Date: 17 April 2015

Title: Plant growth: Why most plants grow better under higher CO_2 concentrations?

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0. Background: atmospheric CO_2 concentration ([CO_2]) has been and will be increasing (Fig. 1).

1. Your homework:

See Fig. 2, and give ***plausible*** explanation to the following questions in plain English. Full answers to these questions are indeed still sought out!

Q1. Why do the crop yields increase when [CO_2] increases?

Q2. Why do the crop yield responses to higher [CO_2] vary by water availability?

Q3. Why do sorghum differ in their yield responses to higher [CO_2] from other species? Note that sorghum is a 'C_4' species.

2. Why are these questions important for you?

2.1. Food production in the future with warmer climate and higher [CO_2] (Fig. 3).

2.2. Carbon cycling and the greenhouse effects on the Earth under increasing [CO_2] (Fig. 4a, b).

3. Top four constituents of plants

C: 45%, H: 6%, O: 41%, N: 3% (Others:

Q: Where do they come from?

C:

H:

O:

N:

Hint: Photosynthesis simplified as

$CO_2 + H_2O + NADPH + ATP \Rightarrow CH_2O + O_2 + NADP^+ + ADP$, where

NADPH: reducing power (Pulling off an O from CO_2 and adding H_2 to it: reduction), and

ATP: chemical energy (What happens if you place CH_2O in O_2 under high temperature…).

$NADP^+$ and ADP are regenerated into NADPH and ATP by using light energy (Fig. 5).

4. Carbon transport from the atmosphere into the cell (Fig. 6).

4.1. Stomata: small pores on leaf surface.

Gas molecules (CO_2, O_3, H_2O…) diffuse through stomata along the gradient of the gas concentration (molecular diffusion). Plants can change opening of the stomata.

Q. Can plants take up CO_2 without losing H_2O via stomata?

4.2. Chloroplasts: tiny organelle arranged along the cellular membrane within the cells.

The site of photosynthesis, where light is absorbed and CO_2 is fixed into sugars.

5. The simplistic view of photosynthesis (Figs. 7 and 8).

Rubisco: the enzyme responsible for CO_2 fixation *and photorespiration*, where CO_2 is lost and energy is consumed. The latter was negligible when the photosynthesis was 'invented'. No O_2 was present in the environment back then! The atmospheric [CO_2] was also high enough for this enzyme… In the present atmosphere, photosynthesis is often limited by Rubisco.

Q1. What happens in CH_2O production, if you increase [CO_2] in the air from near zero to a very high level? Assume that stomatal opening is unchanged.

Q2. What happens in the relationship between [CO_2] and CH_2O production, if you reduce Rubisco?

5.1. Plant growth with increased photosynthesis under elevated [CO_2].

The increased CH_2O production leads to greater plant mass accumulation, which would allow greater leaf and root surface area. Both would, in turn, contribute to greater light and N capture at the initial growth. Later on, however, such 'compound effects' diminishes, as the full captures of light and N are attained and further room of increased capture is depleted.

5.2. Plant growth response to elevated [CO_2] under limited N supply

Q. What happens in the plant growth response to elevated [CO_2], if you reduce nitrogen supply?

5.3. Plant growth response to elevated [CO_2] under water shortage.

Q. What happens in the plant growth response to elevated [CO_2], if you limit water supply?

5.4. C_4 photosynthesis: a 'new' invention against the reduced [CO_2] some 0.3 billion years ago… (Figs. 9 and 10).

Q1. Why the C_4 species show a very little (or no) response in their photosynthesis to elevated [CO_2]?

Q2. Why do the C_4 species show a greater growth response to elevated [CO_2] under water shortage than under sufficient water supply?

References

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