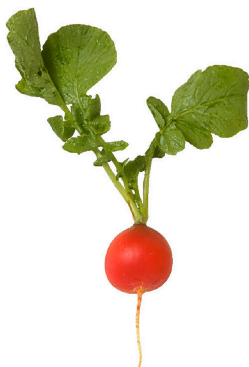
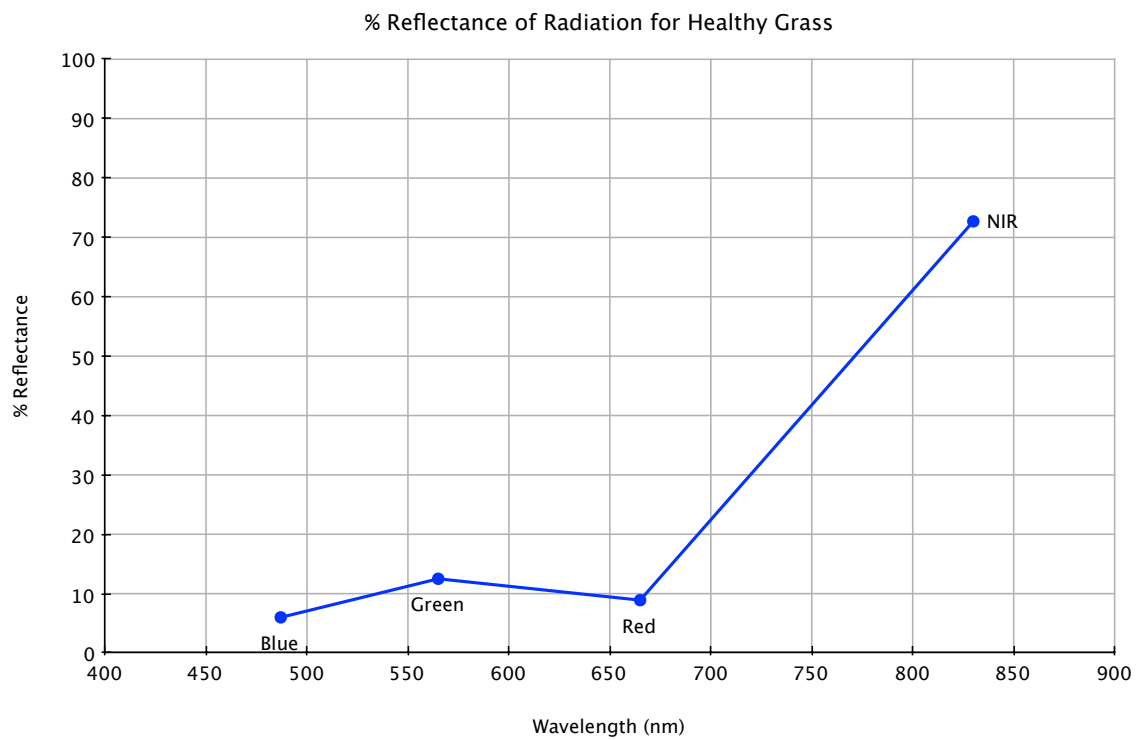

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Elevated CO₂ and Plant Radiative Reflectance

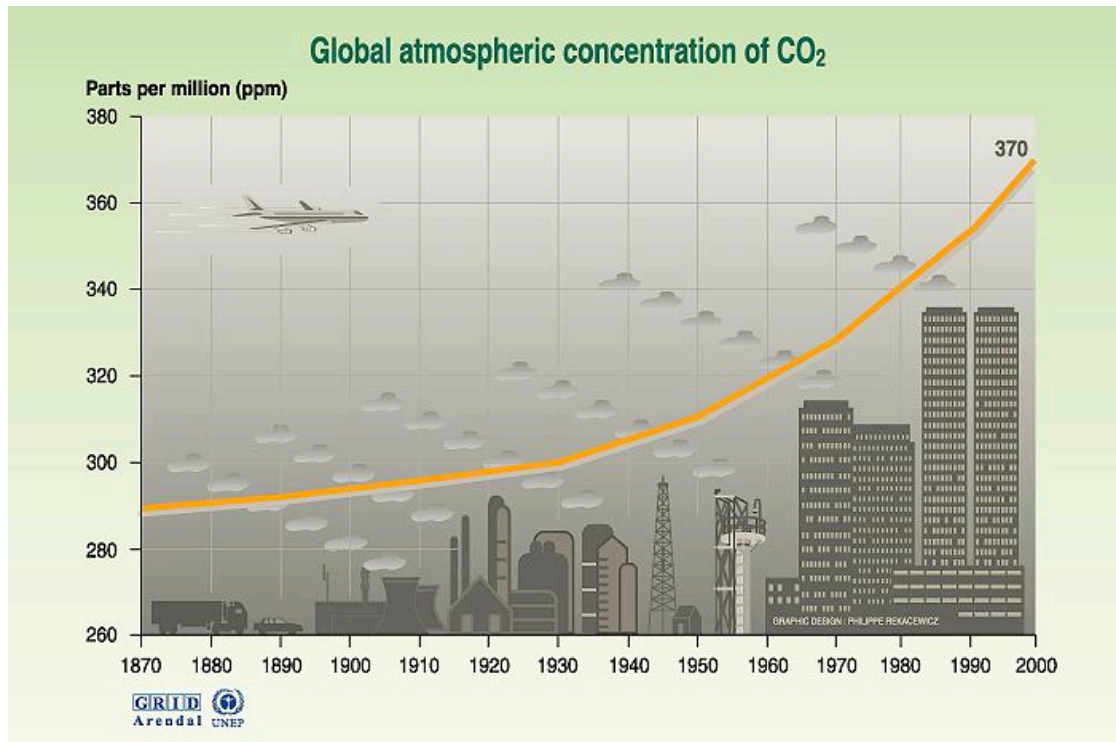
Mark Cresswell and Paul Chipman

m.cresswell@mmu.ac.uk and p.chipman@mmu.ac.uk



PLANT RESPONSES TO ELEVATED CARBON DIOXIDE

One of the key drivers of climate change is a rising concentration carbon dioxide in our atmosphere.



Sources: TP Whorf Scripps, Mauna Loa Observatory, Hawaii, institution of oceanography (SIO), university of California La Jolla, California, United States, 1999

FIG 1: Historical change on Carbon Dioxide concentration (UNEP, 2010 [online])

The approximate concentration of CO₂ in 2010 is 370 parts per million. In the future (see Fig 1), CO₂ may reach values as high as 700ppm by the year 2100 (UNEP, 2010 [online]).

Effects on Plants

Bearing in mind the projections for potential future CO₂ concentrations, experiments have been undertaken to determine what the effects might be on agriculture and food security. Could these increased concentrations actually benefit food production?

In order to accurately reflect the impacts of increased CO₂, one must also consider the effects of temperature change as the climate gets warmer. A study by Hartwell and Vu (2009) looks at the impact of growing citrus trees (orange) in elevated temperature and carbon dioxide conditions. Their findings suggest that at lower temperatures an increased CO₂ environment does indeed lead to an increase in plant biomass (see Figure 2). However they also show that as temperature increases the biomass yield drops as a result of higher temperatures limiting stomatal water flow.

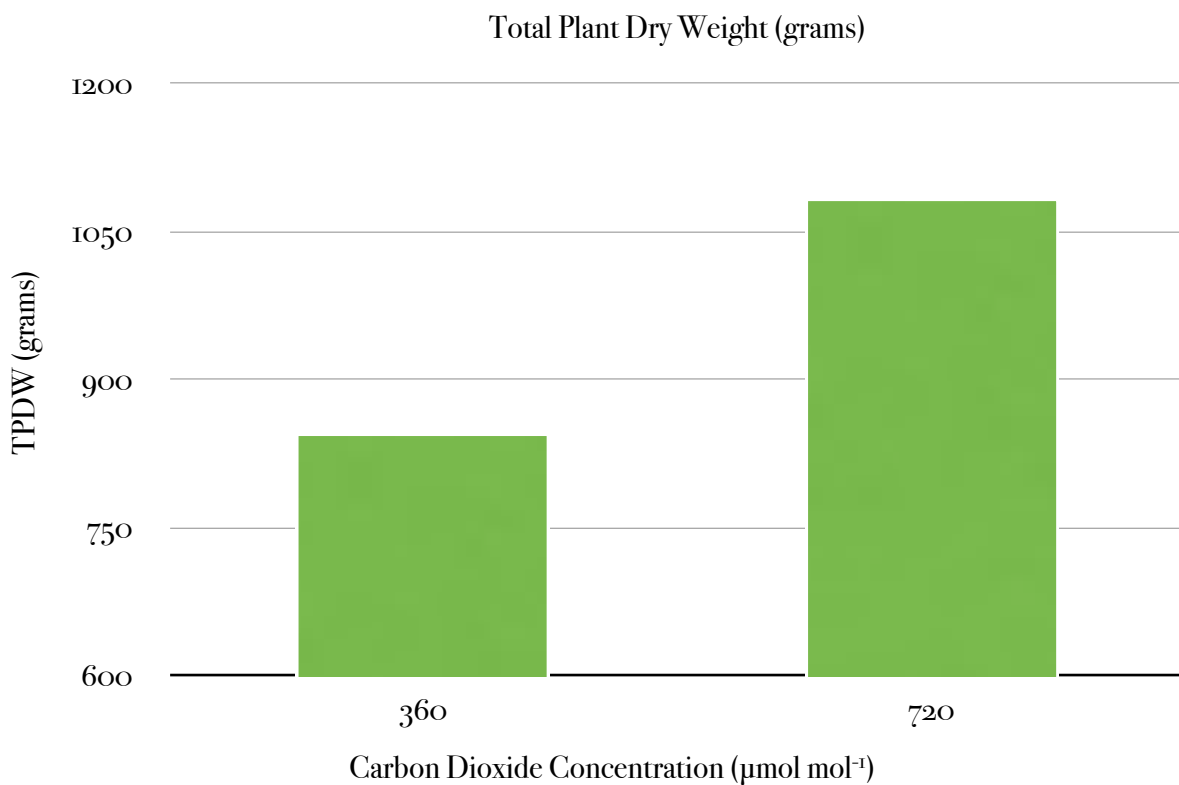


FIG 2: Effect of CO₂ change on biomass production (Hartwell and Vu, 2009)

An earlier study by Baker and Allen (1994) suggests that the key to plant enhancement by rising CO₂ concentrations is an increase in the photosynthetic rate. Their study shows that wheat plants enriched from 332 $\mu\text{mol mol}^{-1}$ to 1390 $\mu\text{mol mol}^{-1}$ CO₂ generally show an increase in photosynthetic rate by 50%. They also show this general pattern to be true for other plant species such as cotton, soybean etc. They have found however that this initial stimulation in photosynthetic rate can tail off and does not necessarily lead to a congruent increase in yield.

Of key interest (apart from rate of growth and yield) is seed production. Recent experimental work by Edwards et al (2003) has concentrated on the effects of elevated soil and atmospheric CO₂ on seed production. They find that if the soil conditions are ignored then seed yield and biomass increase. However, if both atmospheric and soil CO₂ conditions are matched then biomass might remain the same as present day CO₂ concentration - but seed production might actually decline.

A final study discussed here by Högy and Fangmeier (2008) has concentrated on the effects of elevated atmospheric CO₂ on the grain quality of wheat. Their study is inconclusive but generally shows grain quality is altered (reduced protein and amino acids that could be deleterious to health) while productivity increases.

TODAY'S EXPERIMENT

You have access to TWO plant samples for THREE different plant species (Radish, Sweetcorn and Barley). One has been growing in ambient CO₂ concentration (i.e. approx 370ppm) and a similar plant that has been growing in an elevated CO₂ concentration.

You are to collect TWO metrics of plant condition:

- Reflectance of BLUE, GREEN, RED and NEAR-INFRARED (NDVI) radiation and
- Plant condition (colour, size and general condition)

Following your data collection, you must determine if there is any measurable difference between the two plants and if there has been an impact due to CO₂ concentration.

RESULTS

RADISH		Channel 1 Blue 487nm	Channel 2 Green 565nm	Channel 3 Red 665nm	Channel 4 NIR 830nm
AMBIENT CO ₂ Concentration					
ELEVATED CO ₂ Concentration					

SWEETCORN		Channel 1 Blue 487nm	Channel 2 Green 565nm	Channel 3 Red 665nm	Channel 4 NIR 830nm
AMBIENT CO ₂ Concentration					
ELEVATED CO ₂ Concentration					

BARLEY		Channel 1 Blue 487nm	Channel 2 Green 565nm	Channel 3 Red 665nm	Channel 4 NIR 830nm
AMBIENT CO ₂ Concentration					
ELEVATED CO ₂ Concentration					

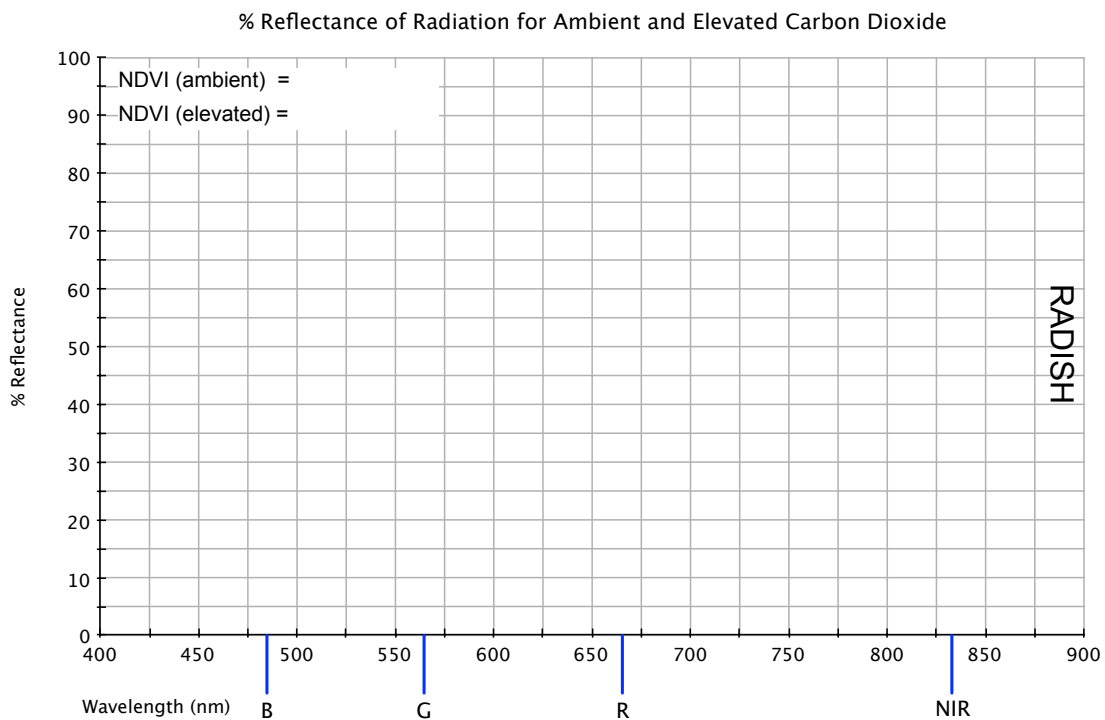
(enter your spectroradiometer Lab observations in the space above)

Once you have measured the relative differences in raw radiance reflectance for both plants, you must *normalise* the data to show relative % of total reflectance and construct a graph.

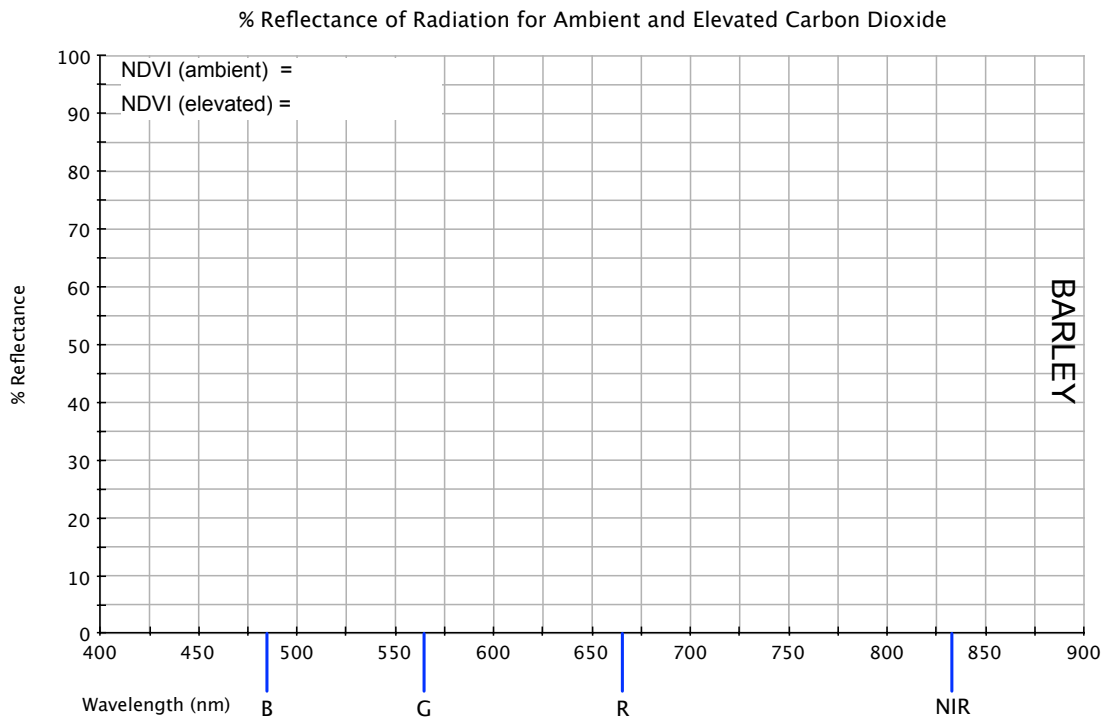
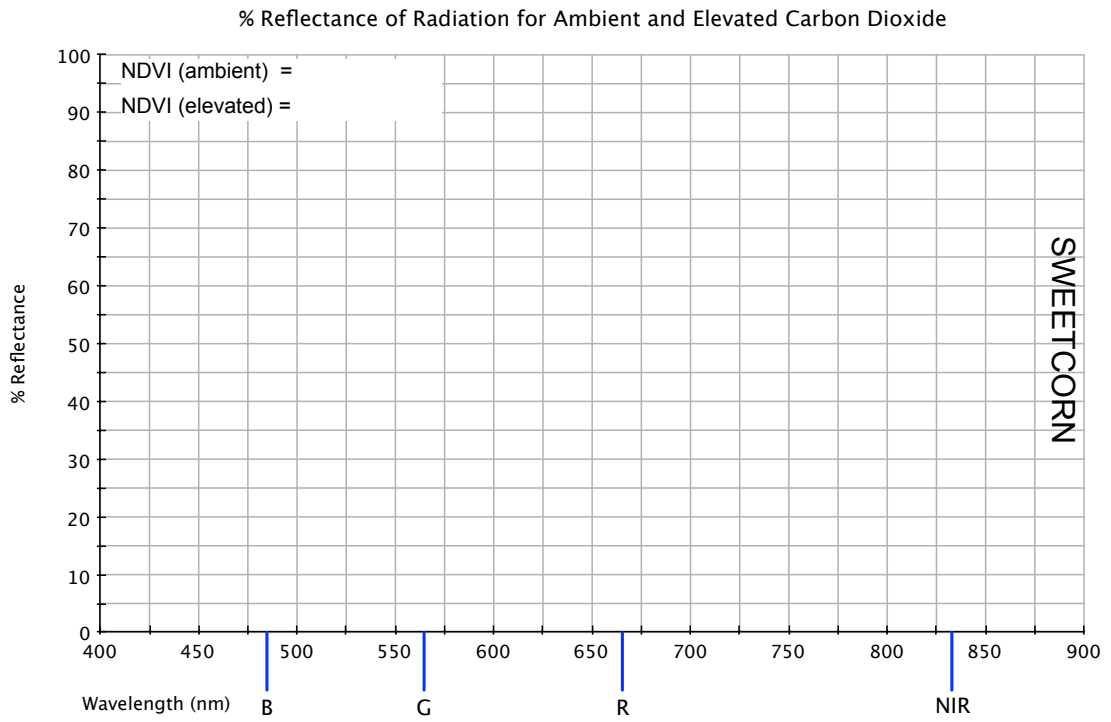
To normalise the data, you:

- 1) SUM all FOUR radiance (channel) values across a row (i.e. $SUM = (B+G+R+NIR)$)
- 2) DIVIDE each channel by the SUM value (e.g. $GREEN = GREEN / SUM$)
- 3) MULTIPLY value by 100 to get a % reflectance (e.g. $GREEN = ((GREEN / SUM) * 100)$)
- 4) Do this for each of the FOUR channel values and create a graph
- 5) Calculate the Normalized Difference Vegetation Index (NDVI) for each plant - and put on the graph

$$NDVI = \frac{NIR - RED}{NIR + RED}$$



(use a PENCIL - apply solid/dashed styles to distinguish between your two lines (one line for each plant) - then add an annotated legend)



Plant Condition Metrics

RADISH	Ambient CO₂	Elevated CO₂
Leaf length (cm)		
Leaf width (cm)		
Colour		
Condition of Leaves		
General estimate of condition		

SWEETCORN	Ambient CO₂	Elevated CO₂
Leaf length (cm)		
Leaf width (cm)		
Colour		
Condition of Leaves		
General estimate of condition		

BARLEY	Ambient CO₂	Elevated CO₂
Leaf length (cm)		
Leaf width (cm)		
Colour		
Condition of Leaves		
General estimate of condition		

By this point, you will know what the difference is between the two plants in terms of their % Reflectance across a range of wavelengths. You also have a description of the physical and visual differences between the two plants.

Question: What can you say about the effects of CO₂ concentration on the spectral and physical characteristics of the two plants you have studied?



Reference List

Allen L. and Vu J. (2009). Carbon dioxide and high temperature effects on growth of young orange trees in a humid, subtropical environment. *Agricultural and Forest Meteorology*. **149** (820-830)

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Edwards G., Clark H. and Newton C. (2003). Soil development under elevated CO₂ affects plant growth responses to CO₂ enrichment. *Basic and Applied Ecology*. **4** (185-195)

Högy P. and Fangmeier A. (2008). Effects of elevated atmospheric CO₂ on grain quality of wheat. *Journal of Cereal Science*. **48** (580-591)