Impact du changement climatique et des pratiques de gestion de la fertilité sur l'agrosystème Blé d'hiver :

Leçons tirées de nos expérimentations en Ecotron

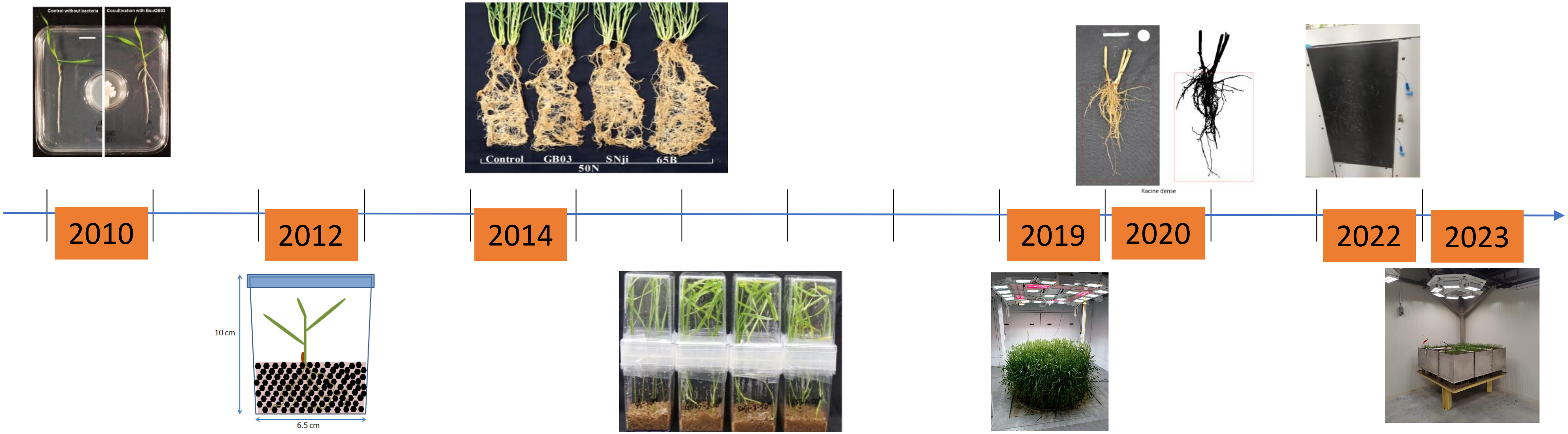
Pr Pierre DELAPLACE

- Plant Sciences -

Journée scientifique - Groupe Céréales à paille – 13 mars 2025

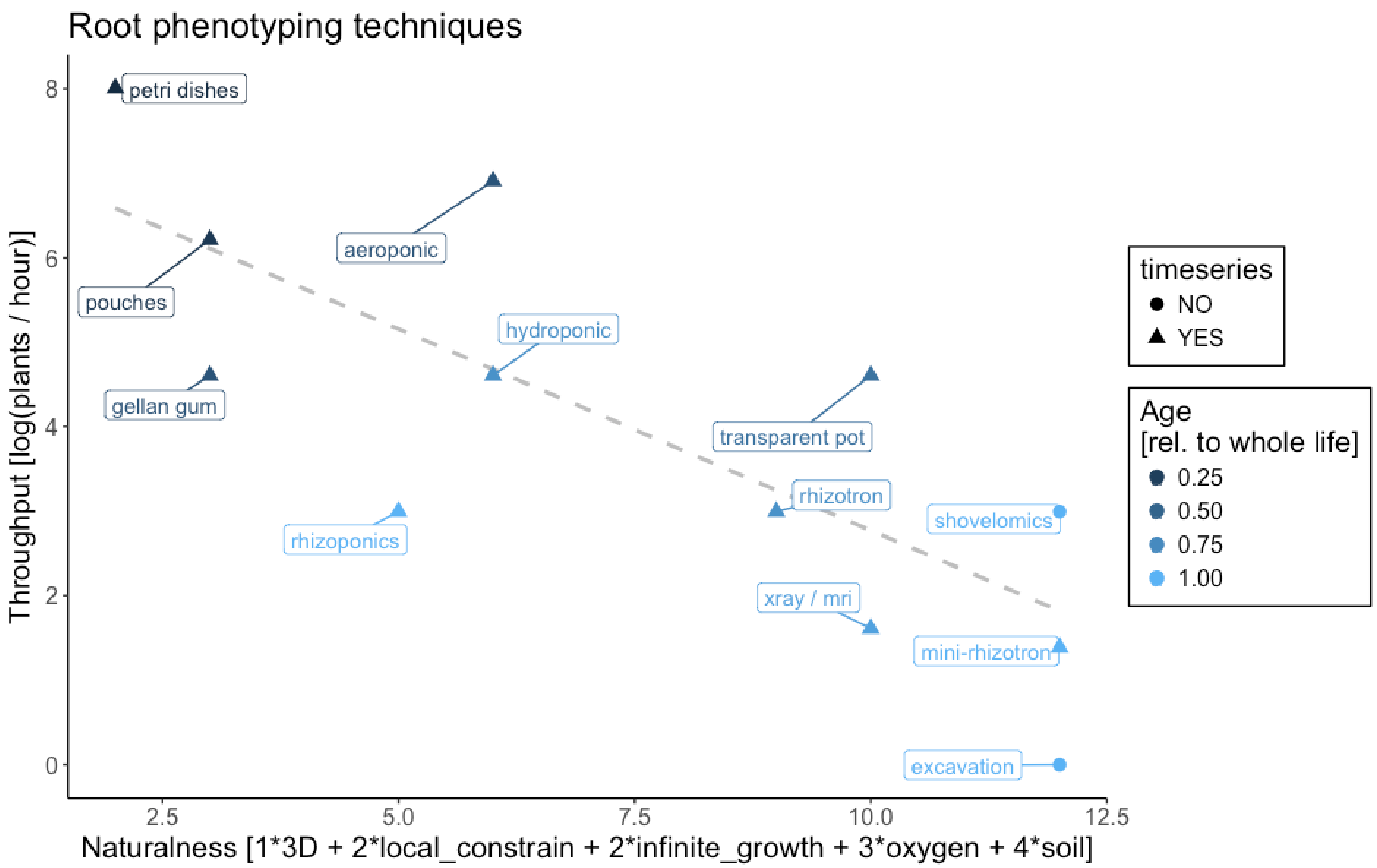
Tout a débuté en… 2010

- Constitution d’une expertise en Ecophysiologie racinaire
- Approches basées sur des hypothèses scientifiques et les dispositifs expérimentaux associés
- Au final : une ligne du temps intéressante, avec un réalisme croissant.



Dispositifs expérimentaux

Habituellement un compromis entre réalisme et débit d'informations collectées



Lobet, G. (2017). Root phenotyping platforms. figshare.

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Reduced winter wheat yields in future meteorological conditions despite CO_2-fertilisation

Leemans, V., Michel, J., Aubinet, M., Antoine, M., Brostaux, Y., Colinet G., Cornelis, J.-T., Degré, A., Duhaubois, G., Dumont, B., Garré, S., Hamdi, R., Longdoz, B., Maghnia, F.Z., Malumba, P., Massart, S., Pierreux, J., Saré, A. R., Soyeur, H., Vanderschuren H, Thonar, C., **Delaplace, P.**

To be submitted to *Science Advances*

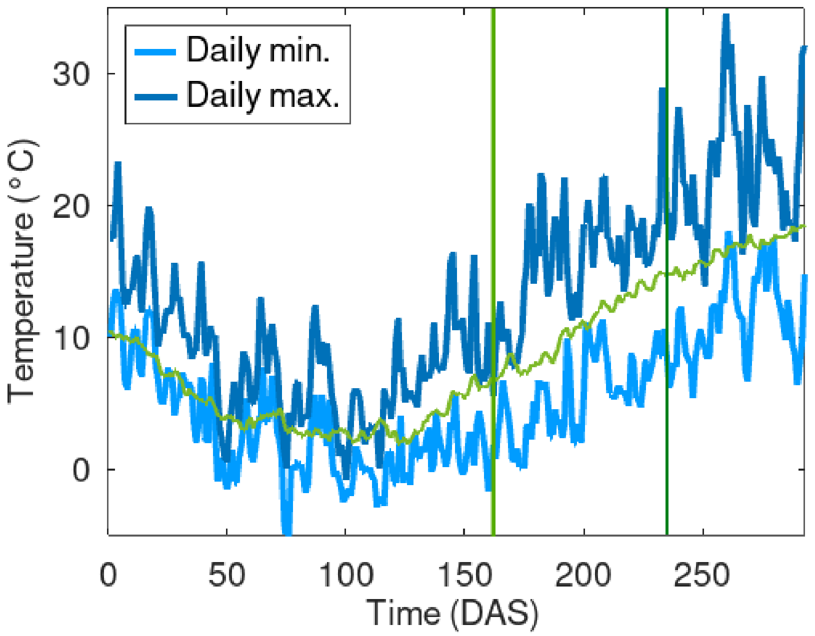
The main objectives:

- Compare the impact of typical present and future meteorological conditions on the performance of a common winter wheat crop.
- The climate simulations, soil type and cropping systems are representative of a typical maritime temperate climate.
- We aimed to empirically test how the predicted future meteorological conditions would impact (i) crop yields, (ii) grain quality, especially nitrogen content, and (iii) the belowground crop compartments including root development.

The experimental setup:

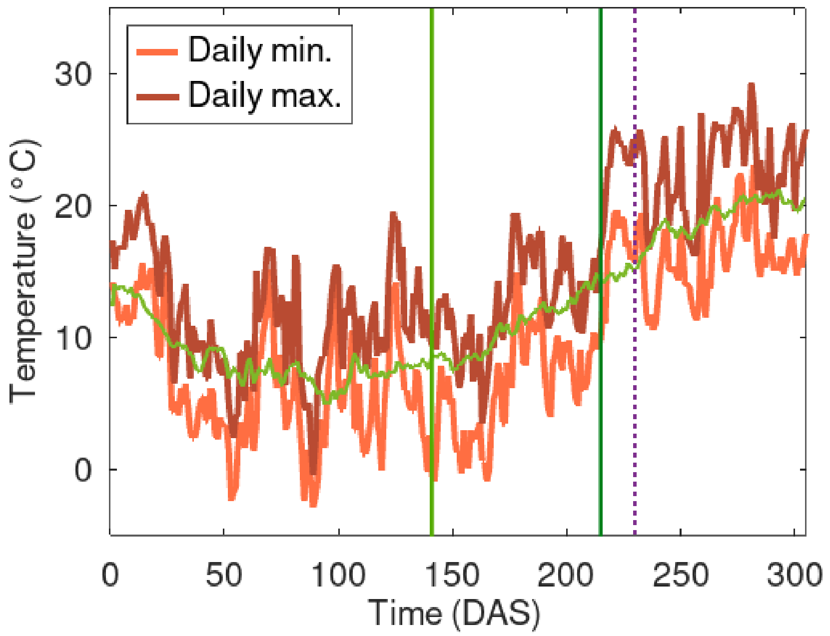
- 2015 vs 2071-2100 based on the RCP 8.5

400-450 ppm CO_2



2015

775 ppm CO_2

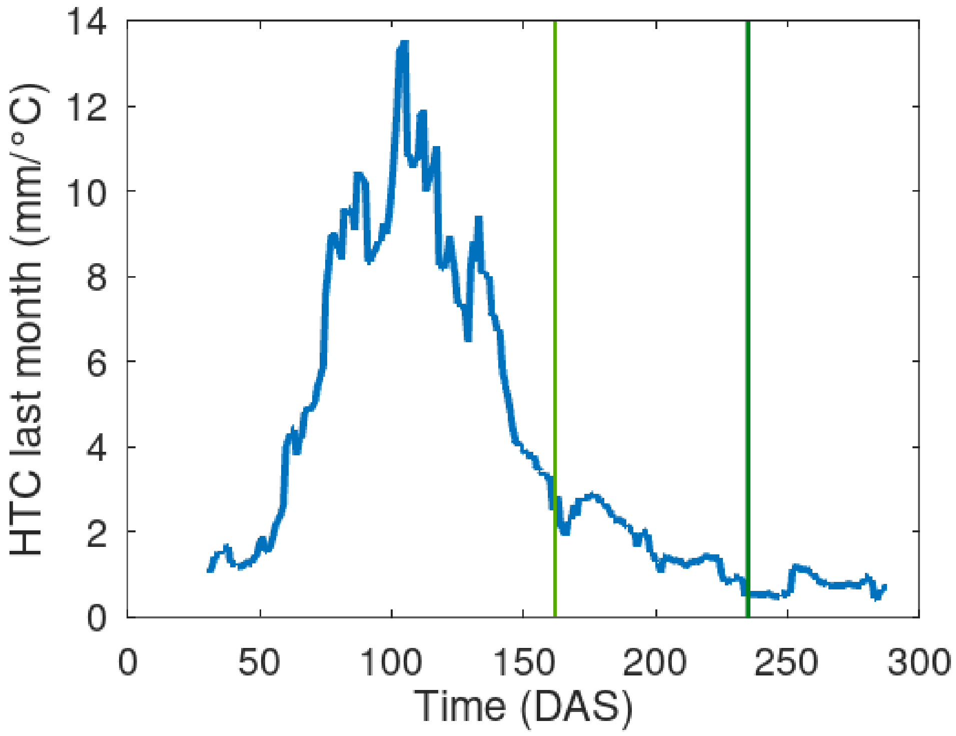


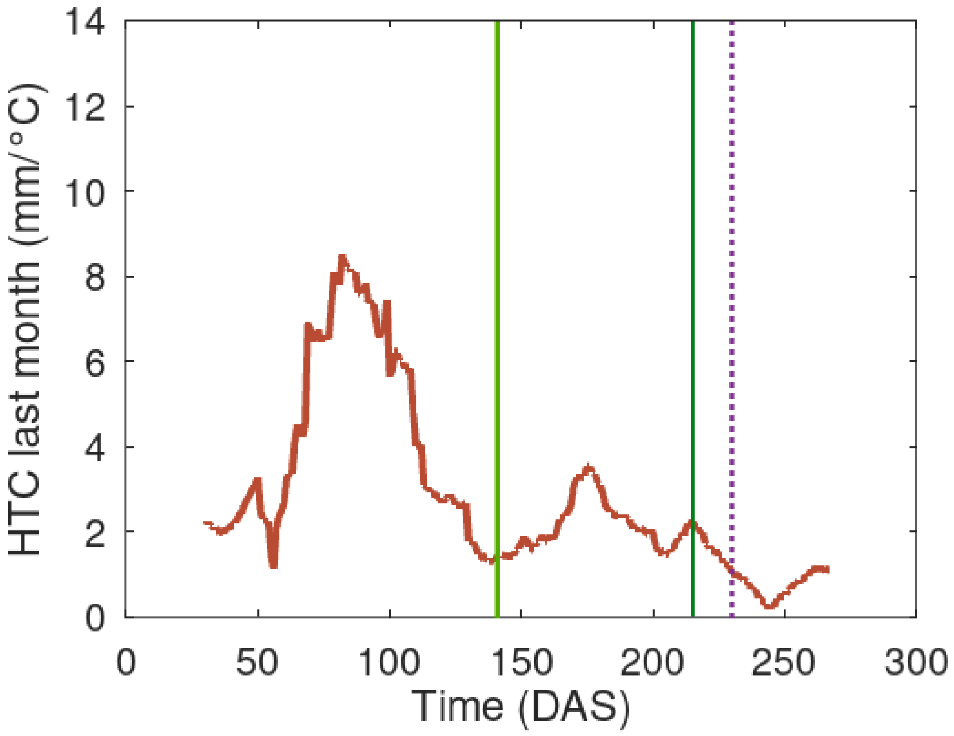
2094

The experimental setup:

- 2015 vs 2071-2100 based on the RCP 8.5

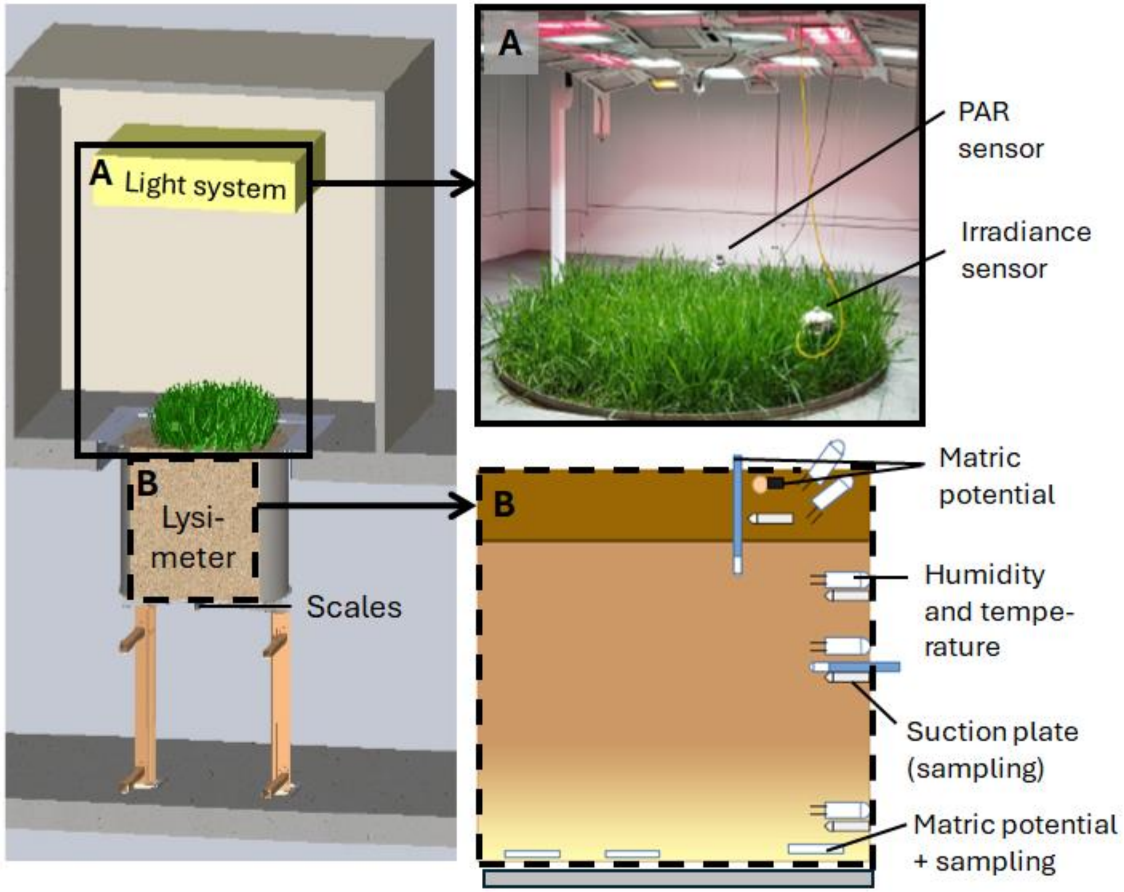
$$HTC = \frac{P_{T>10}}{\Sigma T_{T>10}/10}$$



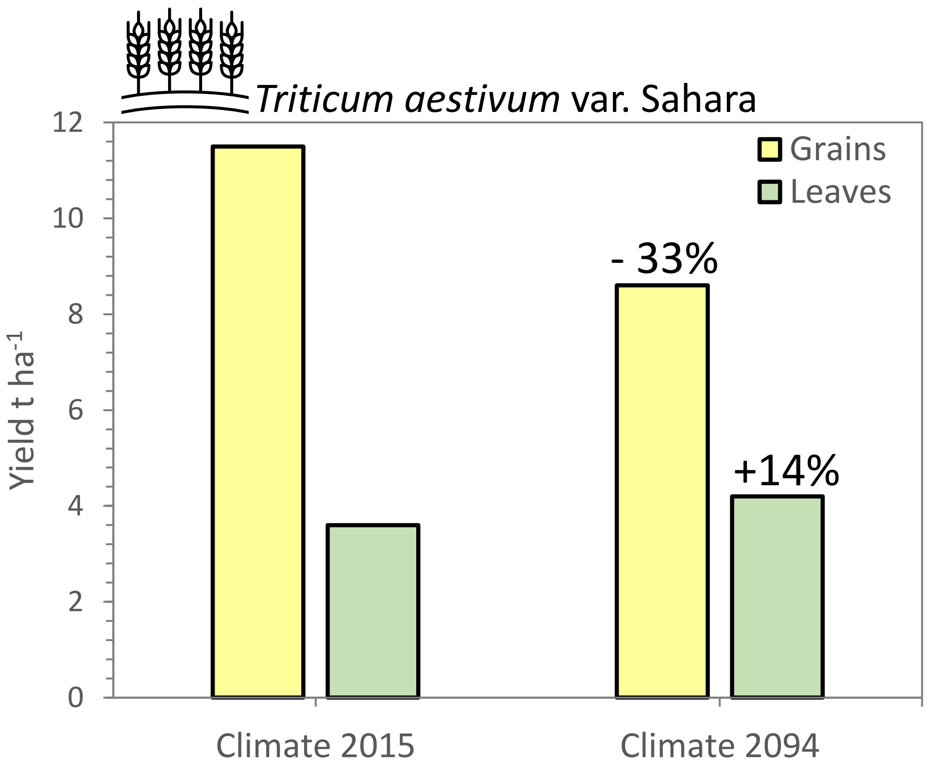


The experimental setup:

- The controlled environment rooms and lysimeters:



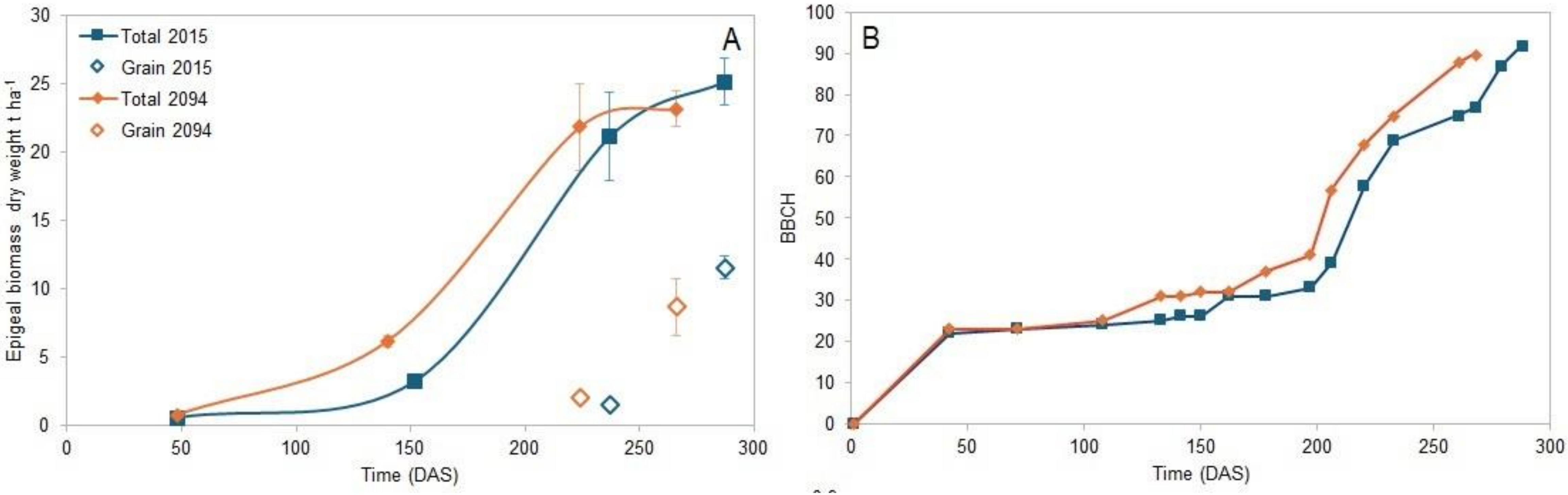
Wheat plants grown under future climatic conditions exhibited a strong drop in yield and harvest index.



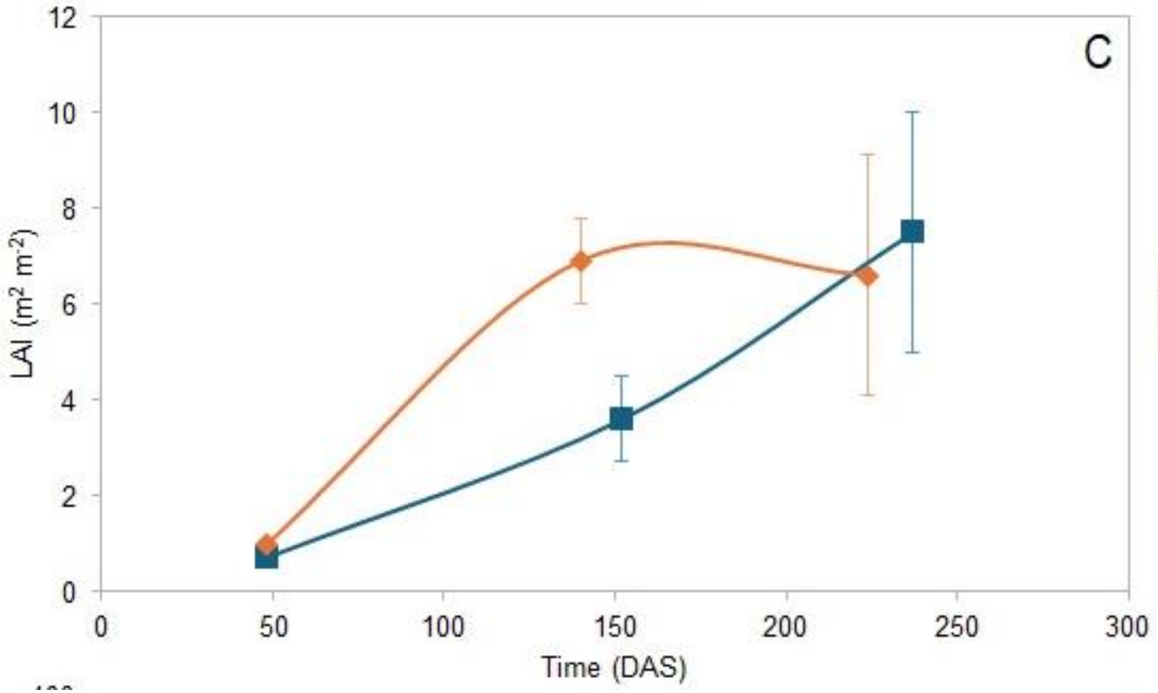
Yield = ear density * grains per ear * grain mass

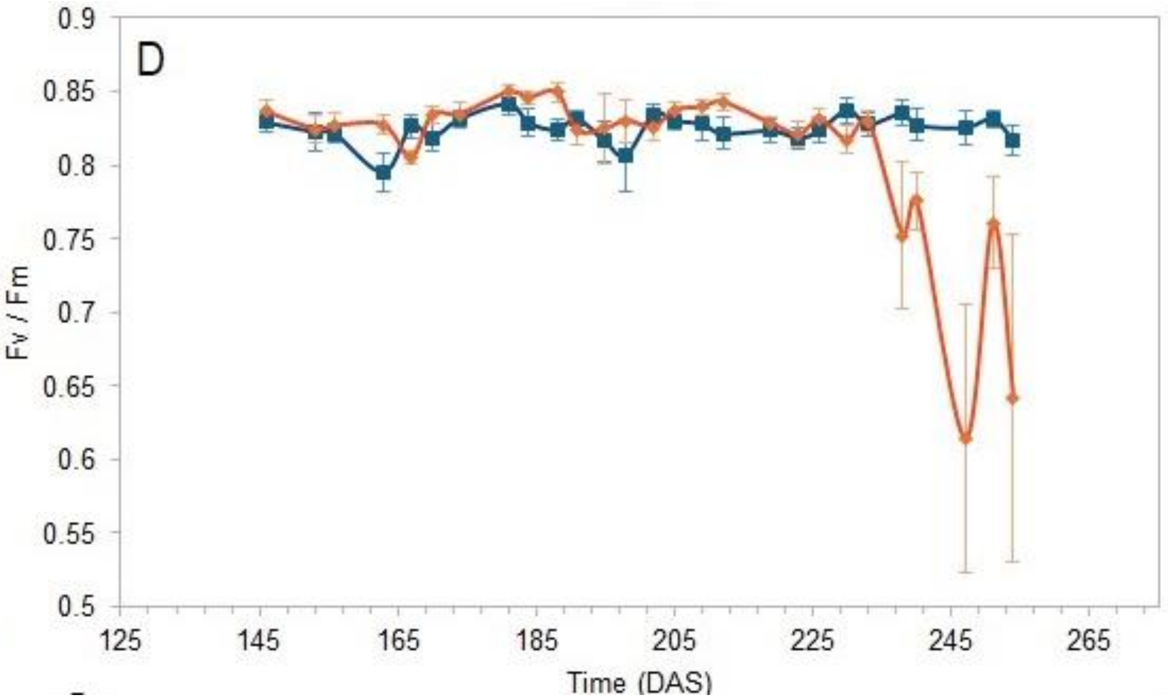
ED: -12%
GPE: -1%
GM: -15%

Wheat plants grown under future conditions accumulated higher biomass earlier, with a shift in phenology afterwards.

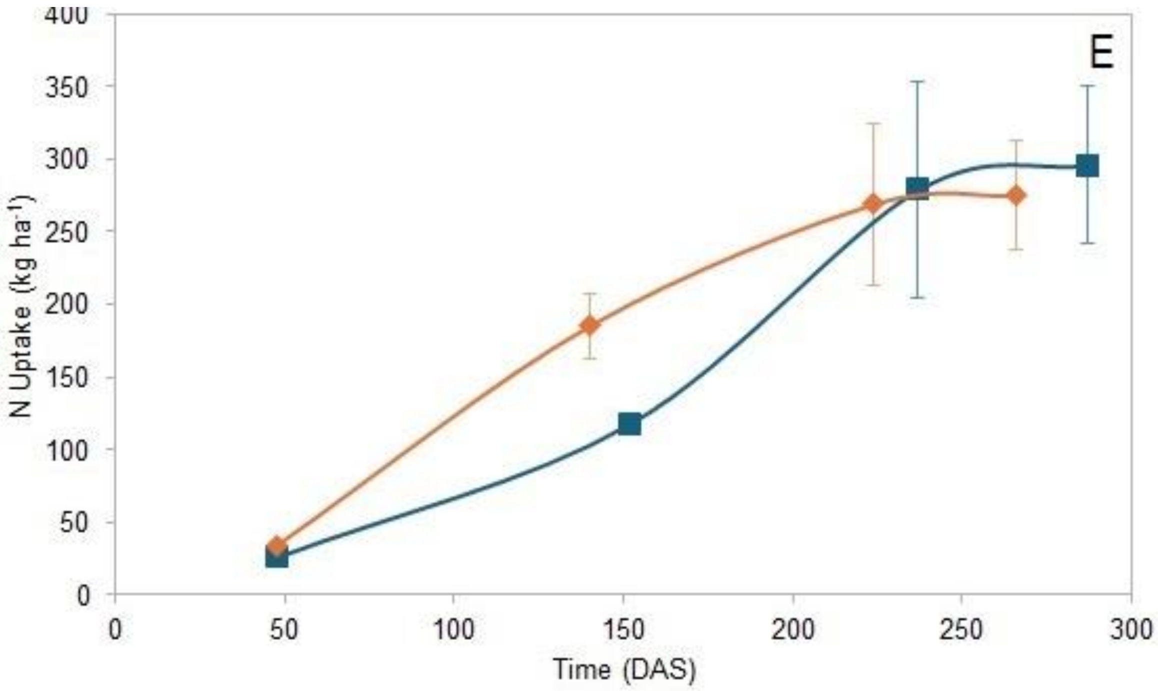


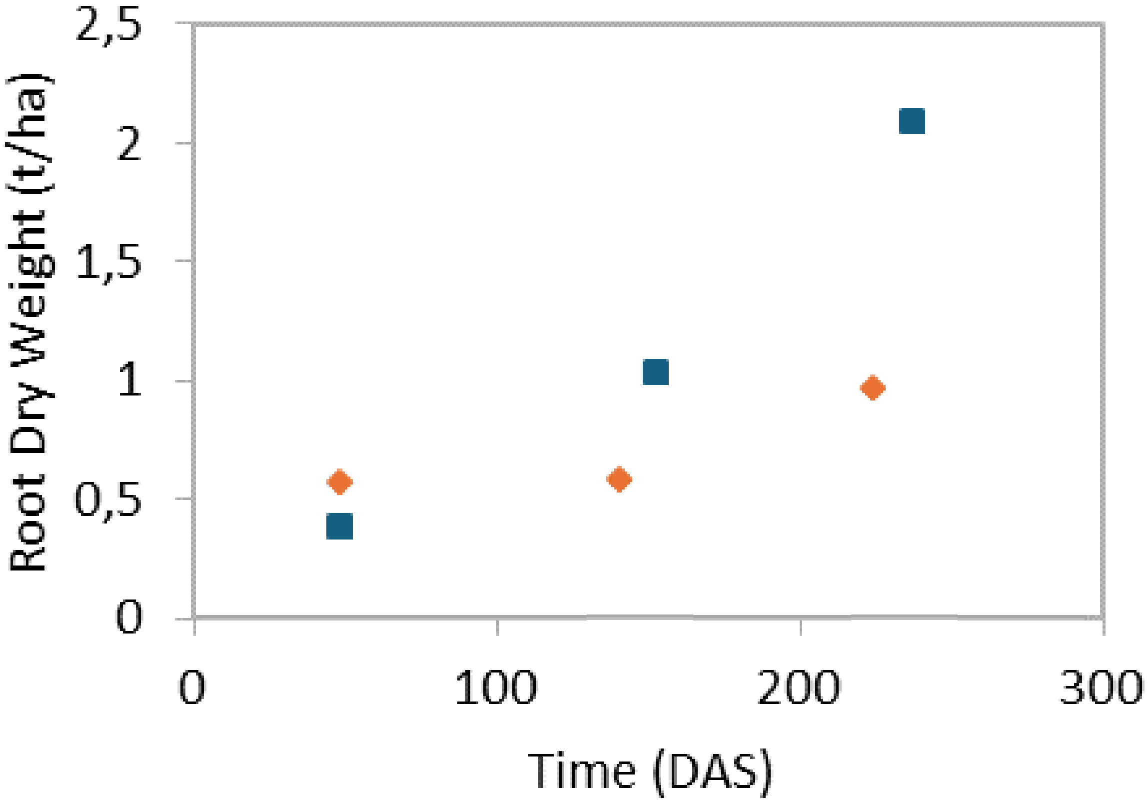
This lead to an early and transient LAI increase and an impaired ability to cope with water stress during grain filling.



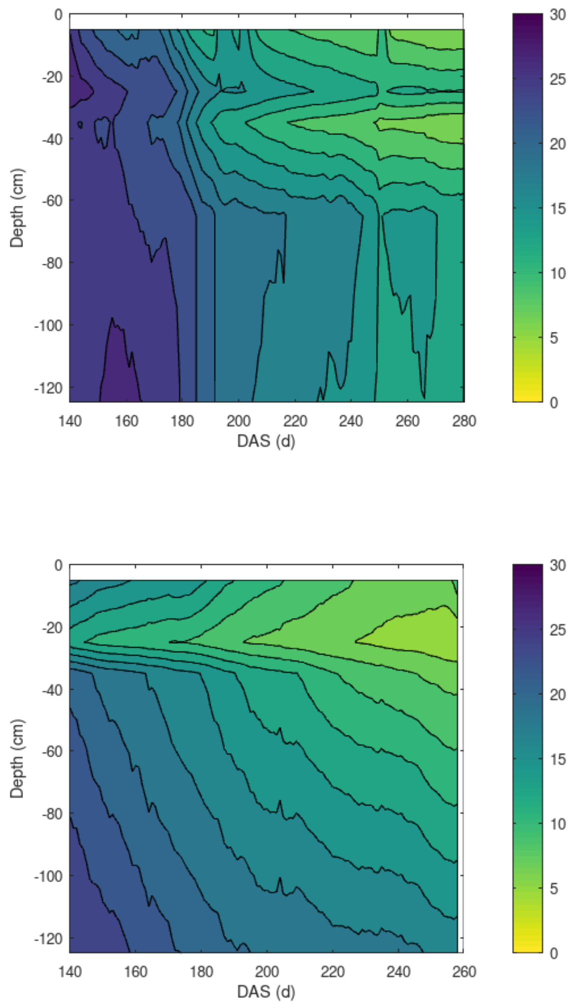


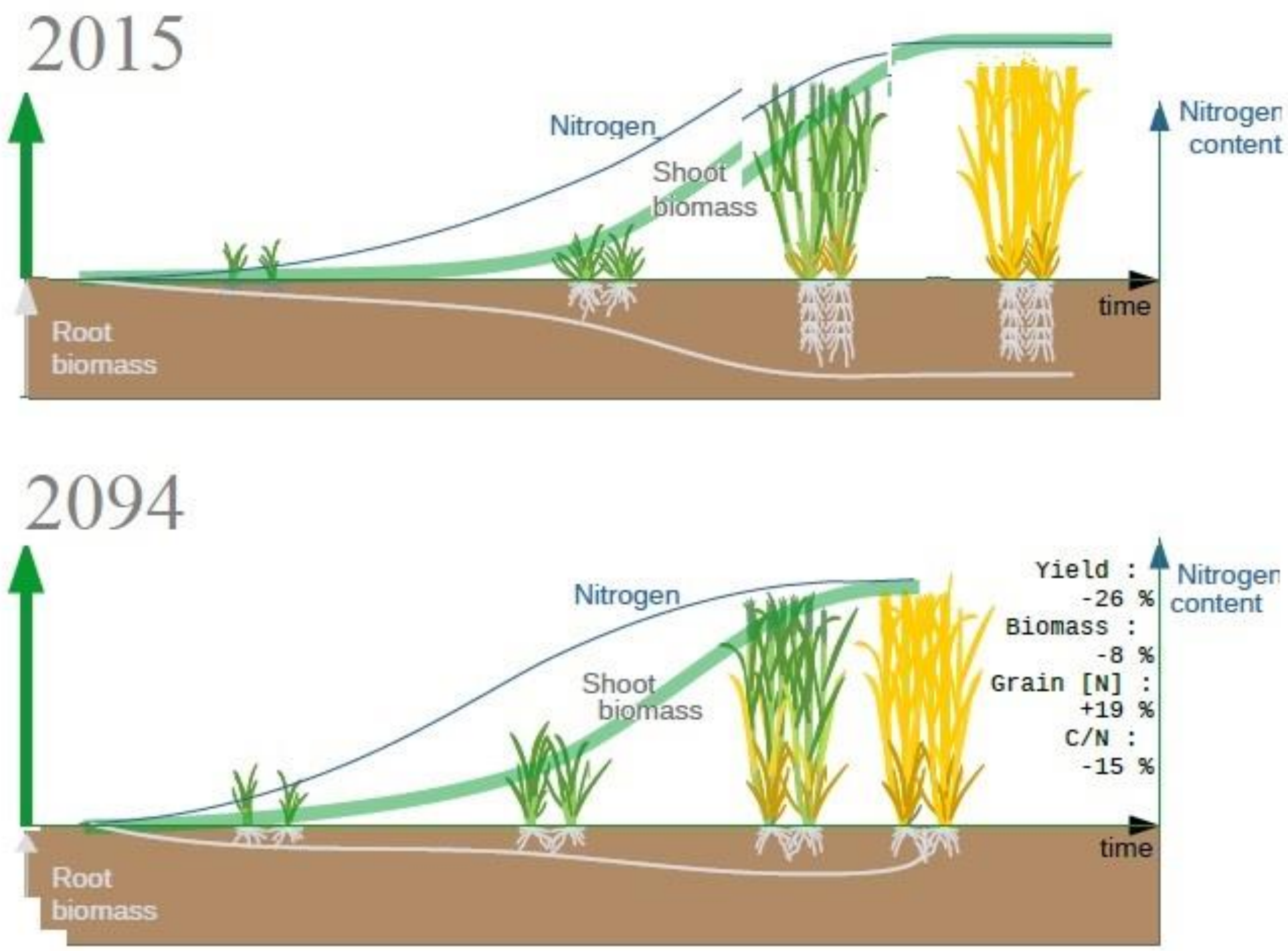
The N uptake was transiently higher in 2094 at tillering. N availability lead to an impaired root development.





This yield penalty is due to several processes related to early growth, resource availability/foraging and stress resistance during grain filling.





Conclusions and perspectives

- The future meteorological conditions during winter favoured immediate epigeal growth but hampered later development.
- The future meteorological conditions reduced the water stress resistance as well as the hypogeal development.
- The impact of the FMC on the crop came thus mainly threefold.
- Later sowing dates could counterbalance the physiological development but fall waterlogging could impede the sowing.
- Breeding should target different root ideotypes able to cope with the expected soil conditions.
- What about the fertilization strategy (SOM management)?

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Trade-offs associated with higher winter wheat yields in low soil organic matter cropping systems under climate change

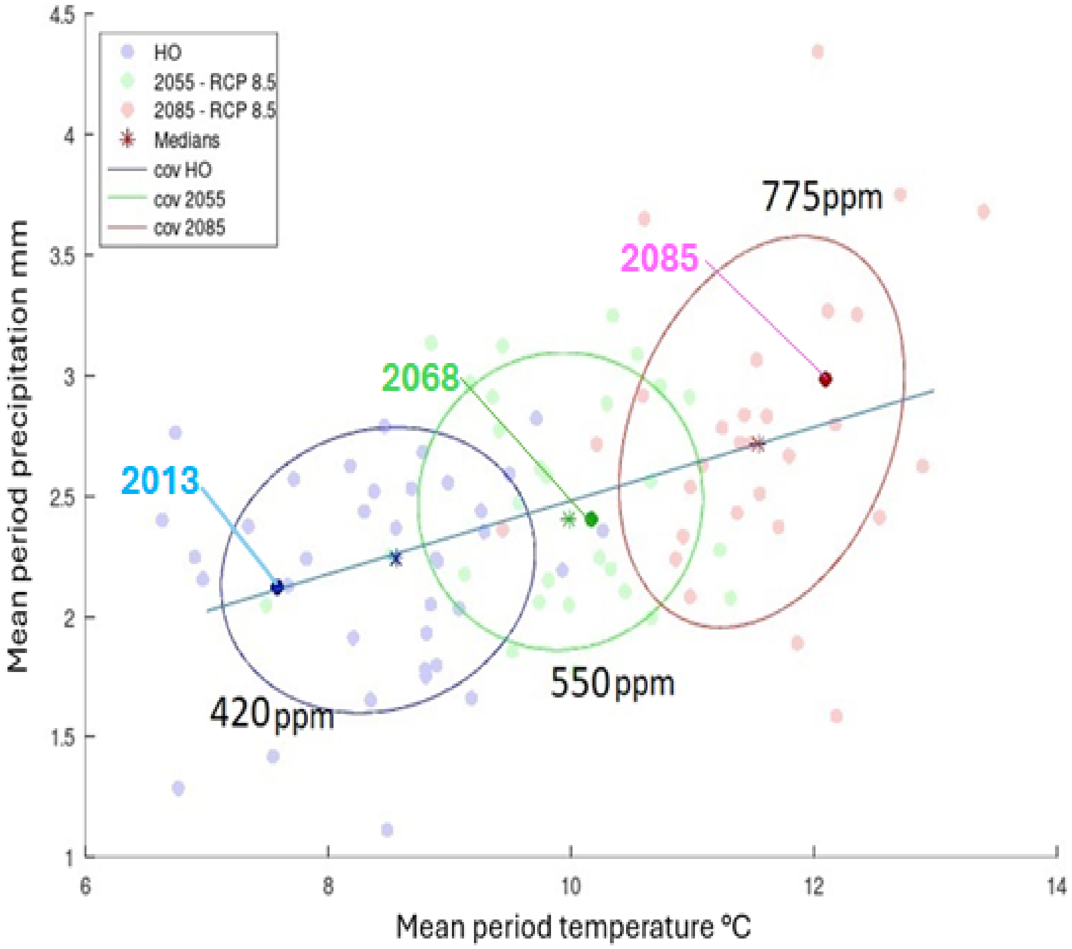
Jennifer Michel, Vincent Leemans, Markus Weinmann, Iñaki Balanzategui-Guijarro, Jimmy Bin, Simon Biver, Adrien Blum, Rachel Börger, Da Cao, Sok-Lay Him, Gaëlle Kirbas, Jacques Le Gouis, Jordi Moya-Laraño, Mayliss Persyn, Jérome Pierreux, Alice Quenon, Sara Sanchez-Moreno, Sarah Symanczik, Florian Vanden Brande, Dominique Van Der Straeten, Markus Wagner, Matthias Waibel, Anna Xayphrarath, Hervé Vanderschuren, Cécile Thonar, **Pierre Delaplace**

Submitted to PLOS Climate

The main questions:

- How do future meteorological conditions impact winter wheat cropping systems ?
- Can low or high organic matter soil management strategies prevent some of the anticipated negative impacts of climate change on crop system performance and yield?

The experimental setup:



Climatic parameters	2013	2068	2085
Mean CO_2 ppm	420	550	775
Mean radiation µmol m^{-2} s^{-1}	51.81	53.98	54.49
Mean temperature °C d^{-1}	7.6	10.2	12.1
Mean precipitation mm d^{-1}	2.1	2.4	3
Hydrothermal index (rel.)	4	4.5	4.7
Maximum temperature °C	26.5	23.4	22.2
Minimum temperature °C	-7.6	-5.8	3.1
n days temperature ≤ 4°C	94	40	3
n days temperature ≥ 22°C	9	7	2
Maximum precipitation mm	46.3	39.0	47.3
Minimum precipitation mm	0.0	0.0	0.0
n days precipitation ≤ 0mm	135	4	3
n days precipitation ≥ 4mm	57	62	72

The experimental setup:

SM1b: Soil monolith sampling

The experimental setup:

2013

CER 1

S2	C_S2	S1
S2	S1	S1
S2	S1	S2

CER 4

C_S1	S2	X-S2
S1	S2	S2
S1	S2	S1

2068

CER 2

S1	S1	S2
S2	S2	S1
S1	C_S2	S2

CER 5

S1	S2	S2
S1	S1	S2
C_S1	S2	S1

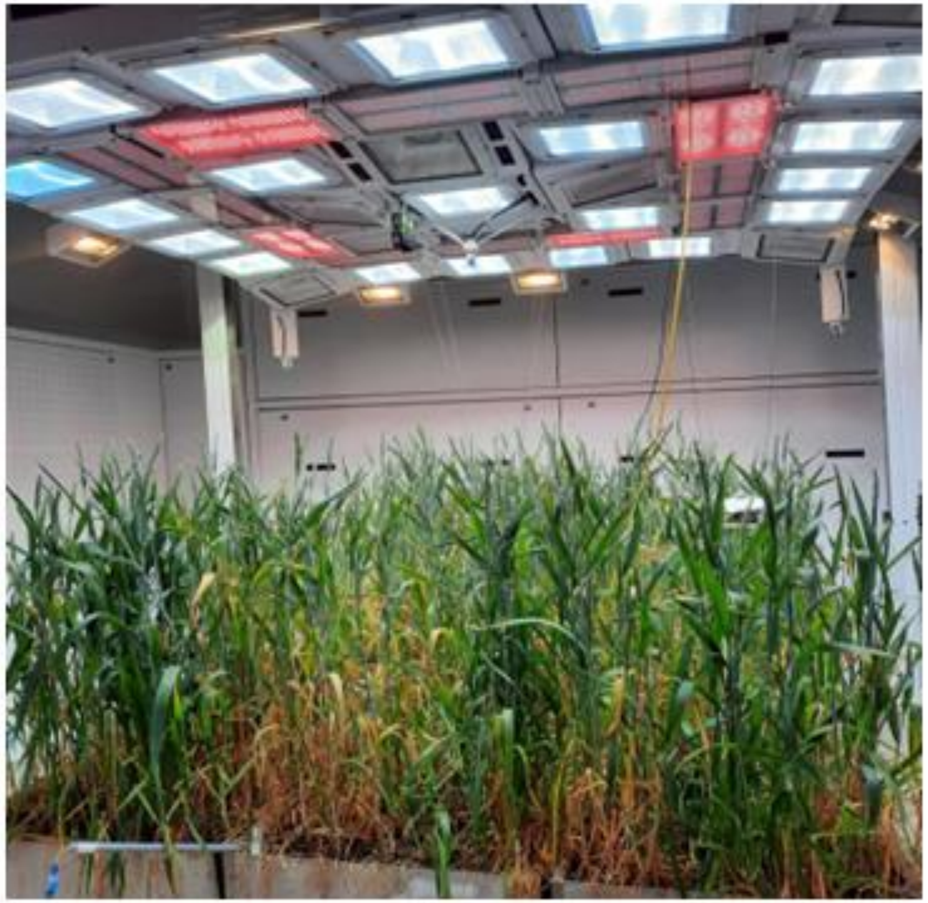
2085

CER 3

S2	S2	S1
C_S1	S1	S2
S1	S1	S2

CER 6

S2	S1	S1
S1	S2	S2
S1	S2	C_S2



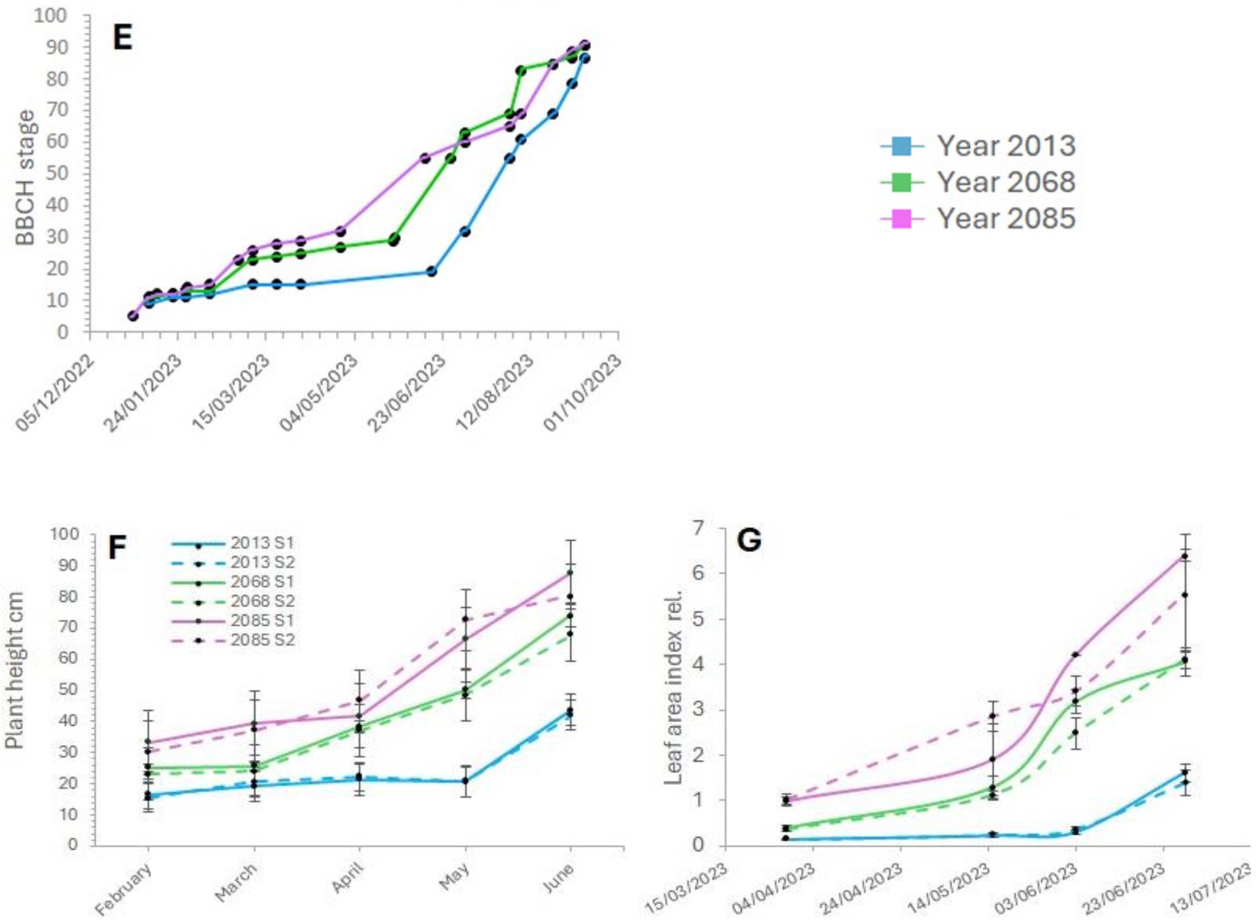
The experimental setup:

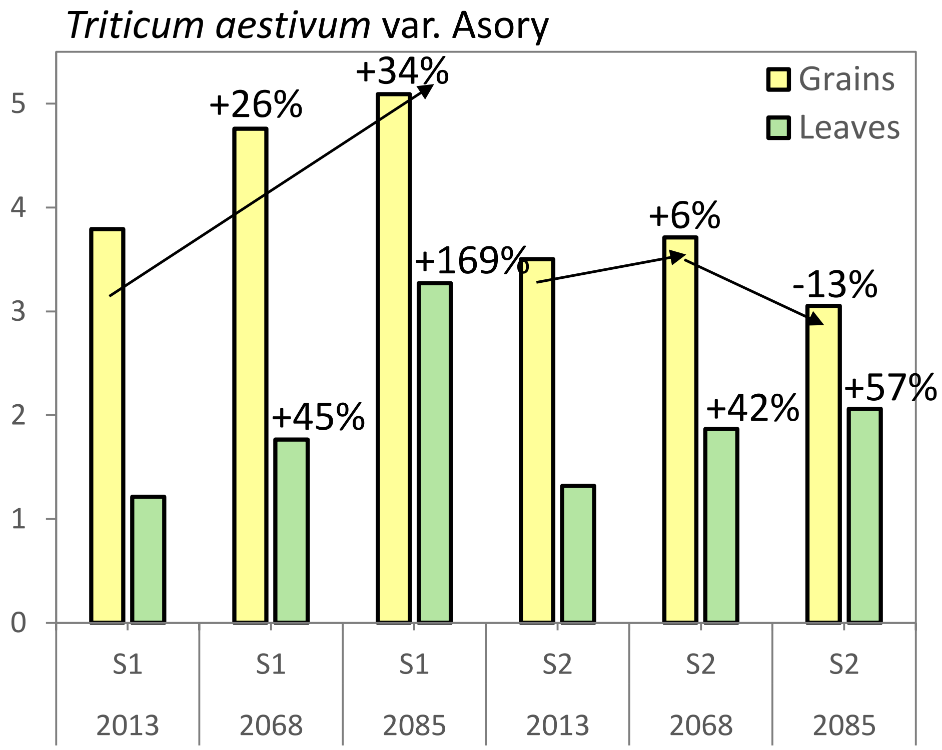
- 2 soils with contrasted long-term OM inputs
- S1 is sandier than S2

Table 1: Physicochemical characterisation of the two soil types at the beginning of the experiment, one composite sample per soil type, sampling depth: 0-20cm. Abbreviations: OM: organic matter, C: carbon, N: nitrogen, P: phosphorous, Mg: magnesium, Ca: calcium.

	C (g kg^{-1})	N (g kg^{-1})	$\frac{C}{N}$	P (mg 100g^{-1})	K (mg 100g^{-1})	Mg (mg 100g^{-1})	Ca (mg 100g^{-1})	pH (H_20)	Humus (%)	Clay (%)	Silt (%)	Sand (%)	Soil classifi-cation
Soil One (S1) "low OM"	9.92	0.94	10.5	13.60	31.20	8.37	218.31	8.04	1.98	12.15	67.13	20.72	Aba(b)0 Silt loam
Soil Two (S2) "high OM"	22.01	2.09	10.5	39.79	72.51	14.70	534.42	8.08	4.23	13.55	78.85	7.60	Aba(b)0 Silt loam

Phenological advance in future meteorological conditions, earlier harvests and yield outcomes





The thousand grain and straw yields are affected by both the climatic scenario and the soil type.

Table 2: Yield components for winter wheat (*Triticum aestivum* var. Asory) grown in two differentially managed soil types (low input S1 and high input S2) in the meteorological conditions of the years 2013, 2068 and 2085. Probability values following analysis of variance with asterisks indicating significance levels at <0.001***, ≤0.05*, >0.05 not significant (ns) and letters indicating grouping based on TukeyHSD test.

	2013		**2068**		**2085**		
	S1	**S2**	**S1**	**S2**	**S1**	**S2**	**p-value**
Grain yield t ha^{-1}	3.79±0.51 ab	3.50±0.34 ab	4.76±0.37 ab	3.71±0.32 ab	5.09±0.50 a	3.05±0.59 b	0.0375 *
Thousand grain weight g	31.12±2.35 a	30.45±6.85 a	35.62±2.77 ab	47.13±8.48 c	45.18±1.95 bc	41.29±3.98 abc	0.0004 ***
Grain nitrogen (%)	2.26±0.20	2.25±0.18	2.00±0.11	1.87±0.11	2.11±0.39	1.97±0.22	0.13 (ns)
Number of heads cube^{-1}	108±20	108±19	111±11	88±9	118±20	101±27	0.36 (ns)
Total fresh weight straw g cube^{-1}	121.54±17.53 a	131.74±52.51 a	176.55±22.84 a	186.71±40.81 a	327.29±71.40 b	206.21±49.92 a	0.00009 ***

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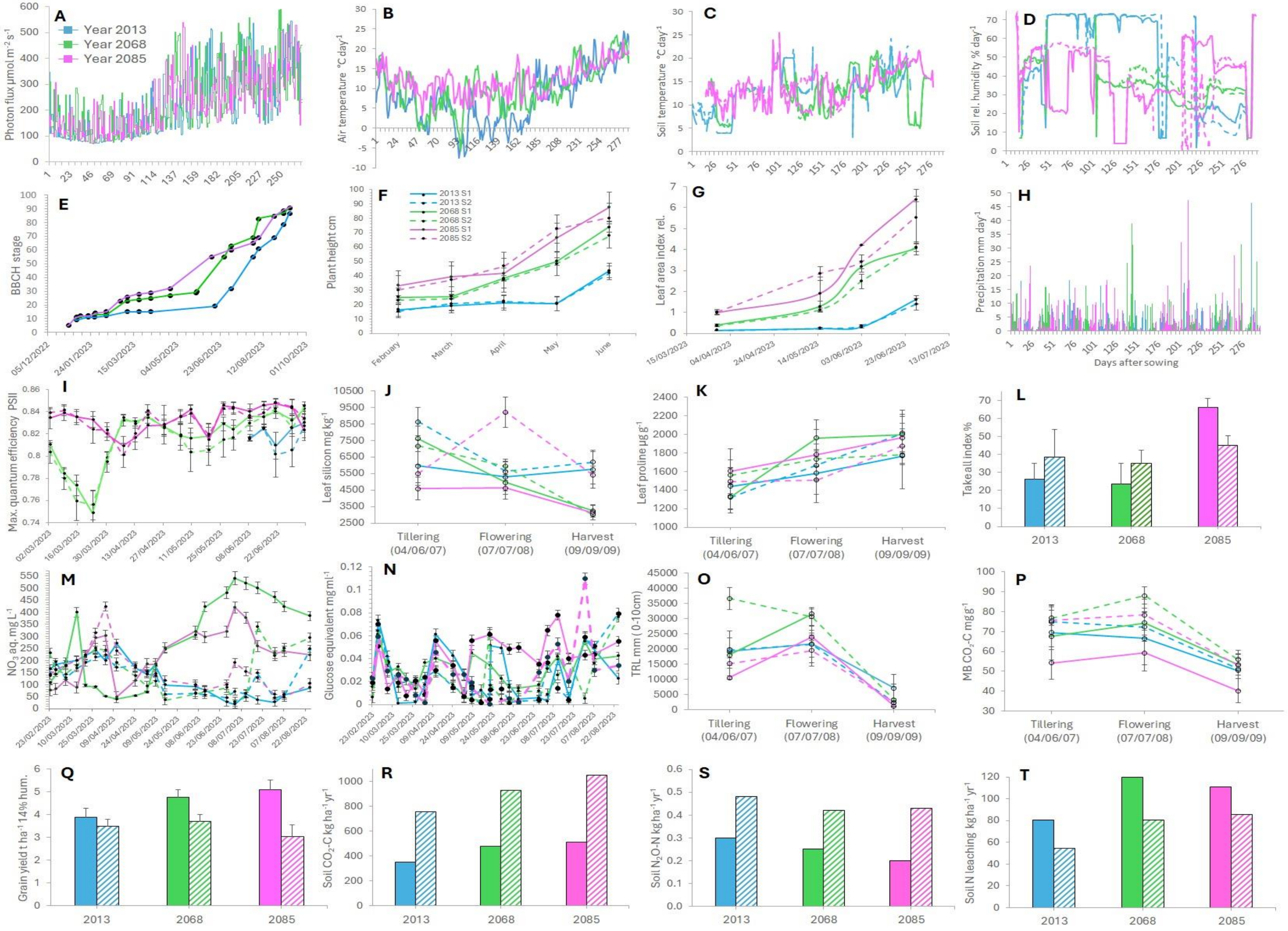
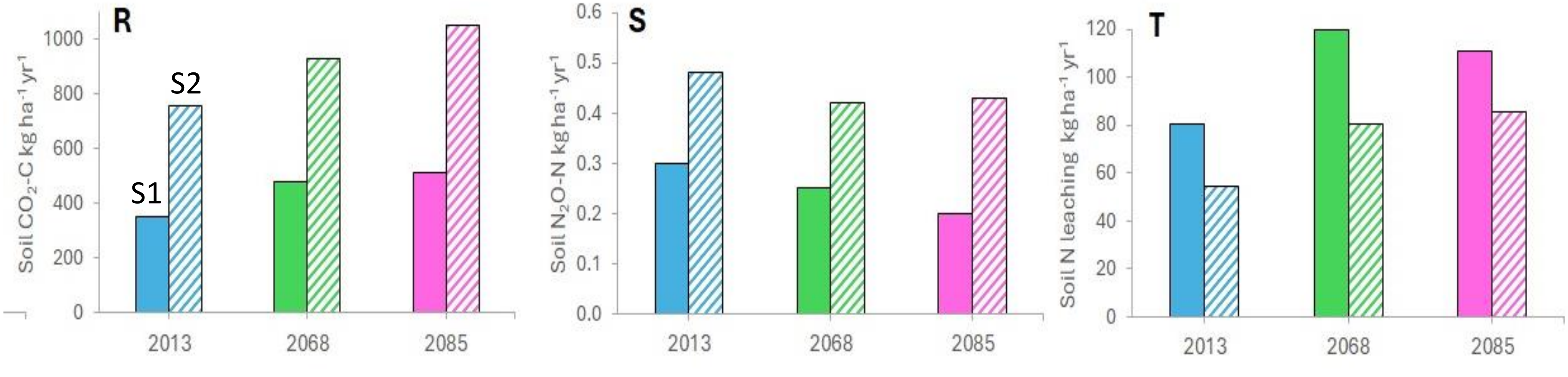
Environmental, crop and soil parameters

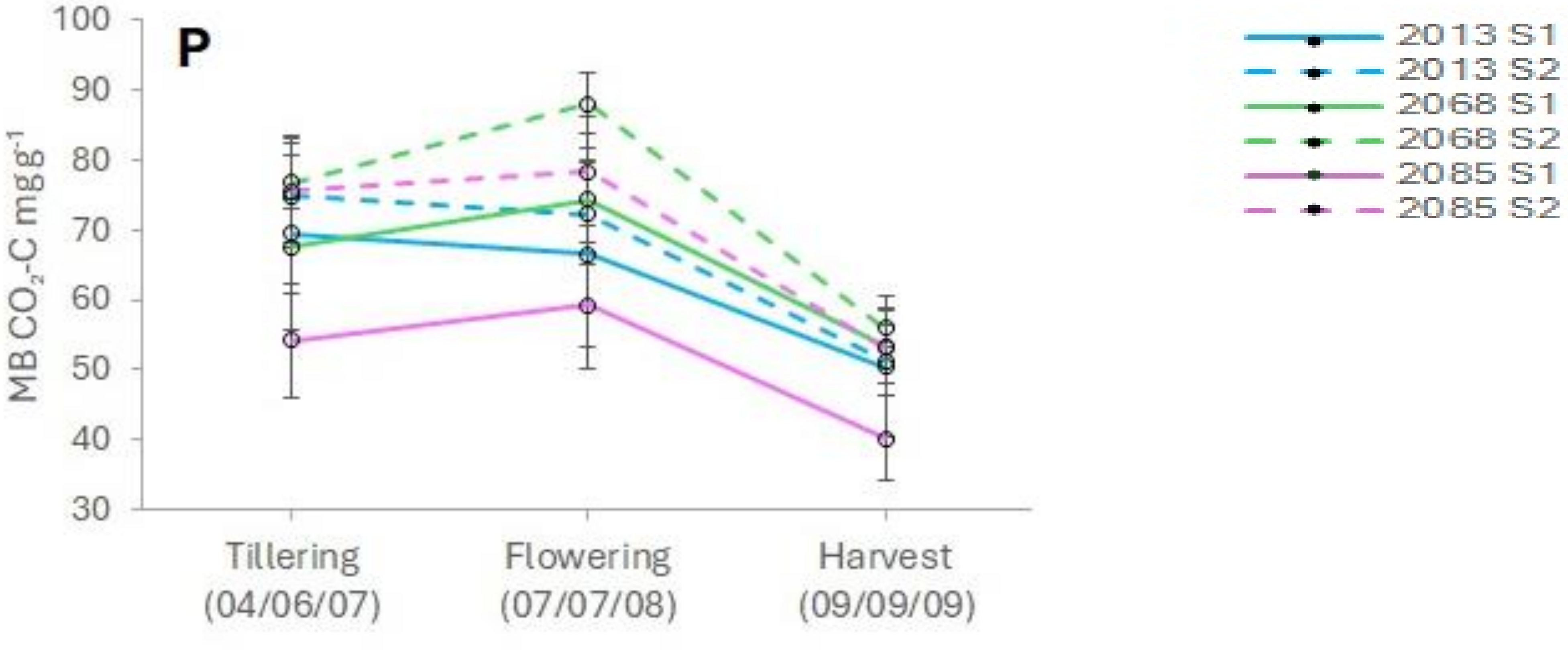


GHG emissions and nitrate leaching potential are affected by SOM and soil texture under future climatic conditions*.

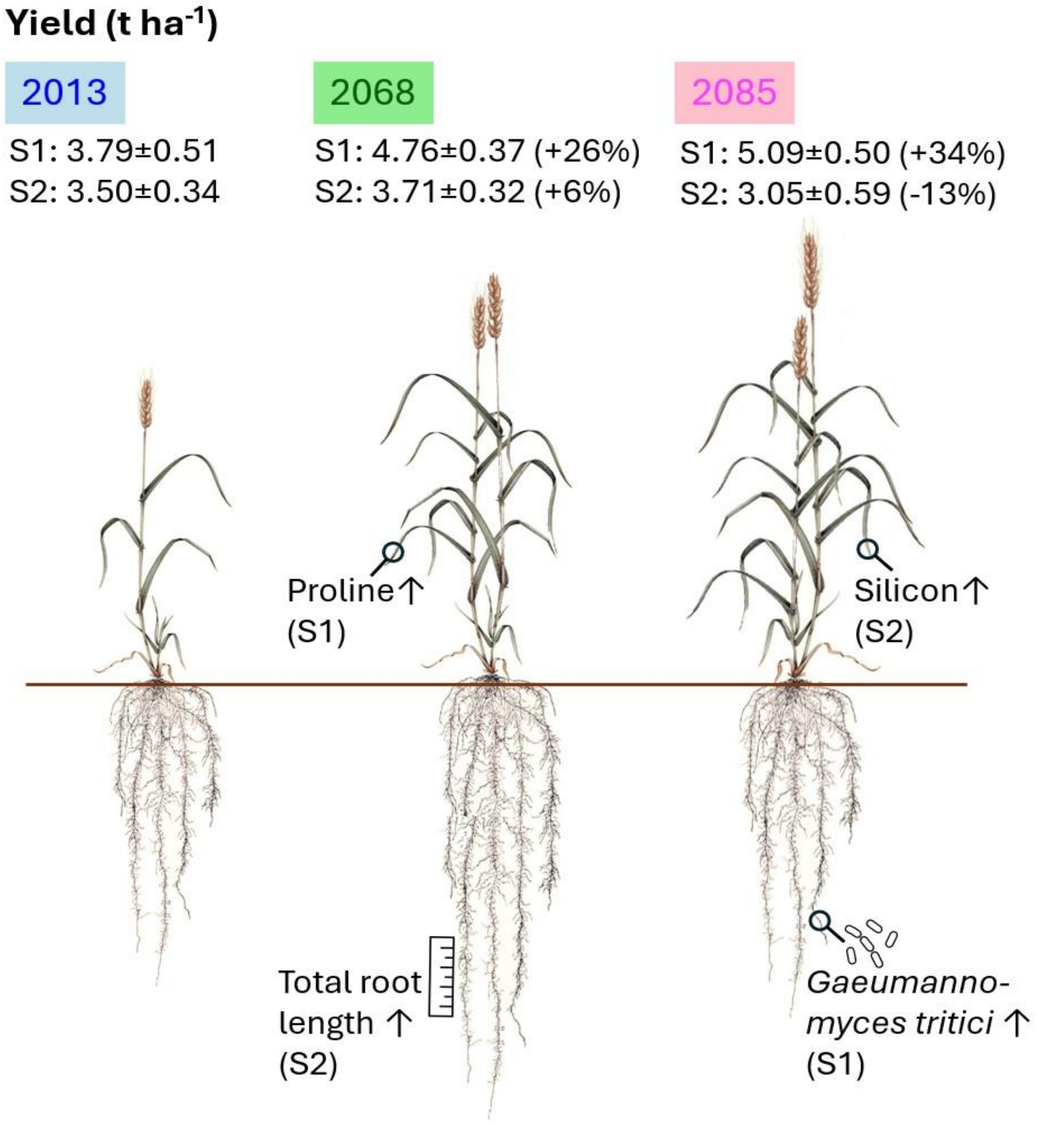


* DNDC modelled

This relates to contrasted soil microbial biomasses.



Plants can develop sucessful adaptive mechanisms to mitigate environmental stress (total root length, silicon, proline)



- The Total Root Length was higher in S2 at tillering in 2068.
- The take-all disease occurrence was higher in S1 in 2085.
- The strongest difference in [Si] between both soils was observed in 2085
- The opposite trend is observed for Proline.

Conclusions and perspectives

- Yield and soil organic matter: Less is more?
  - Consistency with the state of the art
- Quality of harvested grains
  - Nitrogen dilution effect due to CO_2, technology, TKW
- Naturally balancing the nitrogen cycling?
  - GHG emissions, nitrate leaching // MB and soil texture
- Stimulating natural plant adaptation to mitigate stress
  - Take-all disease occurrence without arming the yield, proline, silicon
- Implications of phenological advance for farming practices
  - Lodging, water stress resistance, breeding
- Ecotron constraints
  - Adaptation, realism,

What’s next?!

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This research is part of the BIOFAIR project (www.biofair.uliege.be) funded through the 2019-2020 BiodivERsA joint call for research proposals, under the BiodivClim ERA-Net COFUND programme, and with the funding organisations Agence Nationale de la Recherche (ANR, France; ANR-20-EBI5-0002), Agencia Estatal de Investigación (AEI, Spain; PCI2020-120713-2), Deutsches Zentrum für Luft- und Raumfahrt Projektträger (DLR-PT, Germany), Fonds de la Recherche Scientifique (FNRS, Wallonia, Belgium; R.8001.20), Fonds voor Wetenschappelijk Onderzoek - Vlaanderen (FWO, Flanders, Belgium; FWOERA-NET G0H7320N) & Schweizerischer Nationalfonds (SNF, Switzerland; 31BD30_193869).