

Impact of transpiration rates on foliar silicon concentrations across a range of angiosperm species exposed to water stress.

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Introduction

Materials & Methods

Results

Discussion

PICO Navigation

Click on a panel to see the corresponding section

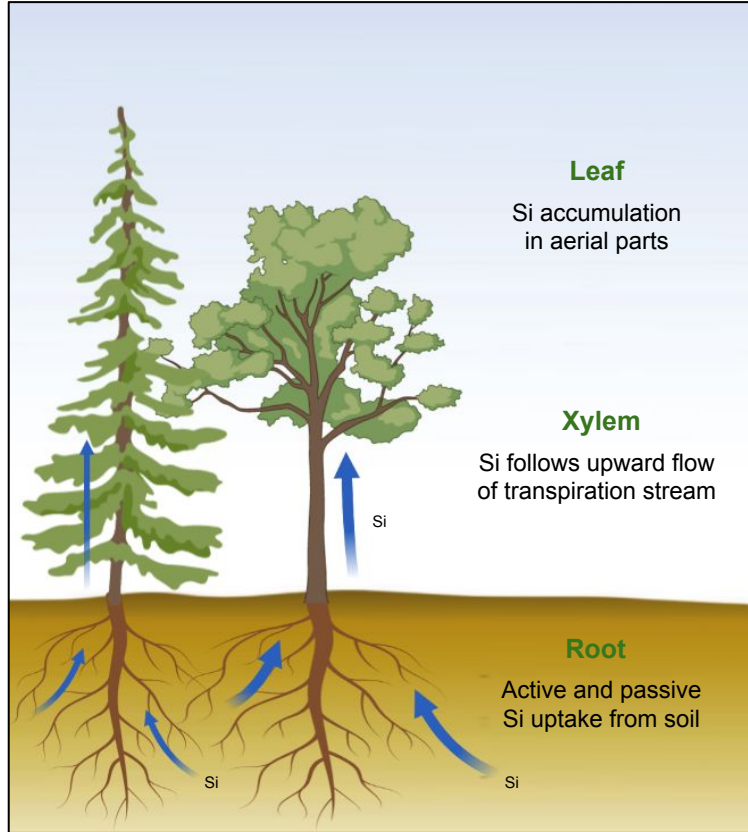


The orange 'Home' button takes you to the section menu

The left / right arrows take you to the next page



Introduction



Silicon uptake and accumulation in plants

Silicon (Si) is acquired by plants both **actively** via transporters and/or **passively** as plants transport water during transpiration. It accumulates in several parts of the plants where it alleviates a range of biotic and abiotic stresses.

There is a lively debate in the literature regarding the **relationship** between plant **Si accumulation** and **transpiration rates**. With some studies showing positive correlations whilst others show none. Most studies focus on grasses and non-woody species.

Here, we exposed nine woody angiosperm species 4 evergreen and 5 deciduous to contrasting watering treatments in order to investigate how foliar Si concentrations were correlated with cumulative transpiration rates and how this varied between plant functional type.



Materials & Methods



9 woody species were grown in a greenhouse and sampled :
5 deciduous and 4 evergreen species from 5 families

Code	Species	Order	Family	Deciduousness
FREX	<i>Fraxinus excelsior</i>	Lamiales	Oleaceae	Deciduous
QURO	<i>Quercus robur</i>	Fagales	Fagaceae	Deciduous
VIVI	<i>Vitis vinifera</i>	Vitales	Vitaceae	Deciduous
PRAV	<i>Prunus avium</i>	Rosales	Rosaceae	Deciduous
LITU	<i>Liriodendron tulipifera</i>	Magnoliales	Magnoliaceae	Deciduous
OLEU	<i>Olea europaea</i>	Lamiales	Oleaceae	Evergreen
PRLA	<i>Prunus laurocerasus</i>	Rosales	Rosaceae	Evergreen
QUIL	<i>Quercus ilex</i>	Fagales	Fagaceae	Evergreen
MAGR	<i>Magnolia grandiflora</i>	Magnoliales	Magnoliaceae	Evergreen



FREX - *Fraxinus excelsior*



QURO - *Quercus robur*



VIVI - *Vitis vinifera*



PRAV - *Prunus avium*



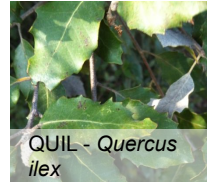
LITU - *Liriodendron tulipifera*



OLEU - *Olea europaea*



PRLA - *Prunus laurocerasus*



QUIL - *Quercus ilex*



MAGR - *Magnolia grandiflora*

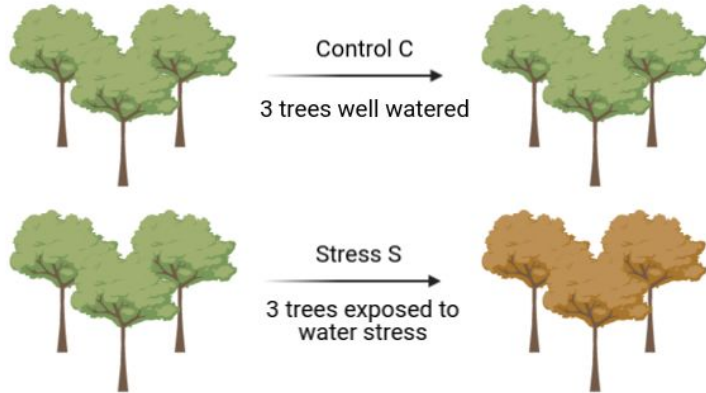


Materials & Methods



Leaves sampled in
May

Leaves sampled in
July



For each species, three trees were well watered throughout the growing season whilst three others were exposed to water stress in the same soil substrates. The stress was initiated after all leaves were fully developed.

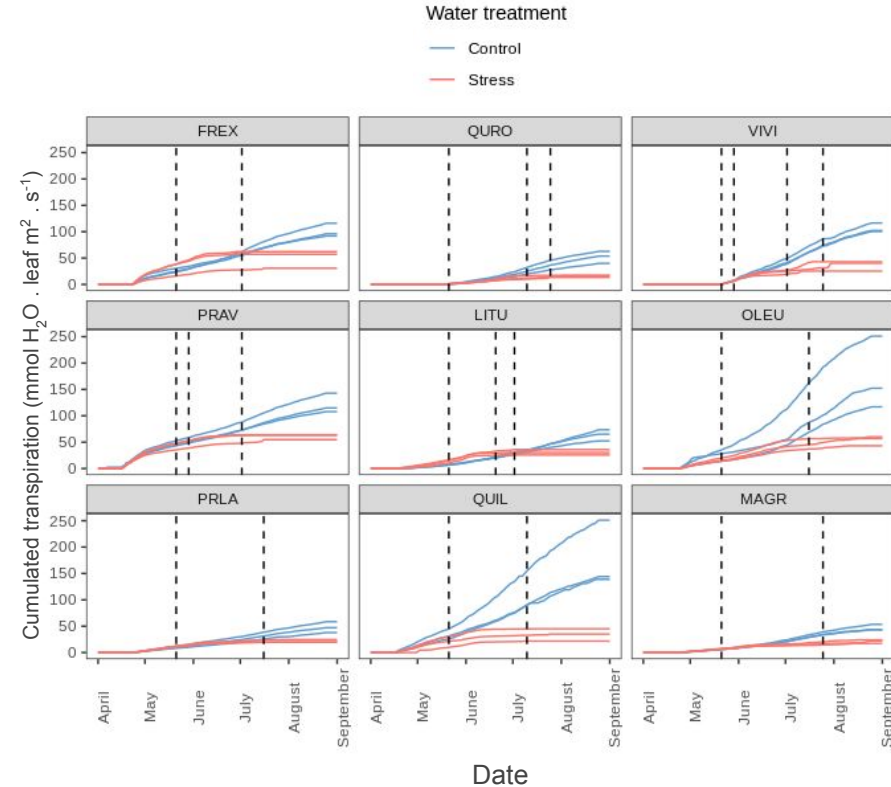
Pre-dawn leaf water potentials were measured regularly during the experiment.

Whole **plant transpiration fluxes** were also monitored continuously with balances, and expressed in $\text{mmol H}_2\text{O m}^2 \text{s}^{-1}$ and expressed on a leaf area basis.

In addition the **foliar Si concentrations** of each plant were measured by ICP-AES after alkaline fusion at two time points in the growing season and expressed in $\text{mg Si} \cdot \text{g}^{-1}$ leaf dry weight or in $\text{mg Si} \cdot \text{m}^{-2}$ leaf.



Results - Plant water status



Cumulated transpiration by species. Dashed lines show the sampling dates for Si analysis of each species in May and July.

The sampling dates for Si analysis may differ between plants and species in May and July.

Between June and July, plants exposed to water stress reached a plateau of cumulated transpiration due to a strong limitation of their transpiration and to a loss of functional leaves.

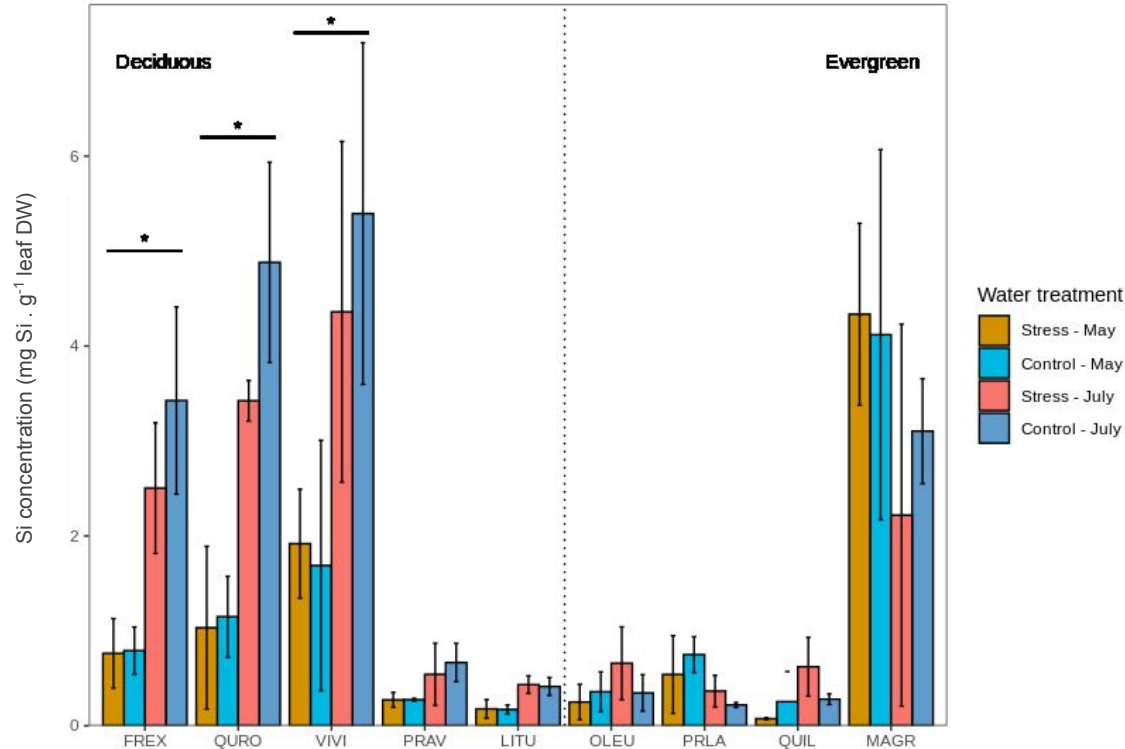
Thereby control plants clearly have higher cumulated transpiration levels after July. However it is less clear before July for some species such as *Fraxinus excelsior* (FREX) or *Liriodendron tulipifera* (LITU) for instance.



Results - Silicon concentrations



Click on a species to see the details.



Measured silicon (Si) for each species, treatment and sampling month. Mean $\pm$ sd (n=3).

Asterisks indicate significant differences between Si concentrations measured in May and July (multifactorial ANOVA).



FREX - *Fraxinus excelsior*



QURO - *Quercus robur*



VIVI - *Vitis vinifera*



PRAV - *Prunus avium*



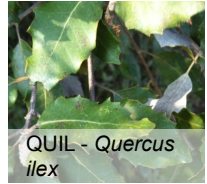
LITU - *Liriodendron tulipifera*



OLEU - *Olea europea*



PRLA - *Prunus laurocerasus*



QUIL - *Quercus ilex*



MAGR - *Magnolia grandiflora*

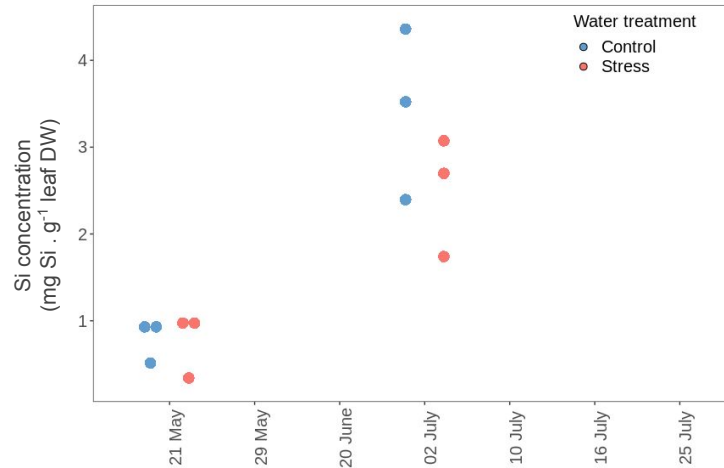


Results - *Fraxinus excelsior*

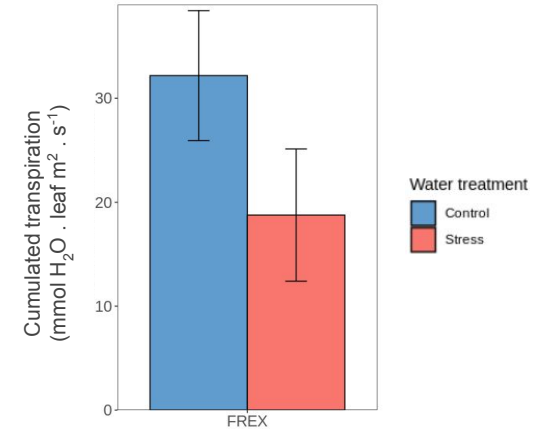
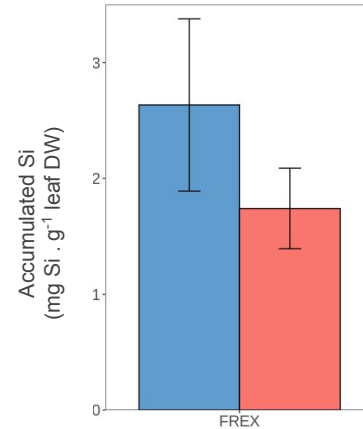


Ash trees accumulated significant amounts of silicon in their leaves during the growing season.

However although control plants seem to have transpired more and accumulated more silicon than stressed plants, no significant differences were detected between watering treatments by multifactorial ANOVA.



Measured silicon (Si) for each treatment and sampling date.



Cumulated transpiration and silicon between sampling dates. Mean $\pm$ sd (n=3).



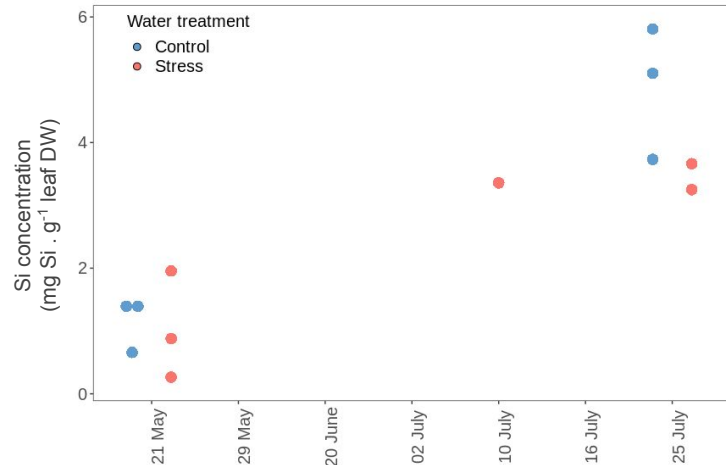
Results - *Quercus robur*



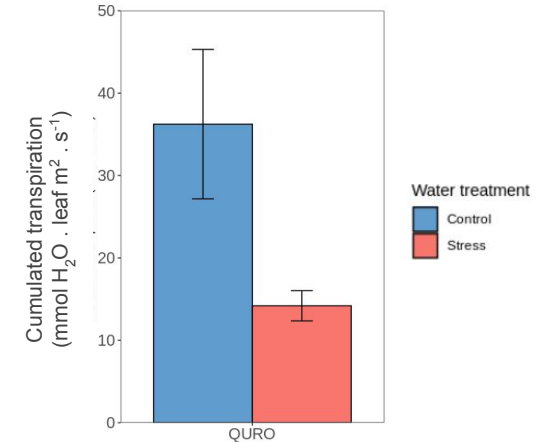
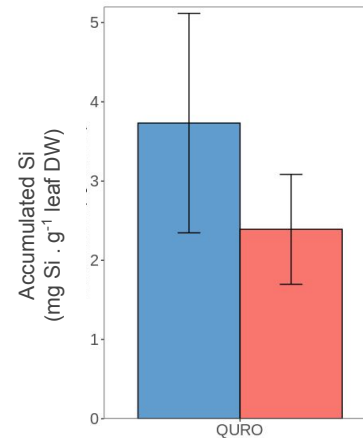
Pedunculate oaks accumulated significant amounts of silicon in their leaves during the growing season.

We can see that the stressed plants harvested with two weeks interval in July showed similar foliar silicon concentrations. This may be explained by the plateau of cumulated transpiration reached by these plants in June and July which limit the differences.

However although control plants seem to have transpired more and accumulated more silicon than stressed plants, no significant differences were detected between watering treatments by multifactorial ANOVA.



Measured silicon (Si) for each treatment and sampling date.



Cumulated transpiration and silicon between sampling dates. Mean $\pm$ sd (n=3).



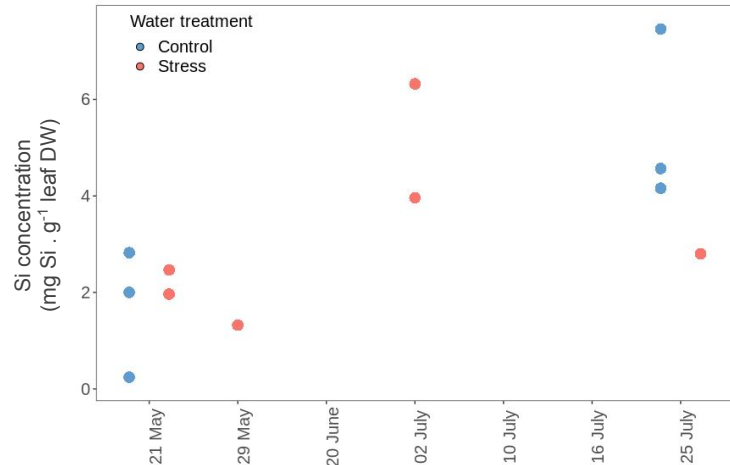
Results - *Vitis vinifera*



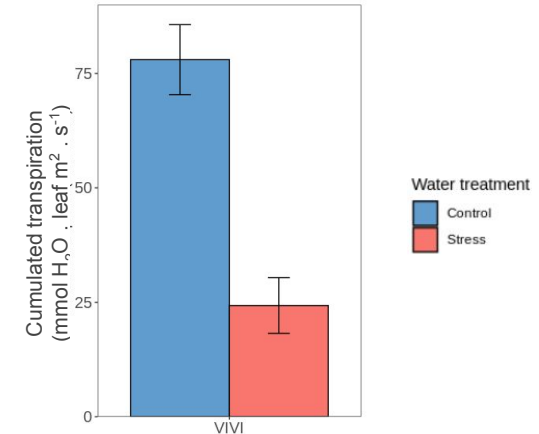
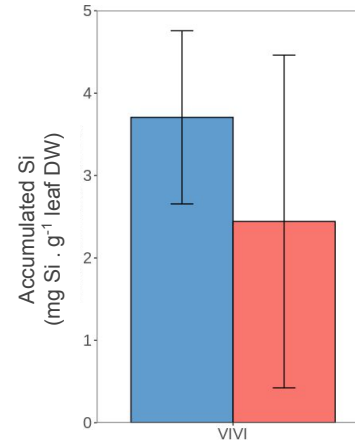
Vines accumulated significant amounts of silicon in their leaves during the growing season.

Surprisingly, the two stressed plants harvested earlier in July have greater silicon concentrations than the stressed plant harvested at the end of July.

However although control plants seem to have transpired more and accumulated more silicon than stressed plants, no significant differences were detected between watering treatments by multifactorial ANOVA.



Measured silicon (Si) for each treatment and sampling date.



Cumulated transpiration and silicon between sampling dates. Mean $\pm$ sd (n=3).

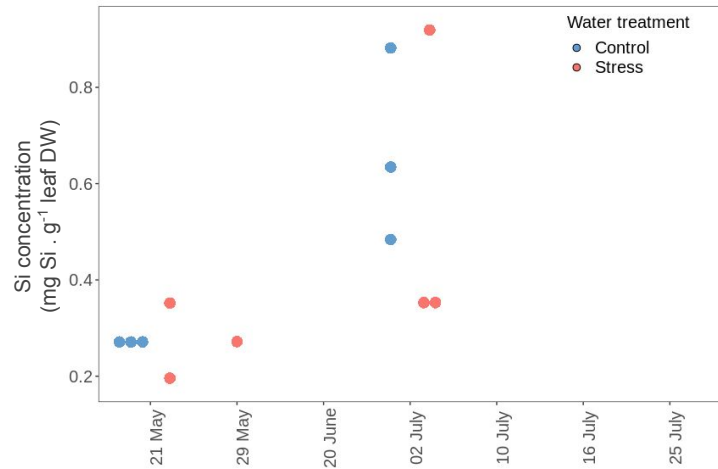


Results - *Prunus avium*

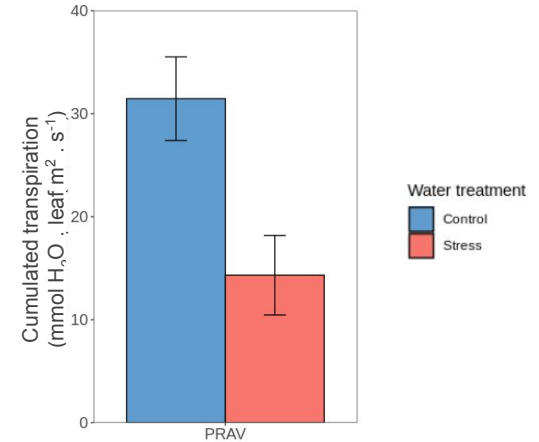
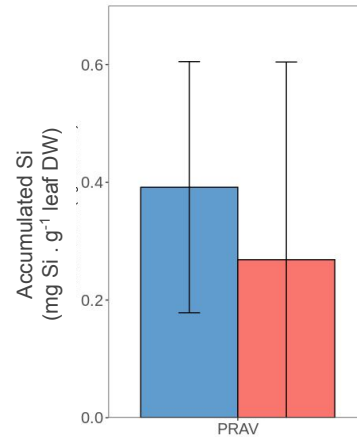


The foliar silicon concentrations of wild cherry trees are very low and did not change significantly during the growing season.

However although control plants seem to have transpired more than stressed plants, no significant differences were detected between watering treatments by multifactorial ANOVA.



Measured silicon (Si) for each treatment and sampling date.



Cumulated transpiration and silicon between sampling dates. Mean ± sd (n=3).



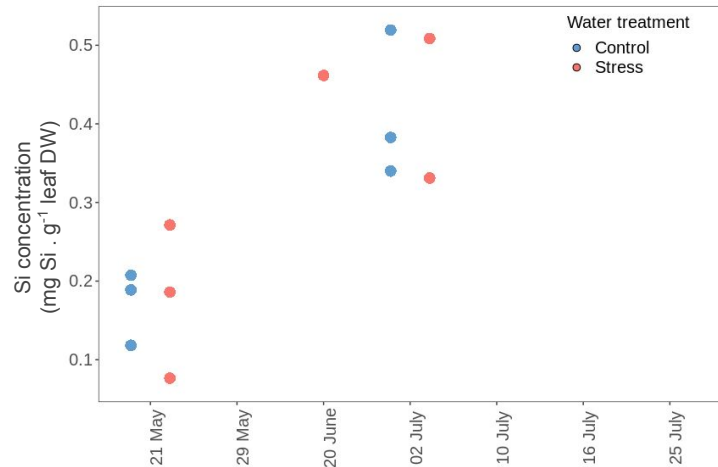
Results - *Liriodendron tulipifera*



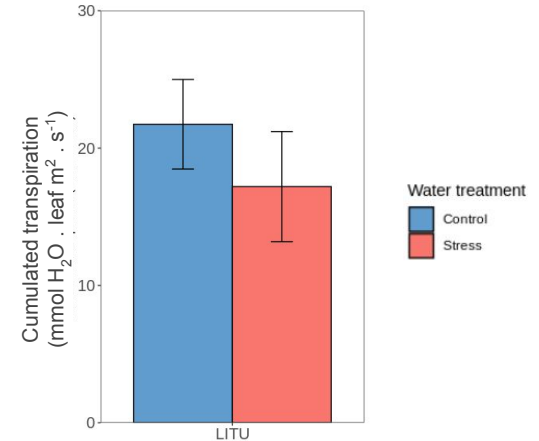
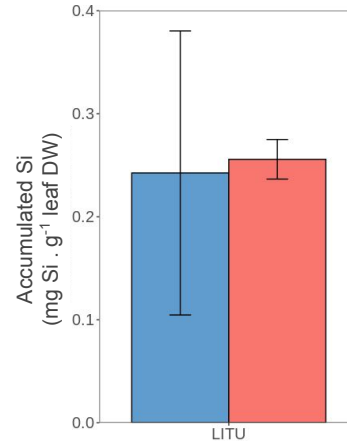
The foliar silicon concentrations of tulip trees are very low and did not change significantly during the growing season.

We can see that the stressed plants harvested with two weeks interval in June and July show similar foliar silicon concentrations. This may be explained by the plateau of cumulated transpiration reached by these plants in June and July which limit the differences.

No significant differences were detected between watering treatments by multifactorial ANOVA.



Measured silicon (Si) for each treatment and sampling date.



Cumulated transpiration and silicon between sampling dates. Mean $\pm$ sd (n=3).

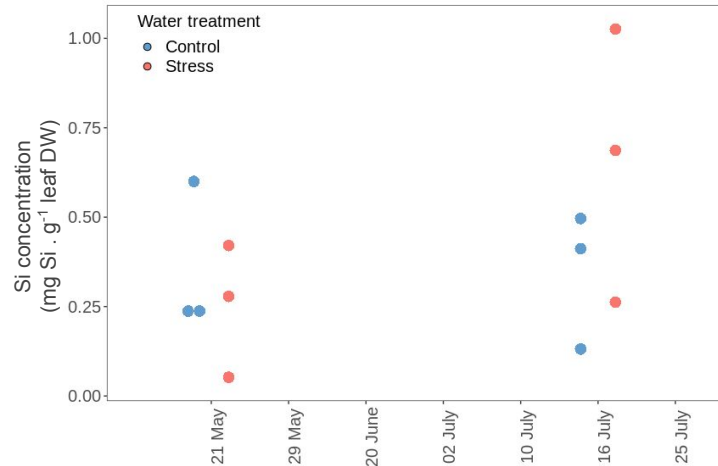


Results - *Olea europea*

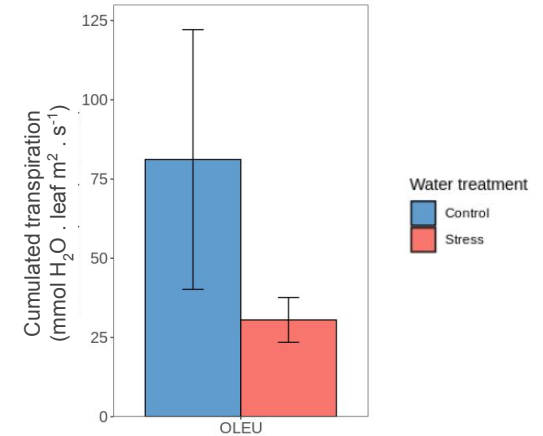
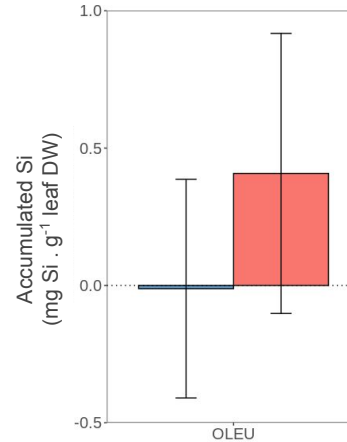


The foliar silicon concentrations of olive trees are quite low and we can't see any clear pattern of accumulation.

Moreover the Si concentrations measured in July are sometimes lower than those of May. This could be due to the different ages of the group of leaves collected for each tree and date. A mixture of leaves from the year and past years may have muddled the results.



Measured silicon (Si) for each treatment and sampling date.



Cumulated transpiration and silicon between sampling dates. Mean $\pm$ sd (n=3).

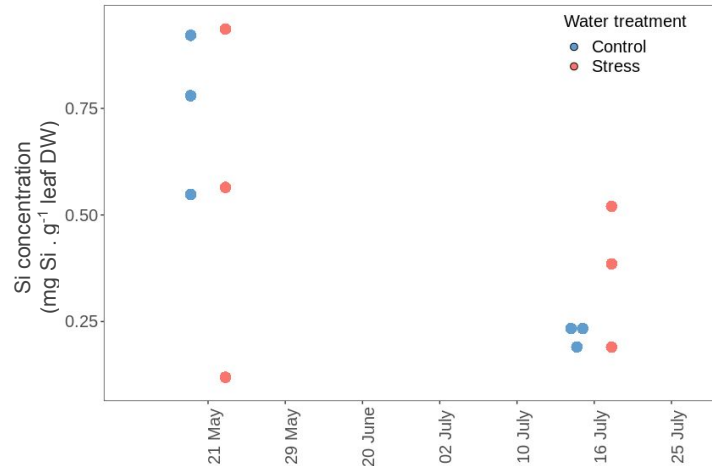


Results - *Prunus laurocerasus*

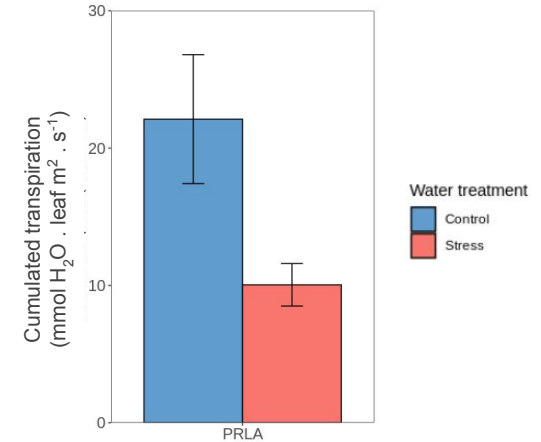
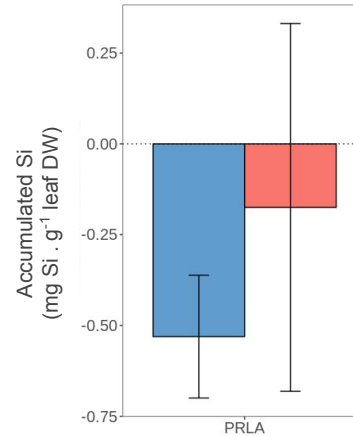


The foliar silicon concentrations of cherry laurels are quite low and we can't see any clear pattern of accumulation.

Moreover the Si concentrations measured in July are lower than those of May. This could be due to the different ages of the group of leaves collected for each tree and date. A mixture of leaves from the year and past years may have muddled the results.



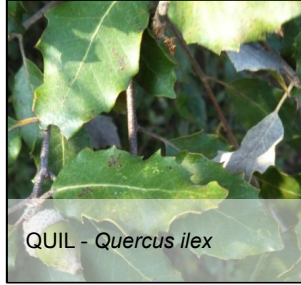
Measured silicon (Si) for each treatment and sampling date.



Cumulated transpiration and silicon between sampling dates. Mean $\pm$ sd (n=3).

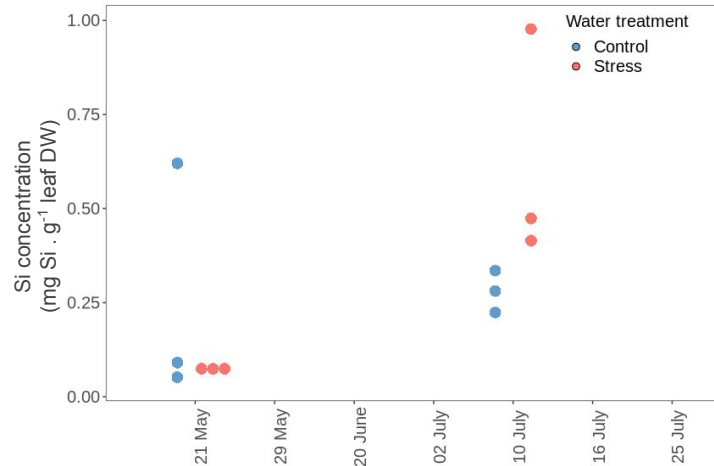


Results - *Quercus ilex*

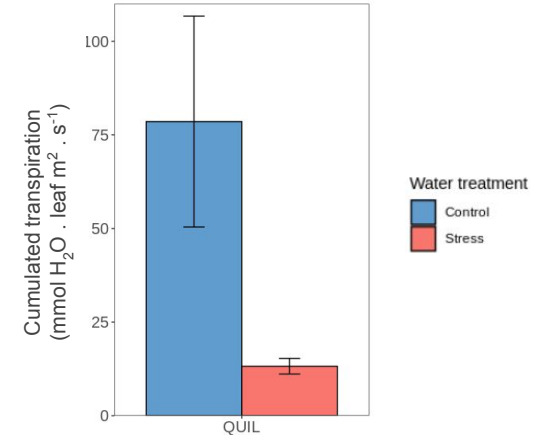
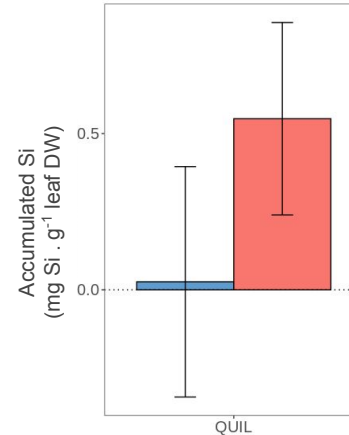


The foliar silicon concentrations of holm oaks are quite low and did not change significantly during the growing season.

Moreover the Si concentrations measured in July are sometimes lower than those of May. This could be due to the different ages of the group of leaves collected for each tree and date. A mixture of leaves from the year and past years may have muddled the results.



Measured silicon (Si) for each treatment and sampling date.



Cumulated transpiration and silicon between sampling dates. Mean $\pm$ sd (n=3).

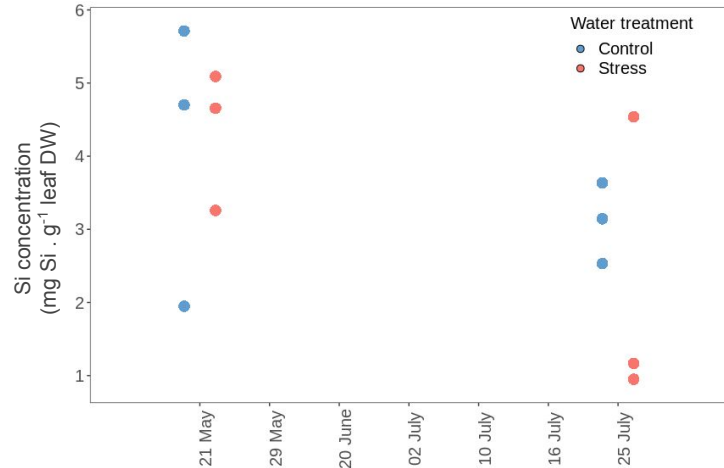


Results - *Magnolia grandiflora*

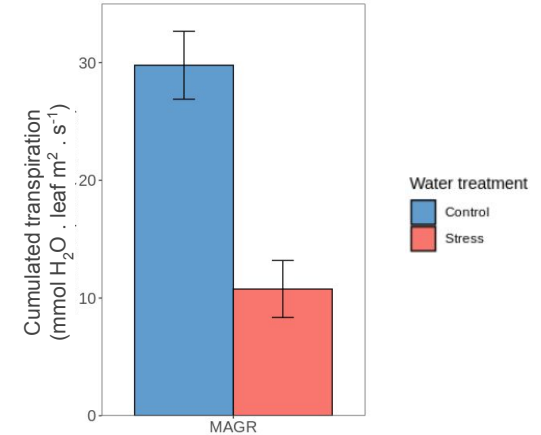
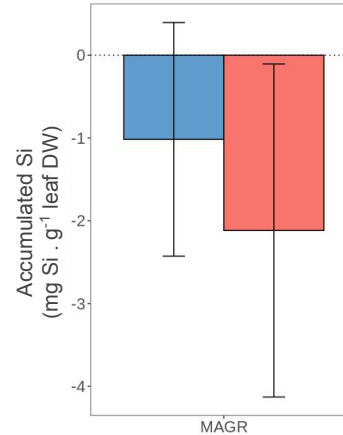


We can't see any clear pattern of foliar accumulation of silicon for magnolias during the growing season.

Moreover the Si concentrations measured in July are lower than those of May. This could be due to the different ages of the group of leaves collected for each tree and date. A mixture of leaves from the year and past years may have muddled the results.



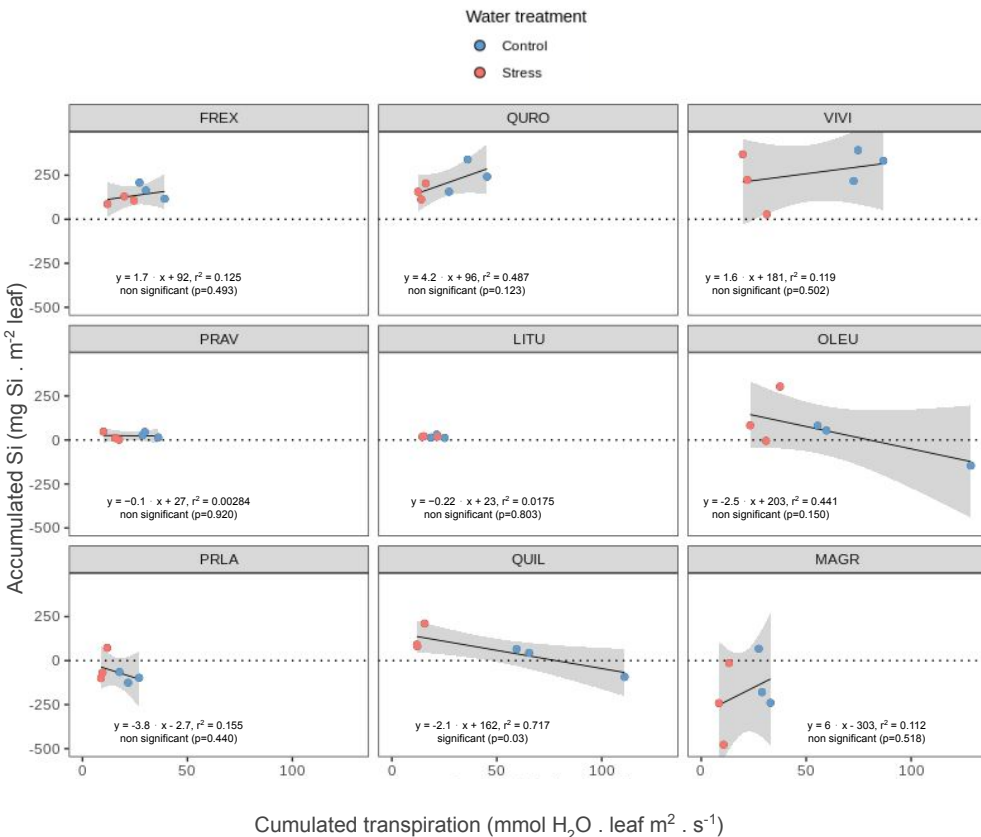
Measured silicon (Si) for each treatment and sampling date.



Cumulated transpiration and silicon between sampling dates. Mean $\pm$ sd (n=3).



Results - Cumulated transpiration and silicon



The silicon accumulated by each plant between their two harvest dates are calculated and plotted against their cumulated transpiration during the same period.

→ Only the three deciduous species *Fraxinus excelsior* (FREX), *Quercus robur* (QURO) and *Vitis vinifera* (VIVI) have accumulated a significant amount of silicon during the growing season.

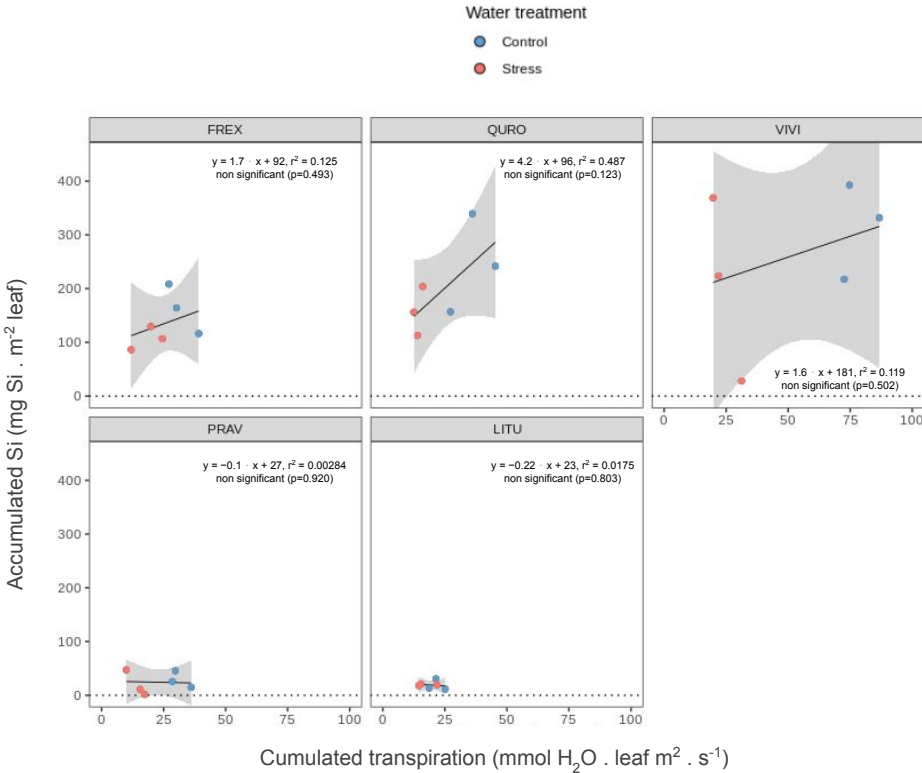
→ Although for some species such as FREX and QURO well watered plants seem to have accumulated more silicon than stressed plants, **no significant differences** were detected **between watering treatments** by multifactorial ANOVA.

→ **No significant positive correlations** between foliar Si concentrations and cumulative transpiration rates were detected by linear regressions for any species.

Linear regressions of accumulated Si and cumulated transpiration by species.



Discussion - Deciduous species



Despite the slight trend observed for our most accumulating species FREX, QURO and VIVI, **no significant positive correlations** between foliar **Si concentrations** and **cumulative transpiration** rates were detected for any species.

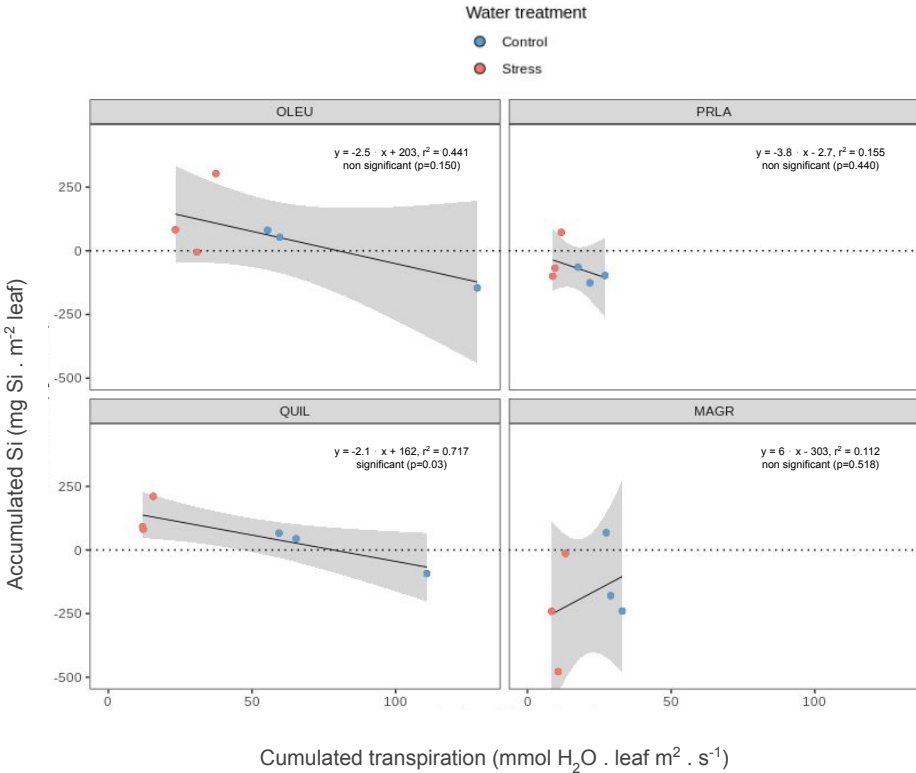
The differences of cumulative transpiration between watering treatments vary greatly among species. However, these differences may not be large enough to allow us to see significant differences in Si accumulation, as the largest cumulative transpiration differences between water treatments can be seen in August and September, after our sampling dates.

The foliar Si concentrations vary greatly between our species but also within the same species and the same treatment. This high dispersion and the low number of points per treatment may also have limited the power of the analysis.

Linear regressions of accumulated Si and cumulated transpiration for each deciduous species.



Discussion - Evergreen species



There is no sign of Si accumulation within our four evergreen species, with even negative values.

This could be due to the different ages of the group of leaves collected for each tree and date. A mixture of leaves from the year and past years may have complicated the results.

Linear regressions of accumulated Si and cumulated transpiration for each evergreen species.



Conclusion



Although three species have accumulated a significant amount of silicon during the growing season, we cannot conclude that there is a correlation between the accumulation of Si and the transpiration within our nine woody species.

Next steps:

- Increase the time between sampling dates to allow more time for plants to accumulate Si.
- Increase the number of plants per treatment.
- Be careful to only sample the current season leaves for evergreen species.