

RISING CO₂: A BOON FOR C₃ PLANTS, BUT IS IT GOOD FOR HUMANS?

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Accepted on Oct 17, 2026

Introduction

Carbon dioxide (CO₂) is often described as a greenhouse gas responsible for global warming. But for plants CO₂ is much more than that, it is the essential source of carbon for photosynthesis. As atmospheric CO₂ concentration increases, many C₃ plants can use the extra CO₂ to increase photosynthesis and under suitable conditions produce more biomass and yield. But there's another part to this story. Elevated CO₂ can increase carbon fixation and biomass but may be accompanied by a decrease in the concentration of some nutritionally important components in crops. This poses a major question for agriculture and for human society: Can rising CO₂ benefit plants while creating nutritional challenges for humans?

Why Rising CO₂ Can Benefit C₃ Plants

Wheat, rice, soybean, chickpea and groundnut are important food crops that use the C₃ pathway of photosynthesis. In these plants the enzyme Rubisco is fixing atmospheric CO₂ during the Calvin cycle. Rubisco can react with both O₂ and CO₂. Reaction with oxygen results in photorespiration, which results in loss of previously fixed carbon and energy. An increase in CO₂ concentration would favor Rubisco to react with CO₂ rather than oxygen and thus photorespiration would be reduced and net photosynthesis increased. This means that in many C₃ plants higher CO₂ can increase photosynthesis. Under appropriate growing conditions this can lead to increased biomass production. Elevated CO₂ can also cause partial stomatal closure, reducing water loss through transpiration and potentially improving water-use efficiency. This response is commonly known as the CO₂ fertilization effect (Fig. 1). However, the response is not unlimited. Water availability, nutrient supply, temperature, light, crop species and genotype all influence how strongly a plant responds to elevated CO₂. Therefore, the increase in growth and yield varies among crops and growing conditions.

More CO₂ Does Not Always Mean More Nutritious Food

Here lies the interesting paradox. When C_3 plants receive more CO_2 , they can fix more carbon and accumulate more carbon-rich compounds, particularly carbohydrates such as sugars and starch. This increased carbon accumulation can contribute to greater biomass and yield. But the plant does not necessarily increase its accumulation of nutrients at the same rate. When biomass and carbohydrate accumulation increase faster than the accumulation of certain nutrients, the concentration of those nutrients per unit weight of plant material can decline. This is commonly described as the nutrient-dilution effect.

For example, when elevated CO_2 increases grain biomass and carbohydrate accumulation faster than the accumulation of protein and minerals, the concentration of these nutrients per unit weight of grain can decline. Several studies have reported reductions in the concentration of nitrogen, protein, iron (Fe) and zinc (Zn) in important C_3 crops under elevated CO_2 . Elevated CO_2 can also influence nutrient uptake, transport and carbon–nitrogen metabolism, which can further contribute to changes in nutrient concentration.

The overall process can therefore be understood simply as:

$\uparrow CO_2 \rightarrow \uparrow \text{carbon fixation} \rightarrow \uparrow \text{carbohydrate accumulation and biomass} \rightarrow \text{nutrients do not increase proportionally} \rightarrow \downarrow \text{concentration of some nutrients}$

This does not necessarily mean that the plant loses all of these nutrients. The important point is that the amount of biomass can increase faster than the accumulation of certain nutrients, resulting in lower nutrient concentration in the edible product. Thus, more biomass does not necessarily mean more nutrition. A crop may produce more grain per hectare, while each kilogram of grain contains a lower concentration of some nutritionally important components.

Why This Matters for Human Nutrition

The issue becomes particularly important because C_3 crops provide a major part of the human diet. Wheat, rice, soybean and many other grains and legumes are important sources of energy, protein and minerals. Humans do not benefit from atmospheric CO_2 directly. We benefit from the food produced by plants. Therefore, if elevated CO_2 increases crop production while reducing the concentration of important nutrients, an increase in food quantity may not translate into a proportional increase in nutritional value. Research under elevated CO_2 has reported reductions in zinc and iron concentrations in C_3 grains and legumes, while protein concentrations can also decline in several non-legume C_3 crops (Fig. 1).

This creates a fascinating contrast

For the plant

More CO₂ → more carbon available for photosynthesis → potentially more carbohydrates, biomass and yield.

For humans

More plant biomass does not necessarily mean proportionally more protein, iron and zinc. This distinction between food quantity and food quality is becoming increasingly important in the context of a changing atmosphere. Producing more grain per hectare is essential for food security. But maintaining the nutritional quality of that grain is equally important for nutritional security.

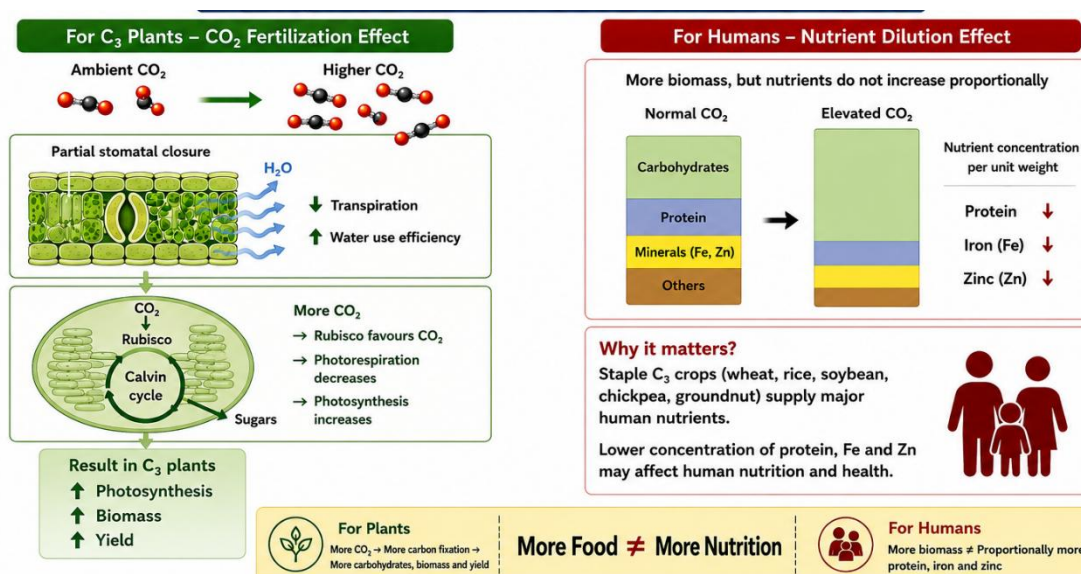


Fig. 1. Physiological and Biochemical impact of elevated CO₂ in C₃ crops

Turning the CO₂ Advantage into a Nutritional Advantage

Rising atmospheric CO₂ is therefore not simply a “good” or “bad” phenomenon for agriculture. Its effects depend on the crop, genotype, temperature, water availability, nutrient supply and growing environment. The challenge for agricultural scientists is to develop crops that can benefit from elevated CO₂ while maintaining their nutritional quality. Plant breeding, biofortification, improved nutrient management and a better understanding of carbon–nitrogen interactions and nutrient metabolism can all contribute to this goal.

Differences among crop varieties also provide an opportunity for crop improvement. Identifying genotypes that maintain higher protein and micronutrient concentrations under elevated CO₂ could become an important breeding objective. Future agriculture therefore needs to move beyond the simple objective of producing more biomass or more grain per hectare. The real objective should be More food, with better nutritional quality, under a changing climate.

The Takeaway

Rising CO₂ can give many C₃ plants an advantage by increasing carbon fixation, photosynthesis and under suitable conditions, biomass and yield. However, the increase in carbon-rich biomass is not necessarily matched by a proportional increase in essential nutrients. Consequently, the concentration of important components such as protein, iron and zinc can decline in several C₃ crops. The challenge for agriculture is therefore not simply to ask “Can plants grow more with more CO₂?” but rather “Can we use the CO₂ advantage of C₃ plants to produce more food while maintaining its nutritional quality?”. The future of agriculture will depend not only on producing more, but on producing more nutritious food for a changing world.

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