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Very high CO_2 levels decrease yield and antioxidant content of some green vegetables

Increases in the amount of CO_2 in the atmosphere can be beneficial to crops, by providing a source of carbon for growth. However, very high levels of CO_2 have the reverse effect, decreasing the yield and quality of vegetable crops, a new study has shown. The researchers say atmospheric CO_2 concentration should be kept below 5 000 ppm to enhance the yield of leafy vegetables such as cabbage and lettuce.

The concentration of carbon dioxide in the atmosphere has reached 400 parts per million (ppm) for the first time in recorded history[1]. As well as driving climate change, elevated levels of CO_2 have important effects on agriculture — although these may not necessarily be negative.

During photosynthesis, plants take up CO_2 from the atmosphere, which provides a source of energy and carbon (needed to synthesise carbohydrates). This means a rise in atmospheric CO_2 concentration can increase growth rate and, therefore, yield of crops. A number of studies have shown beneficial effects of CO_2 on crop growth; a review of over 400 observations showed CO_2 enrichment increased yield by an average of 36%[2].

However, almost all studies have studied effects up to a concentration of 1 200 micromoles per mole (µmol/mol). This is because concentrations above this level are not expected to be reached on Earth for many decades. Yet, there are some situations in which crops may be exposed to such concentrations, such as in volcanic areas or closed greenhouses.

This study looked at the effect of CO_2 at levels ranging from 400 ppm (current concentration — for gases ppm is the same as µmol/mol) to 5 000 µmol/mol, on the yield of two typical leafy vegetables: lettuce (*Lactuca sativa)* and Chinese cabbage (*Brassica chinensis*). The researchers also measured changes to the concentration of antioxidants in the vegetables, molecules which may protect cells from damage and which some studies have linked to the prevention of disease. Antioxidant content can be used as an indicator of crop quality, but findings on how CO_2 affects antioxidant content have been contradictory.

To shed light on this, the researchers subjected the plants to five different CO_2 concentrations: 400, 800, 2 000, 3 000 and 5 000 µmol/mol, in confined chambers. At each concentration, they measured yield, concentrations of specific antioxidants (phenols, flavonoids, glutathione and vitamin C) and total antioxidant activity.

CO_2 concentrations between 1 000 and 3 000 µmol/mol increased both yield and antioxidant content, compared to ground level CO_2 (400 µmol/mol). This was expected by the researchers, as it is in line with the findings of previous studies. More surprisingly, they found that concentrations between 3 000 to 5 000 µmol/mol decreased both yield and antioxidant content, suggesting that very high atmospheric CO_2 levels may impede the growth and quality of plants.

Continued on next page.

1. http://www.esrl.noaa.gov/gmd/ccgg/trends/weekly.html

2. Kimball, B. and Idso, S. (1983). Increasing atmospheric CO_2: effects on crop yield, water use and climate. *Agricultural Water Management* 7(1–3): 55–72.

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The optimal CO_2 concentration for yield of cabbage was 2 000 µmol/mol, while for lettuce it was between 2 000 and 3 000 µmol/mol. The optimal level for antioxidant content was between 1 000 and 3 000 µmol/mol. To enhance the yield and quality of these crops, the authors suggest atmospheric CO_2 concentration should be maintained at least below 5 000 µmol/mol. Ideally, it should not exceed 3 000 µmol/mol.

The finding that agricultural production could be depleted at high atmospheric CO_2 levels has important implications for future food security. However, further systematic studies with a larger number of plants — including other types of crops — are needed before policy conclusions can be made.