Photosynthesis and Water Use in Wheat Ears

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Background

Global population is rising (Fig. 1) and is expected to reach **10 billion by 2050**, increasing pressure to improve crop yields (Fig. 2). Increased yield must also be achieved under future climatic conditions, with predicted increases in temperature, reduced perception and more erratic and extreme weather events.

One target for increasing yield is photosynthesis. The **changing climate**, characterized by **increased CO_2 levels, rising temperatures, and variable water availability**, directly affects wheat growth and underscores the significance of non-foliar photosynthesis in adapting to these changes.

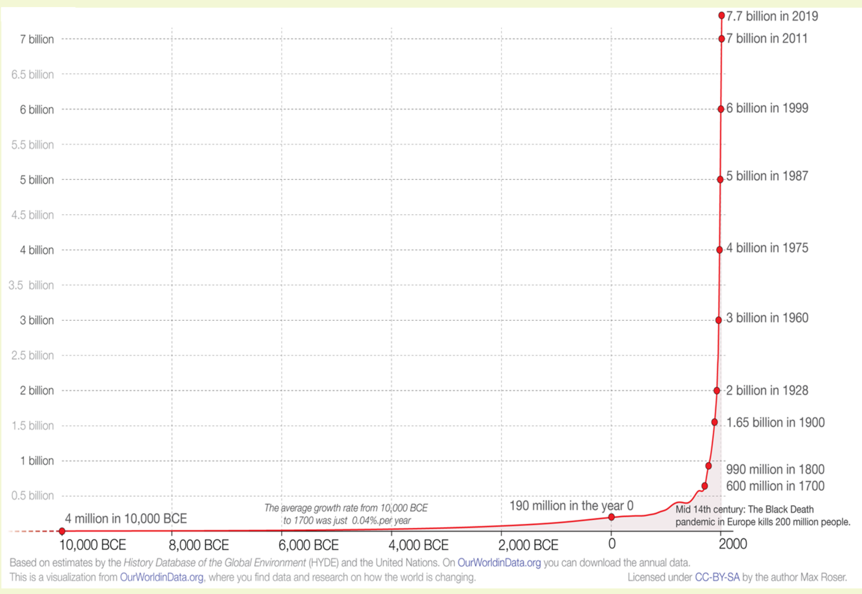

Fig. 1 World population increase over last 12,000 years (ourworldindata.org).

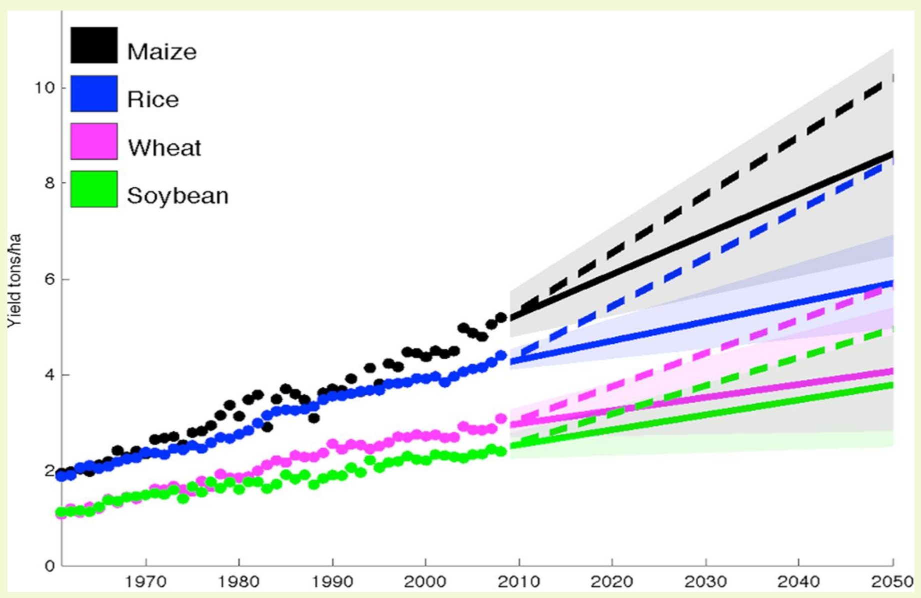

Fig. 2 Projected rate of crop yield increase , indicating current projection (solid line), and required projection for 2050 (dashed line) (Ray *et al.*, 2013).

Non-foliar photosynthesis

To date most physiological measurements of photosynthesis have focused on leaves, which are considered to be the most photosynthetically active tissue.

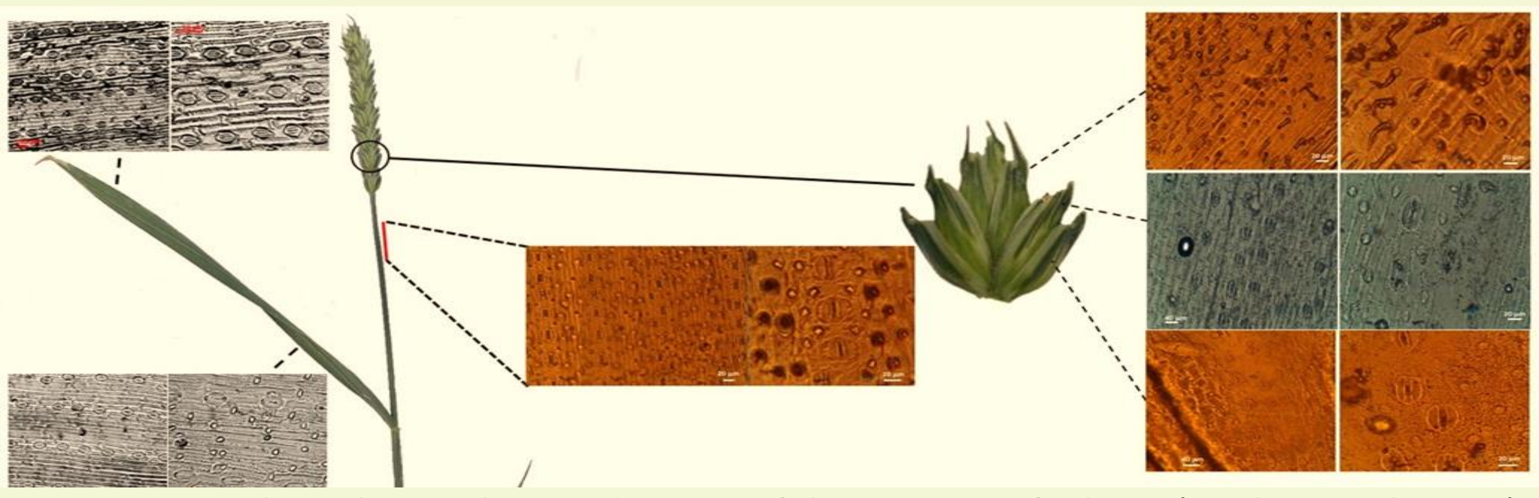

Fig.3 Stomata have been observed on non-foliar organs of wheat (Simkin *et al*. 2019).

Non-foliar organs account for 27-62% of green area per culm (Zhang *et al.,* 2011), and **under water-stressed conditions**, wheat flag leaf photosynthetic capacity and rate decrease (Vincente *et al.,* 2018). Subsequently **ears become the main contributor to the grain filling stage** (Fig. 3) (Hu *et al*., 2019**)**.

Photosynthesis in wheat ears can contribute **10%-60%** to yield (Hu *et al.* 2019), whilst stomata facilitate evaporative cooling and can mediate the effects of high temperatures on fertility and yield.

Aims & Objectives

The primary aim of this research is to quantify non-foliar photosynthesis and water loss through stomata in wheat ears. This will be achieved with the following objectives.

Development of a Novel Gas Exchange Chamber: Design a novel gas exchange chamber that can be utilised alongside mass spectrometry, to determine the source of CO_2 for photosynthesis.

Characterisation of Stomatal Function in Non-Foliar Tissue: Determine water loss through stomata under different environmental stresses.

Impact of Environmental Stresses on Photosynthesis and Yield: Examine the impact of reduced water availability and elevated temperatures on non-foliar photosynthetic efficiency and yield.

Hydraulic Capacity in Wheat Ears: Characterise hydraulic capacity of wheat ears to understand whole plant water relations and quantify water loss via non-foliar organs.

Impact of Temperature on Fertility: Quantify the role of stomata and impact of differences in stomatal density in regulating ear temperature for improved fertility at elevated temperatures.

Experimental Methodologies

Different varieties of wheat will be examined for variation in photosynthetic rates, stomatal density and water use efficiency in both ears and leaves.

Selected lines will be grown under elevated temperatures and drought to elucidate the role of non-foliar photosynthesis and the importance of stomata on these organs.

Fig.4 Custom build gas chamber for wheat ears.

1. Wheat ear gas exchange measurements will be performed using an infra-red gas analyser integrated with a custom-built chamber (Fig. 4) to quantify carbon assimilation and water loss. Measurements will be conducted under different light intensities, CO_2 concentrations, and temperatures.

2. Surface impressions will be taken from the leaves and wheat ears to determine differences in stomatal density.

3. Thermography will be used (Fig. 5) to assess the impact of temperature and water loss on wheat ear and fertility.

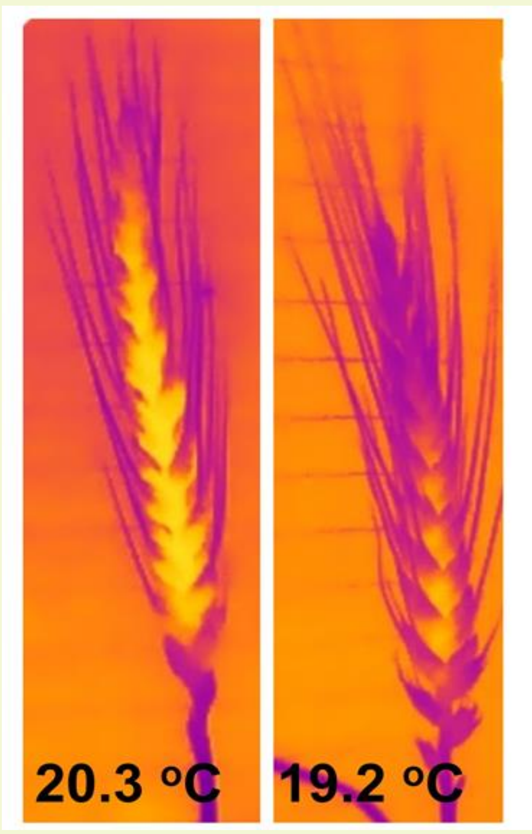

Fig.5 Example of thermal images from wheat ears with different stomatal densities (Lawson & Milliken 2023).

4. Development of gas exchange chamber to be used with mass spectrometry.

We are currently developing a gas exchange chamber (Fig. 6) that can be used in conjunction with mass spectrometry (Fig.7). This will enable the use of stable isotopes to be used under alongside IRGA gas exchange to determine how much CO2 is refixed from respiration.

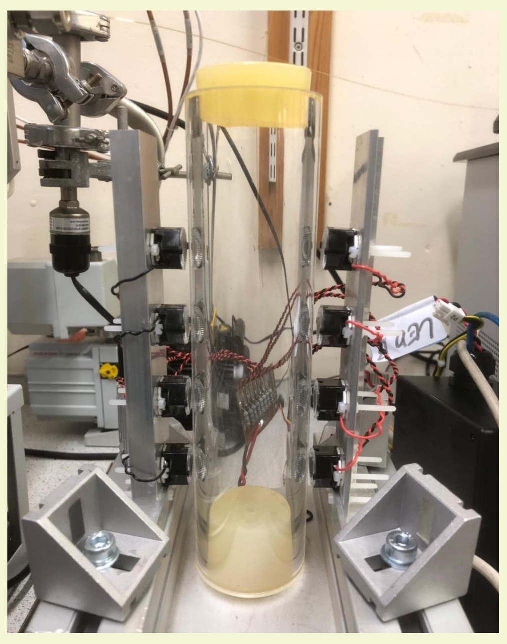

Fig.6 Prototype of the gas exchange chamber for mass spectrometry.

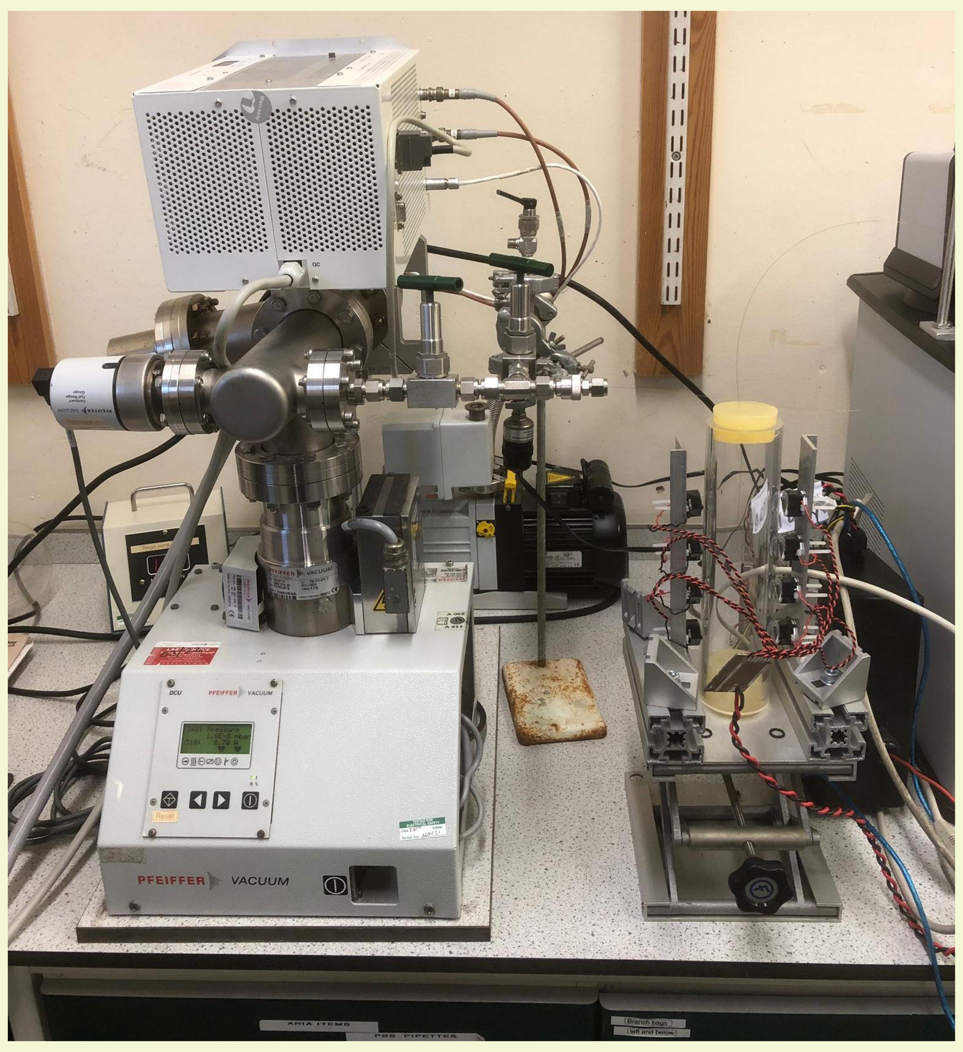

Fig.7 The prototype of the gas exchange chamber, connected to the mass spectrometer.

Summary

This research explores advanced methods to understand the importance of foliar photosynthesis and stomatal behavior in these tissues on yield. We will quantify non-foliar photosynthesis and water loss under future climatic scenarios. Wheat adaptability and, aiming to address global food security in future climate scenarios. This work will provide novel targets for future breeding programmes to support yield stability in changing climatic conditions.

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