Measuring leaf elongation rate and transpiration in response to drought and elevation of atmospheric CO_2 concentration

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Context

- Grasses productivity is determined by **leaf area** development.
- With **climate change**, plants are going to face increase of CO_2 concentrations ([CO_2]) and reduction of water availability. The effects of **elevated [CO_2] and water stress interaction** on leaf growth are difficult to predict.
- **Transpiration** is key variable because it determines the water flow and resource allocation among plant organs and is highly affected by soil water availability and [CO_2], but it remains **difficult to predict**.
- **Functional-structural plant modeling** (FSPM) is a suitable tool for integrating the effects of climate change on resource acquisition by plants in interaction with their morphogenesis.
- However **limited information** is available on dynamics of individual plants exposed to contrasting environmental conditions in terms of [CO_2] and water availability.

→ **We need data on transpiration flow of individual plants for model implementation and evaluation.**

Material and methods

- Experimental design

An experiment was performed in two growth chambers set at **[CO_2] = 800 and 200 ppm**. A total of 480 plants of **winter bread wheat**, **perennial ryegrass**, and **tall fescue** were arranged in single plastic pots in each chamber (Fig. 1a). Plants were irrigated daily with a standard nutritive solution. After the elongation of the 7th leaf, water was withheld in half of plants (W^-) while the other plants were watered as before (W^+).

- Leaf elongation rate (LER) measurement

Leaf length was measured daily on the main stem of **10 plants per treatment** with a ruler. We calculated LER per tiller by **cumulating the elongation of all visible leaves of the main stem**.

- Plant water status measurement

A **system of load cells** has been installed under plants for which LER was measured (Fig. 1b). To **acquire plant weight every minute**, a Node-RED program was installed on a Raspberry PI and interrogated a NodeMCU ESP8266 card installed on each load cell through a Broker MQTT Mosquitto (Fig. 1c). Weight values were imputed to a supervision software.
Plant transpiration and **Soil Relative Water Content** (SRWC) were computed gravimetrically.

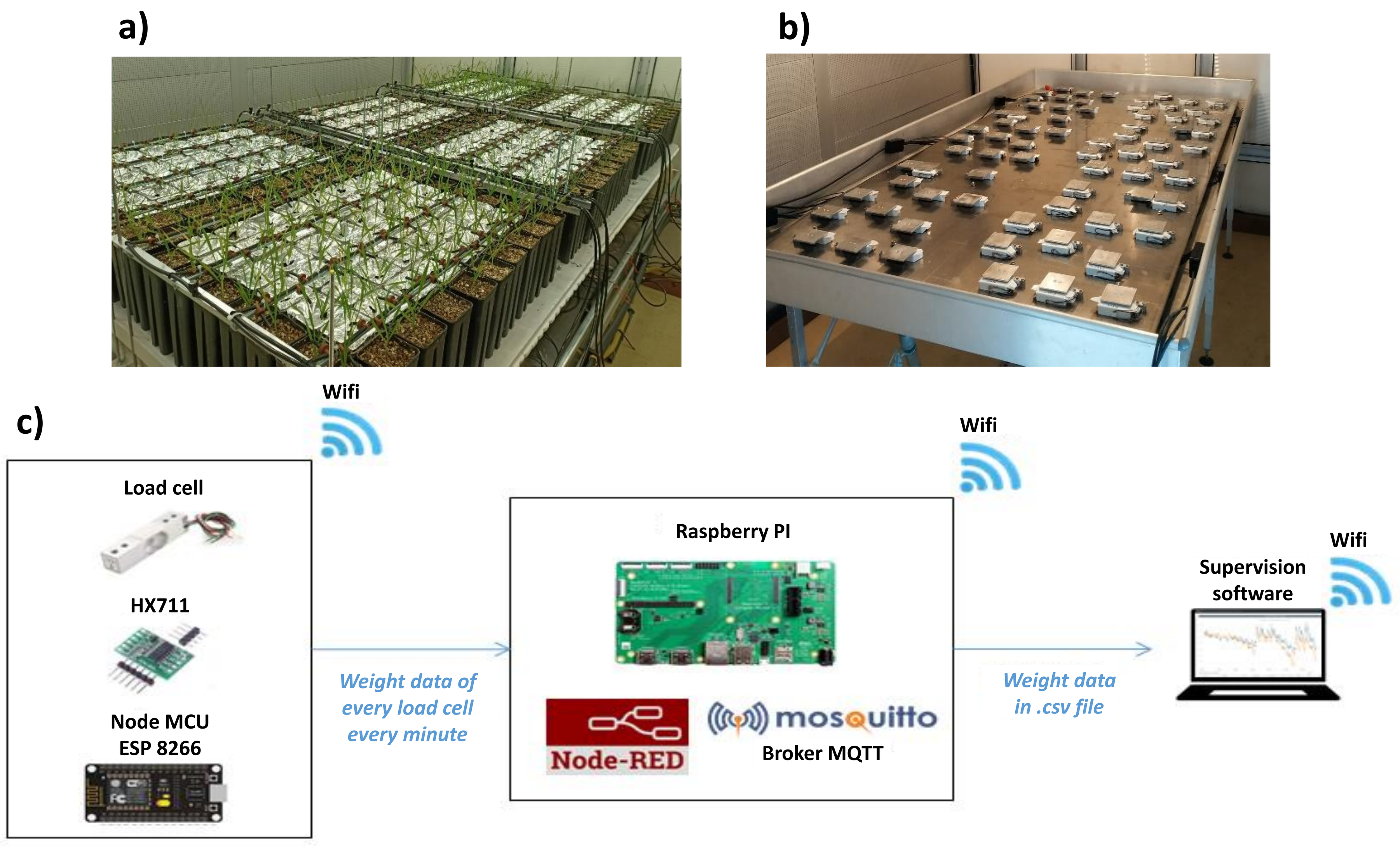

Figure 1. a) *Experimental setup of one of the two growth chambers.* ***b)*** *System of connected load cells to measure the transpiration rate of individual plants.* ***c)*** *Explanatory diagram of the connection between load cells and the supervision software.*

Results and discussion

- Daily plant transpiration **increased** during the experiment and total water loss showed contrasted dynamics according to treatments (Fig. 2b).

Plants of **tall fescue** and **wheat** consumed the **same water quantity** at both [CO_2] in W^+ condition (Fig. 2a), while plants were much **more developed at 800 ppm** (Fig. 2b). Elevated [CO_2] induced **stomatal closure** (data not shown), which **limits water loss** while maintaining **high photosynthetic activity** and plant growth.

Plant transpiration of ryegrass drastically increased with [CO_2], and **was 45% higher at 800 ppm than 200 ppm** in W^+ treatment (Fig. 2a). This results was due to a greater leaf area development with CO_2 (Fig. 2b), mainly on **tillering** (data not shown). Under W^- treatment **after drought start**, plant transpiration **decreased by 30-40%** for both [CO_2] and all three species (Fig. 2a).

- Drought affected leaf elongation as LER decreased with SRWC at both [CO_2] and for all three species (Fig. 2c). However LER of **ryegrass** decreased slower with SRWC at 800 ppm, indicating that **leaves elongated faster at elevated [CO_2].**

Some leaves of tall fescue and ryegrass **continued to elongate at SRWC close to 0 at 800 ppm**. LER of wheat had greater sensibility to SRWC (Fig. 2c).

- **Plants transpiration response** was explained rather by **tillering** than LER dynamics (unless for ryegrass for which CO_2 effect on LER was significative).

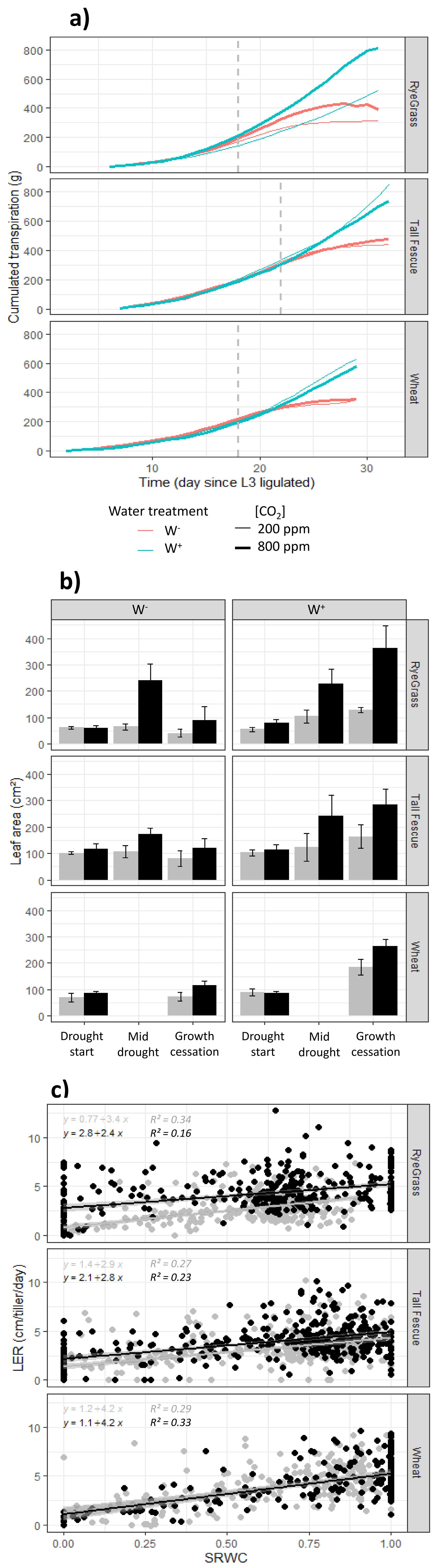

Figure 2. a) *Cumulated transpiration of the plants. Color blue: W^+, red color: W^-, thickest curves: 800 ppm, finest curve: 200 ppm, grey vertical dotted line: drought start.* ***b)*** *Leaf area of the plants at drought start, mid-drought and growth cessation. Color black: 800 ppm, color grey: 200 ppm* ***c)*** *LER as function of the SRWC. Lines and equations relates to linear regression. Color black: 800 ppm, color grey: 200 ppm*

Conclusion

- This **innovative automatic weighing device** allowed us to measure the **transpiration of individual plants** and to observe their water status under **different environmental conditions**.
- Results enables to quantify **[CO_2] and water stress interaction on LER**.
- This study will be used to validate the **model's ability to simulate leaf growth in a wide range of environments**.