31st SCOTTISH FLUID MECHANICS MEETING
29/05/2018
University of Aberdeen

University of Glasgow

A specialised wind tunnel for investigation of ecophysiological response of plants to wind

O. Zhdanov,[1] A. Busse,[1] M. R. Blatt,[2] H. Zare-Behtash[1]
[1] *Aerospace Sciences Division, School of Engineering, University of Glasgow*
[2] *Laboratory of Plant Physiology and Biophysics, University of Glasgow*

1. Introduction

One of the consequences of climate change will be changing wind patterns and intensities (Pryor et al., 2005). Wind can have either beneficial (wind pollination, seed dispersal, increased photosynthesis) or detrimental effects (reduced photosynthesis, loss of biomass, wind induced damage) on plants.
Plants have developed a number of strategies to adapt to their wind environment: streamlining and reconfiguration, damping and wind induced pruning. Figure 1 shows an example of adaptation of a tree to prevailing winds, a so called flag tree. In this project a combined study focusing on both aerodynamic and biological aspects of plant adaptation to the wind conditions is performed.


Fig 1: Flag tree - an example of permanent adaptation of plants to wind conditions in Greenock, Scotland (near Firth of Clyde)

Project Objectives:

- Develop a facility to study plants' response to wind induced mechanical loads
- Investigate adaptation of plants to wind and obtain comprehensive data combining both aerodynamic and ecophysiological studies
- Explore application of findings to biomimetic engineering structures

2. Arabidopsis

Thale cress (*Arabidopsis Thaliana*) is widely used for research in plant sciences and is the most studied higher plant (Page & Grossniklaus, 2002). At present there are over 30,000 different mutations that have been characterised in this species.

Main features:
- Small size (20-30 cm)
- Short lifecycle (around 6 weeks)
- Large number of seeds (up to 10,000 per plant)
- Easy cultivation in restricted space


Fig 2: Different Arabidopsis genotypes


Fig 3: Arabidopsis inside the wind tunnel test section at the initial stage of stem development (design objective ii)

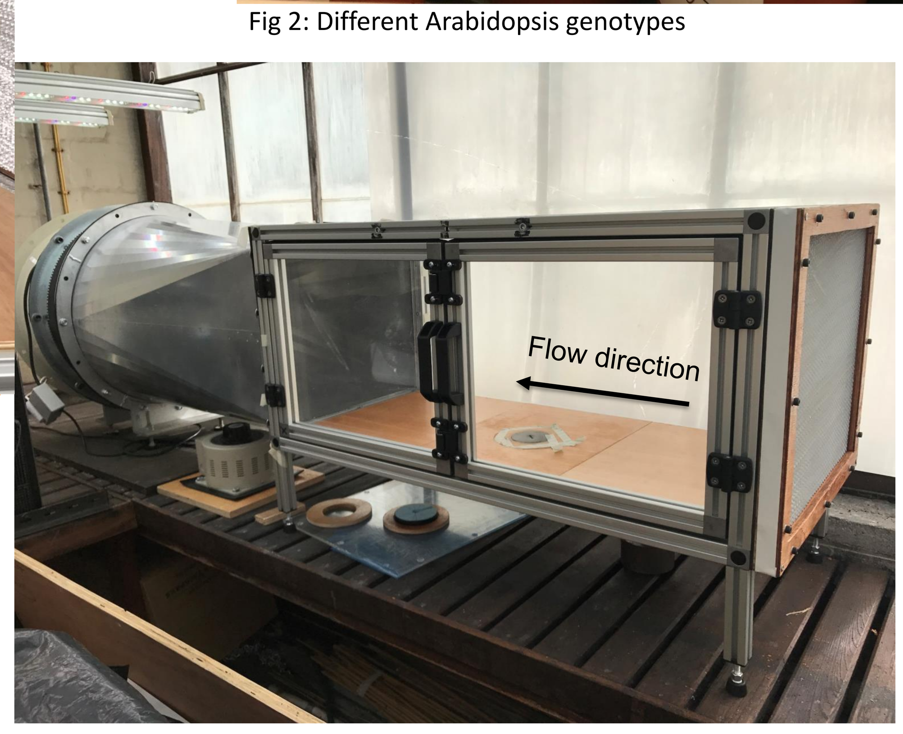


Fig 4: Wind tunnel is placed in the Bower building green house (design objective i)

3. Specialised wind tunnel

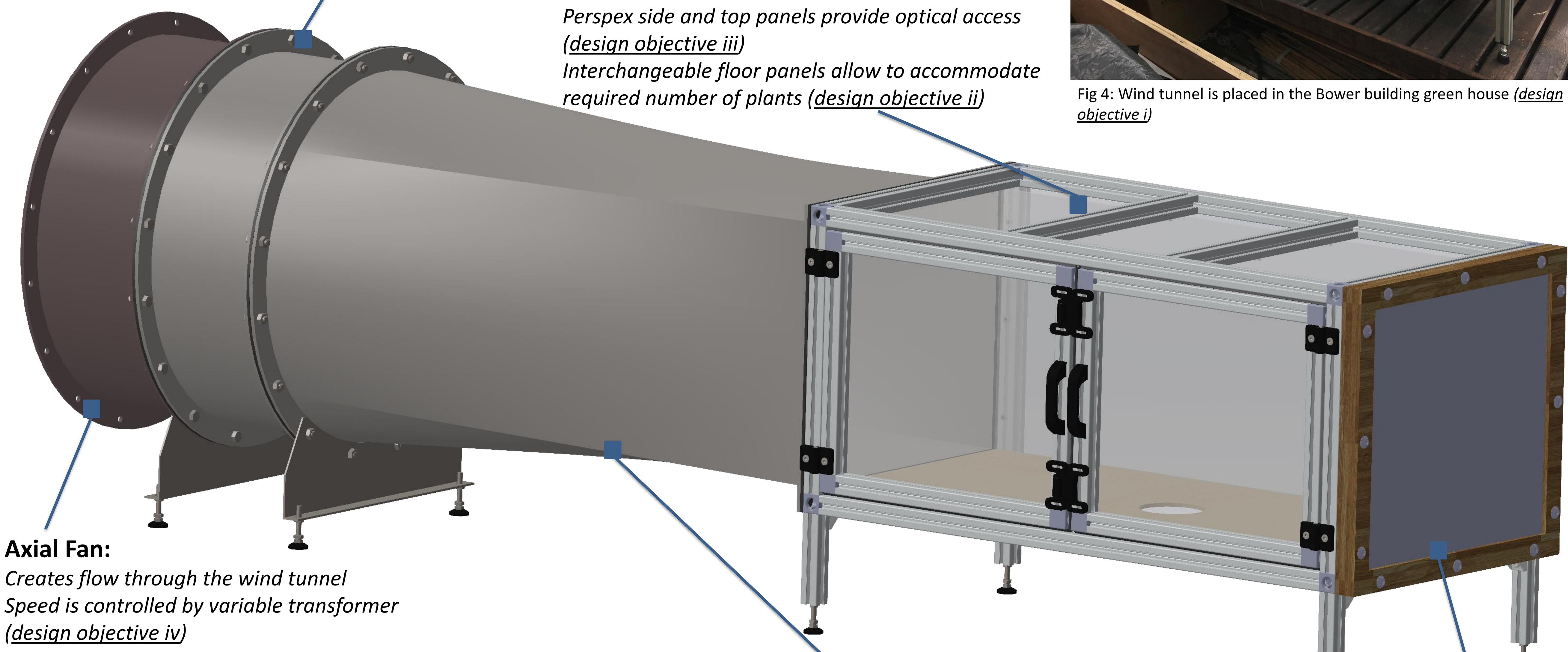
A new wind tunnel facility has been designed and built for this project as existing University of Glasgow wind tunnels have busy schedules, are expensive to run continuously for the duration of the planned experiments and do not have a suitable environment for growing plants.

Design objectives:

i) Create controllable environment (temperature, light) suitable for growing plants
ii) Possibility to accommodate single plant, multiple plants, or plant canopies
iii) Optical access to the test section to monitor plant growth and to take measurements
iv) Create uniform, steady flow

Flexible connector:
Prevents spreading of vibrations from fan into the test section (design objective iv)

Test section:
Perspex side and top panels provide optical access (design objective iii)
Interchangeable floor panels allow to accommodate required number of plants (design objective ii)



Axial Fan:
Creates flow through the wind tunnel
Speed is controlled by variable transformer (design objective iv)

Diffuser:
Serves as transition piece
Reduces flow speed before the fan (design objective iv)

Honeycomb:
Reduces turbulence level of the flow (design objective iv)

4. Wind tunnel characteristics

Type: open circuit
Max flow speed: 10.5 m/s
Turbulence intensity: 1.7%

Test section:
- Length 1m
- Width 0.45m
- Height 0.4m

Characterisation of the test section was performed using a Dantec StreamLine Pro constant temperature anemometer.

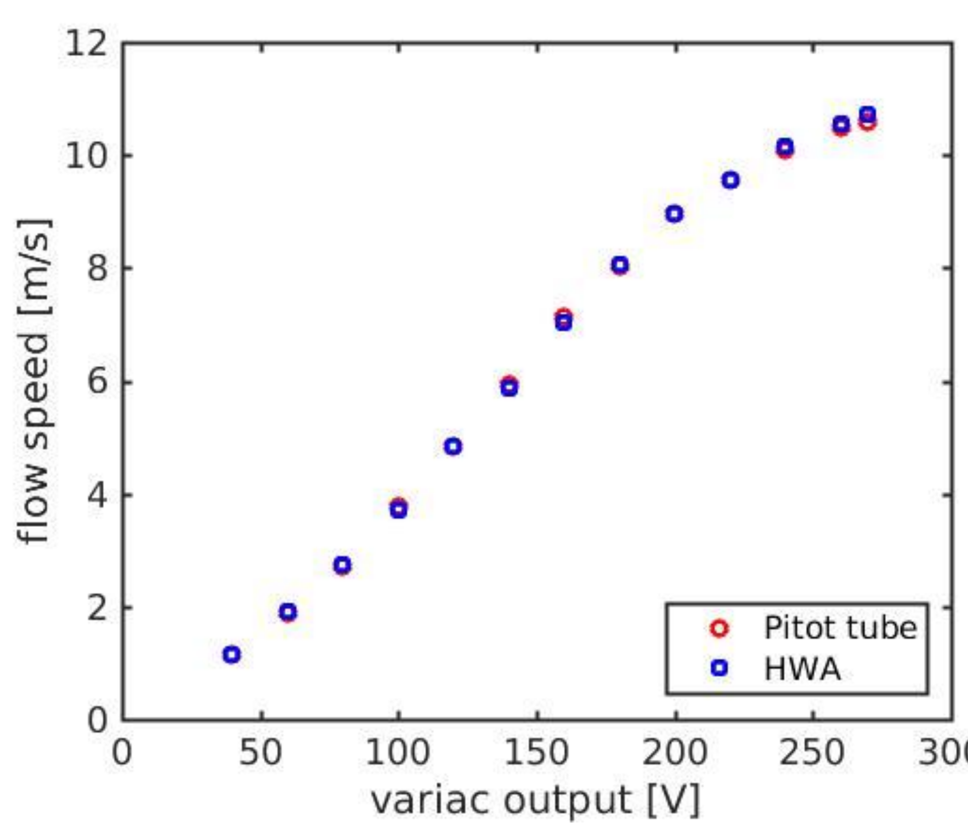


Fig 5: Results of the wind tunnel test sections calibration at the centre point using Pitot tube and Hot-Wire Anemometry (HWA)

5. Traverse system

A 3-axis traverse system was designed and built for utilisation with this wind tunnel.
- Light weight
- High precision (similar systems used in CNC machines)
- Easy to attach to the wind tunnel
- Allows measurements at any point of the test section in planes normal to the flow direction

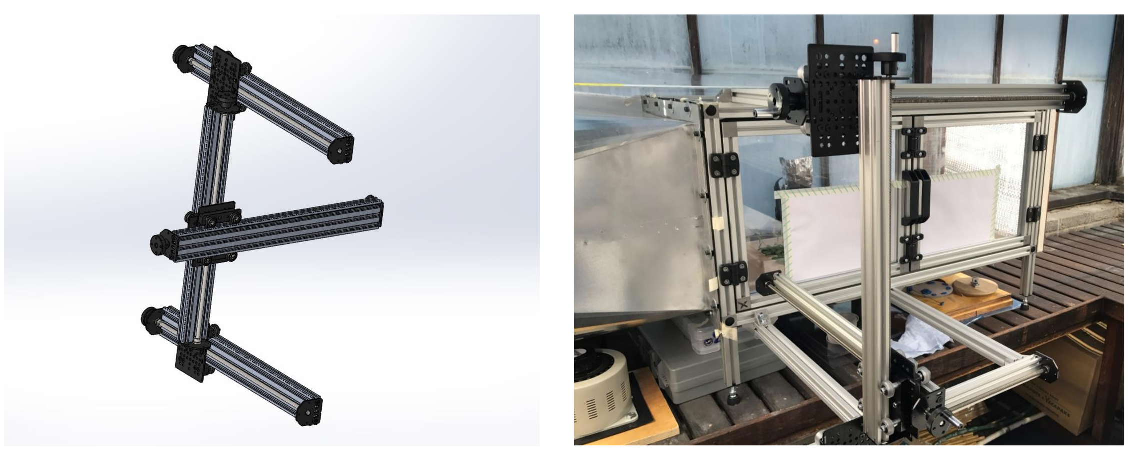


Fig 6: Left – 3D CAD model of the traverse system; Right – wind tunnel with installed traverse system

6. Dandelion fruit dispersal study

The wind tunnel has already proved itself as a flexible facility for various types of plant related studies. Investigations on dandelion fruits dispersal were performed in collaboration with the Biological Form + Function Lab, University of Edinburgh. In terms of this project a turbulence generating grid was added in the wind tunnel and used to check influence of turbulence on dandelion seeds dispersal.


Fig 7: Left – turbulence generating grid. HWA measurements showed the turbulence intensity level of 9.5%; Right – dandelion inside the wind tunnel test section during an experiment

Acknowledgments

We gratefully acknowledge support via a Lord Kelvin – Adam Smith scholarship
O.Z. would like to thank Dr Thomas Jelly for training in the use of hot-wire anemometry

References

Pryor, Barthelmie, Kjellström, 2005. Climate Dynamics 25, 815-835
Page, Grossniklaus, 2002. Nature Review Genetics 3(2), 124-136