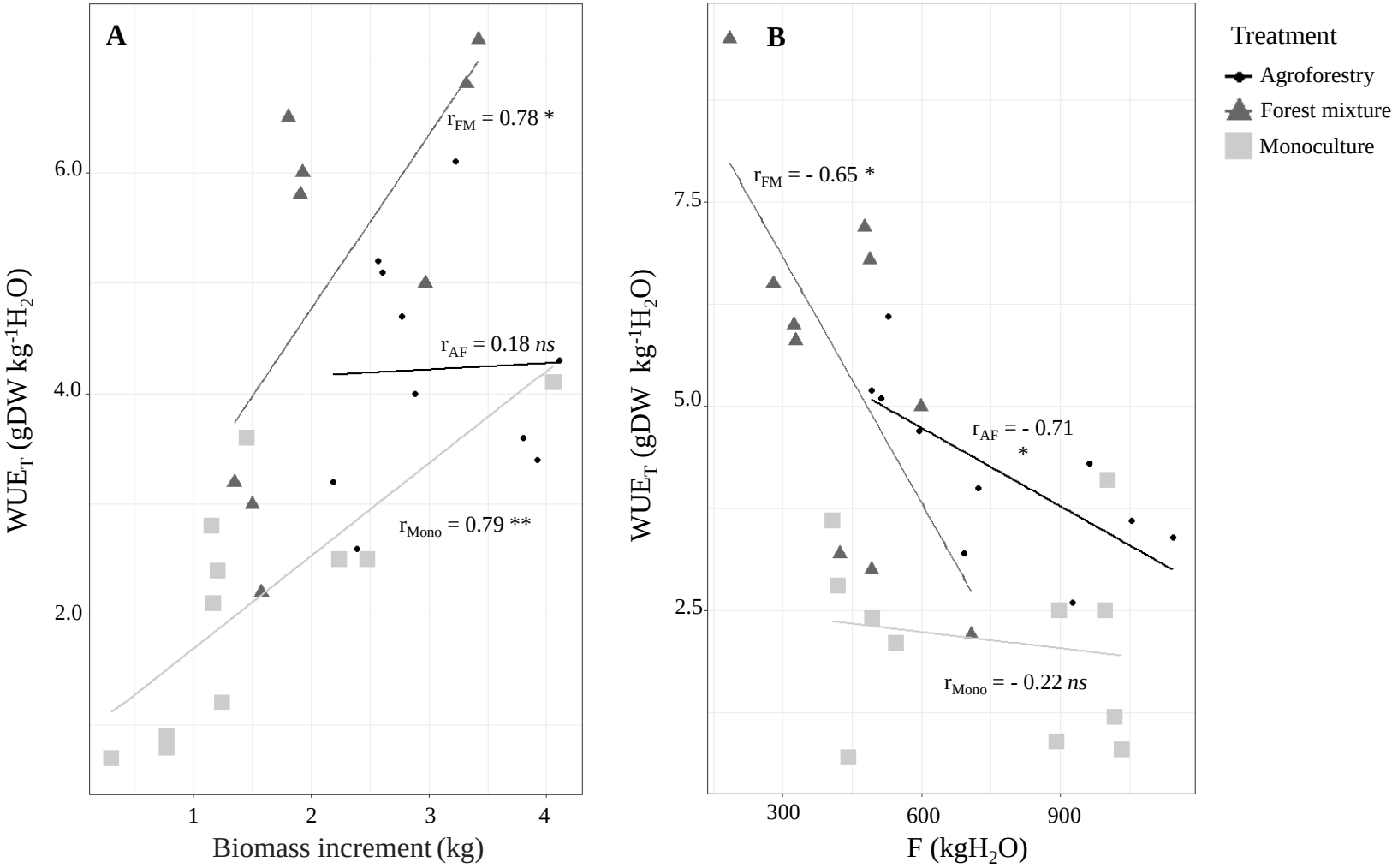
WUE drivers at leaf level







WUE drivers at tree level



Soil water availability

	JUNE			JULY			AUGUST			SEPTEMBER		
	AF	FM	Mono	AF	FM	Mono	AF	FM	Mono	AF	FM	Mono
$\Psi_{predawn}$ (MPa)	-0.15 ± 0.01 ^{a}	-0.19 ± 0.01 ^{ab}	-0.25 ± 0.02 ^{b}	-0.18 ± 0.02 ^{a}	-0.15 ± 0.01 ^{a}	-0.35 ± 0.02 ^{b}	-0.29 ± 0.02 ^{a}	-0.32 ± 0.01 ^{a}	-0.34 ± 0.01 ^{a}	-	-	-
SWC at 10 cm depth (%)	46.1 ± 0.2 ^{c}	30.2 ± 1.2 ^{b}	27.6 ± 1.7 ^{a}	41.9 ± 0.3 ^{c}	25.4 ± 0.2 ^{b}	20.4 ± 0.3 ^{a}	39.5 ± 0.3 ^{c}	22.3 ± 0.3 ^{b}	18.1 ± 0.1 ^{a}	41.9 ± 1.8 ^{c}	26.6 ± 1.8 ^{b}	22.2 ± 1.3 ^{a}
Cumulative rainfall (mm)		63.1			5.6			48.2			47.6	
Mean temperature (°C)		16.5			19.5			20.8			15.8	