

# The Many Benefits of Atmospheric CO<sub>2</sub> Enrichment



*Science and Public Policy Institute  
Center for the Study of Carbon Dioxide and Global Change*

**How humanity and the rest of the biosphere will prosper from this amazing trace gas that so many have wrongfully characterized as a *dangerous air pollutant!***

## *How do I love thee? Let me count the ways.*

So wrote Elizabeth Barrett Browning in a romantic poem that perfectly captures the all-encompassing emotion of love. Though Miss Browning surely had humans in mind when she wrote these words, she would not have been far off the mark had she attributed them to plants; for if plants could articulate their feelings, they too would surely recite these same lines ... *to carbon dioxide*.

Atmospheric carbon dioxide is the *elixir of life*. It is the primary raw material out of which plants construct their tissues, which in turn are the materials out of which animals construct theirs. This knowledge is so well established, in fact, that we humans – and all the rest of the biosphere – are described in the most basic of terms as *carbon-based lifeforms*.

Nowadays, however, it seems that all we ever hear about atmospheric CO<sub>2</sub> are the presumed *negative* consequences of its increasing concentration. Time and again, world governments, non-governmental organizations, international agencies, societal think tanks, and even respectable scientific organizations attempting to assess the potential consequences of this phenomenon, have spent multiple millions of dollars writing and promoting large reports about it. Yet, nearly all of these endeavors have failed miserably, by not evaluating, or even *acknowledging*, the manifold real and measurable *benefits* of the ongoing rise in the air's CO<sub>2</sub> content. As a result, the many important and positive impacts of atmospheric CO<sub>2</sub> enrichment remain underappreciated and largely ignored in the debate over what to do, or not do, about anthropogenic CO<sub>2</sub> emissions.

***The Many Benefits of Atmospheric CO<sub>2</sub> Enrichment*** – A new book written by Drs. C. D. and S. B. Idso and produced by the *Science and Public Policy Institute* (Vales Lakes Publishing, LLC, Pueblo West, Colorado, USA) – attempts to rectify this imbalance by outlining 55 ways in which the modern rise in atmospheric CO<sub>2</sub> is benefiting earth's biosphere, as reported in the peer-reviewed scientific literature. And like *love*, carbon dioxide's many splendors are seemingly endless. Order your copy now, and enjoy this guide to the wonderful CO<sub>2</sub>-enriched world of the future, made bright by the amazing molecule that the U.S. Environmental Protection Agency has had the audacity to so wrongly characterize as *a dangerous air pollutant!*

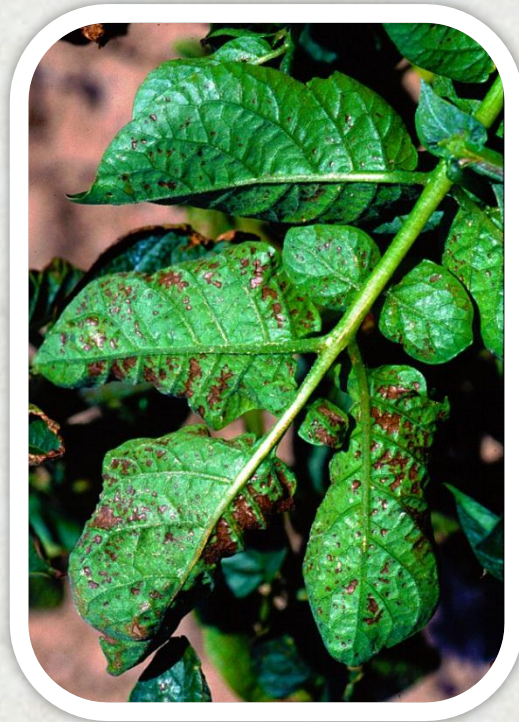


Roses in bloom at the tomb of Elizabeth Barrett Browning on the Cimitero degli Inglesi, Florence.



## The 55 Benefits

**1. Air Pollution Stress (Non-Ozone)** – As the  $\text{CO}_2$  content of the air rises, most plants reduce their stomatal apertures, thereby decreasing their uptake of harmful air pollutants that might otherwise damage their tissues and, in the case of agricultural crops, reduce their yields. As a result, enriching the air with  $\text{CO}_2$  tends to **reduce** – and sometimes even **more** than compensate for – the negative effects of **real** air pollutants on plant photosynthesis and growth.



**2. Air Pollution Stress (Ozone)** – Plants grown in  $\text{CO}_2$ -enriched air nearly always exhibit increased photosynthetic rates and biomass production relative to plants grown at the air's ambient  $\text{CO}_2$  concentration. In contrast, plants exposed to elevated ozone concentrations typically display reductions in photosynthesis and growth. Thus, it is important to determine how major crops and forest trees respond to concomitant increases in the abundances of these two trace gases of the atmosphere, in case their concentrations continue to increase in the years and decades ahead; and when such experiments are conducted,  $\text{CO}_2$  is found to be the perfect antidote for countering the negative effects of increasing levels of ozone pollution.



**3. Avoiding Human Starvation and Plant and Animal Extinctions** – Unless the air's  $\text{CO}_2$  content continues its upward trajectory, humans will experience mass starvation, and untold numbers of plants and animals will face extinction over the last half of the current century.

**4. Bacteria** – Rising atmospheric  $\text{CO}_2$  concentrations will likely allow greater numbers of beneficial bacteria (that help sequester carbon and nitrogen) to exist within soils and anaerobic water environments, which two-pronged phenomenon would be a great boon to both terrestrial and aquatic ecosystems.

**5. Biodiversity** – The ongoing rise in the air's CO<sub>2</sub> content will likely **not** be a threat to ecosystem species richness, contrary to what some have suggested, for a number of studies indicate that earth's increasing atmospheric CO<sub>2</sub> concentration may actually **increase** the niche security of many of the planet's different life forms, thereby helping to preserve both regional and global biodiversity.

**6. Biogenic Volatile Organic Compounds (BVOCs)** – Real-world evidence indicates that (1) both rising air temperatures and CO<sub>2</sub> concentrations significantly increase desirable vegetative BVOC emissions, particularly from trees, which constitute the most prominent photosynthetic force on the planet, and that (2) this phenomenon has a large number of extremely important and highly beneficial biospheric consequences.

**7. Biomass** – Atmospheric CO<sub>2</sub> enrichment nearly always significantly increases plant dry weight or biomass.

**8. C<sub>4</sub> Plants** – C<sub>4</sub> plants can – and **do** – respond positively to increases in the air's CO<sub>2</sub> concentration by exhibiting enhanced rates of photosynthesis and biomass accumulation, especially under conditions of water insufficiency, in contrast to the erroneous view that such plants will not benefit from earth's rising atmospheric CO<sub>2</sub> concentration.

**Mean percentage yield increases produced by a 300 ppm increase in atmospheric CO<sub>2</sub> Concentration**

Crop	%	Crop	%
<b>CAM</b>		<b>ROOTS AND TUBERS</b>	
<i>Average</i>	<b>15.0</b>	Carrots	60
<b>C<sub>3</sub> CEREALS</b>		Cassava	87
Barley	66	Onions	28
Rapeseed	62	Potatoes	35
Rice	37	Sugar Beets	33
Sunflower Seed	36	Sweet Potatoes	46
Wheat	43	<i>Average</i>	<b>48.2</b>
<i>Average</i>	<b>48.8</b>	<b>VEGETABLES</b>	
<b>C<sub>4</sub> CEREALS</b>		Cabbages	27
Maize	22	Cauliflower	34
Sorghum	18	Green Chillies & Peppers	25
<i>Average</i>	<b>20.0</b>	Cucumbers and Gherkins	39
<b>FRUITS AND MELONS</b>		Eggplants	54
Other Fresh Fruit	30	Lettuce	40
Pumpkins, Squash, Gourds	18	Tomatoes	20
<i>Average</i>	<b>24.0</b>	Other Vegetables	53
<b>LEGUMES</b>		<i>Average</i>	<b>36.5</b>
Beans	32	<b>WOODY PLANTS</b>	
Broad Beans	39	<i>Average</i>	<b>51.0</b>
Cow Peas	86		
Okra	32		
Peas	31		
Soybeans	46		
<i>Average</i>	<b>44.3</b>		

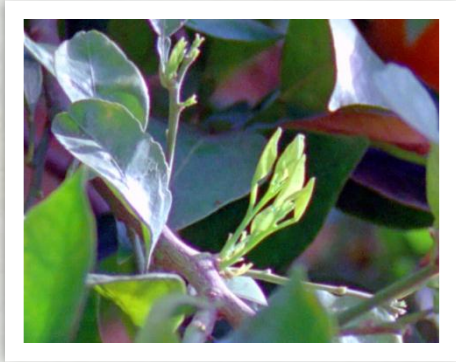
Source: Idso, CD and Idso, KE. 2000. Forecasting world food supplies: The impact of the rising atmospheric CO<sub>2</sub> concentration. Technology 7S: 33-55.

**9. CAM Plants** – Some researchers have suggested that CAM plants will not respond positively to higher levels of atmospheric carbon dioxide. However, a number of experimental studies show that they do.

**10. Carbon Sequestration** – Rising atmospheric CO<sub>2</sub> concentrations lead to more numerous and more robust plants, which yearly remove ever-greater quantities of CO<sub>2</sub>-derived carbon from the atmosphere, storing it initially in their own tissues, eventually in the soil, and ultimately in the depths of the sea.



**11. Diseases of Plants** – *There are a number of CO<sub>2</sub>-induced changes in physiology, anatomy and morphology that enhance plant resistance to disease at elevated atmospheric CO<sub>2</sub> concentrations; and in some cases, these benefits completely counterbalance the negative effects of pathogenic infections on overall plant productivity.*



**12. Early Growth** – *Atmospheric CO<sub>2</sub> enrichment is particularly important in helping plants get a good start early in their life cycles (in the case of annual plants) and early each spring (in the case of perennials), often boosting their growth rates as soon as growth begins, which strong and early stimulation is regularly found to be responsible for enhanced productivity throughout all subsequent stages of their lives.*

**13. Earthworms** – *Earthworms respond to increases in the air's CO<sub>2</sub> content via a number of plant-mediated phenomena in ways that further enhance the positive effects of atmospheric CO<sub>2</sub> enrichment on plant growth and development, while at the same time helping to sequester more carbon more securely in the soil and thereby reducing the potential for CO<sub>2</sub>-induced global warming.*

**14. Evolution** – *The ongoing rise in the air's CO<sub>2</sub> content will likely exert selection pressure on earth's naturally-occurring terrestrial plants, which should improve their performance in numerous ways in the face of changes in various environmental stressors via the process of micro-evolution.*

**15. Flowers** – *At higher atmospheric CO<sub>2</sub> concentrations, most plants generally produce more and larger flowers.*



**16. Fluctuating Asymmetry** – *Higher concentrations of atmospheric CO<sub>2</sub> tend to reduce fluctuating asymmetry in plant leaves, leading to more symmetrical leaves that appear to be less susceptible to attack by herbivores.*

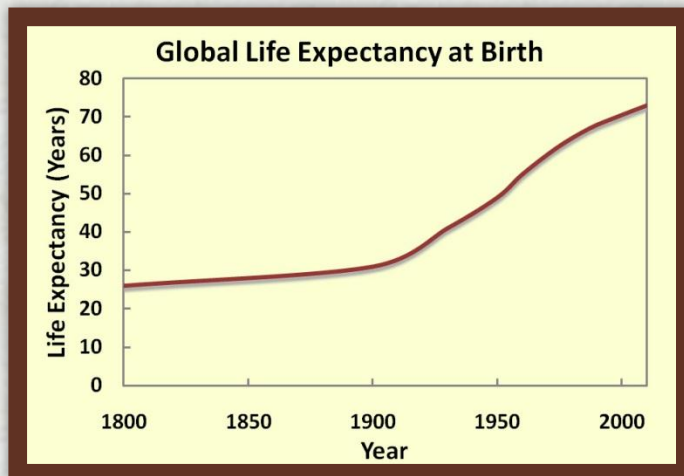
**17. Glomalin** – *Atmospheric CO<sub>2</sub> enrichment increases the production of a protein called **glomalin** by common root-dwelling soil fungi; and this protein provides a wide range of benefits, including (1) enhancing the stability of soil aggregates, which improves the capacity of soils to store more carbon and better preserve it, and (2) decreasing the risk of potentially toxic elements to soil microorganisms and plants.*

**18. Health-Promoting Substances** – *Not only does atmospheric CO<sub>2</sub> enrichment enhance the productivity of the crops grown by farmers, it significantly increases the quantity and potency of the many beneficial substances found in their tissues (such as vitamin C and other antioxidants), which ultimately make their way onto our dinner tables and help us better contend with the multitude of maladies that regularly afflict us.*



**19. Herbivory** – *As the air's CO<sub>2</sub> content continues to rise, more productive and profuse terrestrial and aquatic vegetation will likely support a proportional increase in plant herbivores, with both "the eaten and the eaters" benefiting alike.*

**20. Hormones** – *Atmospheric CO<sub>2</sub> enrichment has been shown to enhance plant growth and development by increasing the concentrations of plant hormones that stimulate cell division, cell elongation and protein synthesis.*



**21. Human Longevity** – *The last 150 to 200 years have seen a significant degree of global warming, as the earth has recovered from the global chill of the Little Ice Age and transited into the Current Warm Period. Simultaneously, the planet has experienced a rise in atmospheric CO<sub>2</sub> concentration that has taken it to levels not experienced for eons. Yet these much-maligned "twin evils" of the climate-alarmist movement have had no discernible negative influence on human health, as*

*represented by perhaps the best integrative measure of their myriad possible influences, i.e., human lifespan. In fact, they may actually have helped to **lengthen** human lifespan.*

**22. Human Mortality (All Causes)** – *According to the world's climate alarmists, rising atmospheric carbon dioxide concentrations cause global warming, which temperature increase, they further opine, will lead to greater human mortality. However, upon examination of pertinent real-world data, it becomes clear that warmer temperatures actually lead to a **decrease** in temperature-related deaths, which phenomenon represents one of the many indirect benefits of atmospheric CO<sub>2</sub> enrichment.*

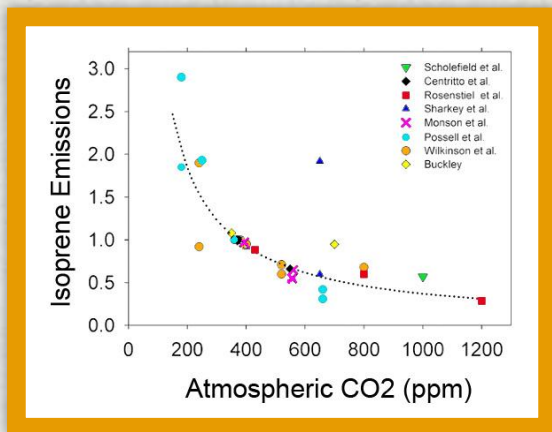


**23. Human Mortality (Cardiovascular)** – *Climate alarmists would have people believe that CO<sub>2</sub>-induced global warming will pose numerous challenges to human health, including premature death due to heat-induced cardiovascular problems. However, the results of several studies demonstrate that global warming is actually beneficial to humanity in this regard, in that it reduces the incidence of cardiovascular diseases related to low temperatures and wintry weather by a much **greater** degree than it increases the incidence of cardiovascular diseases associated with high temperatures and summer heat waves.*



**24. Human Mortality (Respiratory)** – *Climate alarmists would have people believe that CO<sub>2</sub>-induced global warming will pose numerous challenges to human health, including premature death due to heat-induced respiratory problems. However, the results of several studies make it abundantly clear that rising temperatures have a net **positive** impact on the respiratory health of the planet's human population.*

**25. Iodocompounds** – *A CO<sub>2</sub>-induced stimulation of marine emissions of iodocompounds provides a natural brake on the tendency for global warming to occur as a consequence of **any** forcing, as more iodocompounds lead to the creation of more abundant and more-highly-reflective clouds over greater areas of the world's oceans, which phenomenon results in more solar radiation being reflected back to space.*



**26. Isoprene** – *Based on a number of experimental findings, the ongoing rise in the air's CO<sub>2</sub> content will likely lead to significant reductions in the air's concentration of isoprene – which is responsible for the production of vast amounts of tropospheric ozone – thereby helping to reduce the atmospheric presence of the latter noxious trace gas that negatively impacts earth's plant and animal life.*

**27. Light Stress** – *Under less-than-optimal light intensities, the benefits of atmospheric CO<sub>2</sub> enrichment on plant growth are often greater than when light conditions are ideal.*

**28. Lipids** – Hydrophobic molecules consisting of fats, oils and waxes that possess long non-polar hydrocarbon groups arranged in fatty-acid chains called **lipids** are major components of plant and animal membranes that are extremely important to the well-being of nearly all living organisms; and their quantity and quality are both significantly enhanced in the presence of elevated atmospheric CO<sub>2</sub> concentrations.



**29. Medicinal Plants** – Atmospheric CO<sub>2</sub> enrichment positively impacts the production of numerous health-promoting substances found in medicinal plants, many of which have been demonstrated to be effective in fighting a number of devastating human maladies, including tumors, cancers, fevers, heart disease, and other ills.

**30. Monoterpenes** – Monoterpenes constitute a major fraction of the biogenic volatile organic compounds or BVOCs given off by plants; and they help protect earth's terrestrial vegetation by acting as scavengers of reactive oxygen species that are produced within plants experiencing significant heat stress. They also function as deterrents of pathogens and herbivores, and are known to aid plant wound healing after damage inflicted by herbivores. In addition, monoterpenes may attract pollinators and herbivore predators.



**31. Nectar** – Greater concentrations of atmospheric CO<sub>2</sub> tend to boost nectar production by flowers, which improvement can increase the attractiveness of the flowers to bees and other pollinators, thereby increasing pollination activity and fruit set and yield.

**32. Net Primary Productivity** – Just as there is incontrovertible evidence that the vitality of mankind has increased dramatically over the course of the Industrial Revolution, in tandem with the increases in air temperature and atmospheric CO<sub>2</sub> concentration concomitantly experienced, so too is there irrefutable evidence that the vitality of earth's plant life has done the same.



**33. Nitrogen Fixation** – *Increases in atmospheric CO<sub>2</sub> concentration stimulate nitrogen fixation in most of the world's legumes, i.e., plant species that form symbiotic relationships with nitrogen-fixing soil bacteria; and this phenomenon will likely lead to increased nitrogen availability in earth's soils as the air's CO<sub>2</sub> content continues to rise, ultimately generating large increases in crop and natural ecosystem productivity.*

**34. Nutrient Acquisition** – *Most species of plants respond to increases in the air's CO<sub>2</sub> content by displaying enhanced rates of photosynthesis and biomass production, both above and below ground. In the latter instance, there are typically significant increases in fine-root numbers and surface area; and this phenomenon tends to increase total nutrient uptake under CO<sub>2</sub>-enriched conditions, which further stimulates plant growth and development.*

**35. Phosphorus Acquisition** – *Many people have long presumed that the growth stimulation due to the aerial fertilization effect of atmospheric CO<sub>2</sub> enrichment will not be sustained as time progresses, due to insufficient amounts of soil phosphorus. However, several studies conducted over the past decade or so suggest that a CO<sub>2</sub>-enriched atmosphere actually **enables** plants to obtain the extra phosphorus they may require under such circumstances.*

**36. Photosynthesis** – *Atmospheric CO<sub>2</sub> enrichment typically increases the photosynthetic rates of nearly all plants, while almost never lowering it.*



**37. Progressive Nitrogen Limitation** – *Climate alarmists have long contended that the striking CO<sub>2</sub>-induced growth enhancements initially experienced by long-lived plants in scientific studies will gradually disappear with the passage of time, as the plants slowly deplete the soils in which they are growing of their initial store of nitrogen. However, long-term atmospheric CO<sub>2</sub>-enrichment experiments show that this **progressive nitrogen limitation** (or PNL) **hypothesis** is not supported by real-world data, as even soils that were low in nitrogen at the start of many long-term atmospheric CO<sub>2</sub> enrichment experiments have continued to supply sufficient nitrogen to continually maintain the initial high level of the CO<sub>2</sub>-induced stimulation of plant growth.*



**38. Reactive Oxygen Species** – *Reactive oxygen species (ROS) are generated by the normal metabolism of cells; and they create oxidative stresses in organisms that tend to shorten their lives. This negative consequence of ROS is largely counteracted by a CO<sub>2</sub>-enhanced antioxidant defense system that increases resistance to stress, leading to anti-ageing benefits and enhanced life span.*



**39. Root Exudation** – *At the same time that elevated CO<sub>2</sub> increases plant growth, it stimulates the exudation of nutrients and carbon from plant roots into the soil. This phenomenon typically enhances biotic activity within the rhizosphere, or plant root zone, which often increases the availability of mineral nutrients to plants.*

**40. Root Production** – *Elevated CO<sub>2</sub> nearly always increases root biomass – often even more than shoot biomass – by increasing the size of taproots and the number and size of lateral roots, along with fine-root biomass and a number of other important root properties.*

**41. Salinity Stress** – *Atmospheric CO<sub>2</sub> enrichment has been shown to stimulate the growth of agricultural crops, woody plants and halophyte species growing under stressful conditions of high salt concentration, demonstrating that such an environment does not thwart the growth-promoting effects of elevated CO<sub>2</sub>.*

**42. Seeds** – *Atmospheric CO<sub>2</sub> enrichment often increases seed mass, yield, germination success, and other qualities that bode well for the future of earth's biosphere.*



**43. Soil Erosion** – *As a result of the direct effects of atmospheric CO<sub>2</sub> enrichment upon the primary plant processes of photosynthesis and transpiration, which lead to dramatic increases in plant water use efficiency, many plants are greatly expanding their ranges and the amount of soil surface they cover, thereby stabilizing more soil and better protecting it from erosion by their presence both above and below ground.*



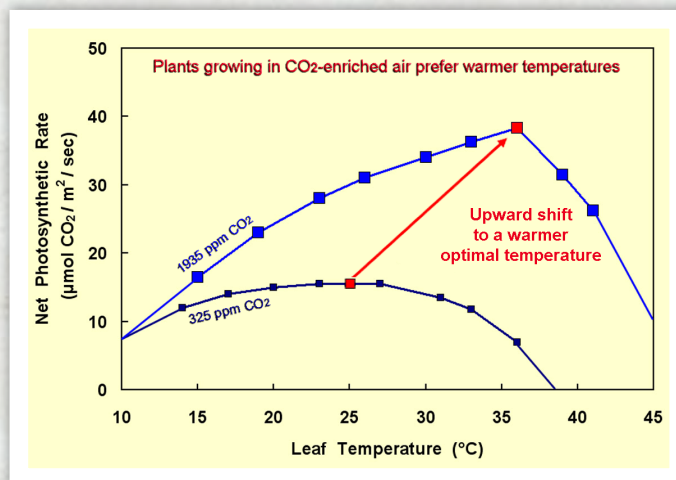
**44. Soil Toxicity** – Increases in the air's  $\text{CO}_2$  content help plants to better withstand the deleterious effects of harmful elements that may be present in the soil at toxic levels.

**45. Starch** – As the air's  $\text{CO}_2$  content continues to rise, nearly all of earth's vegetation will respond by exhibiting enhanced rates of photosynthesis and greater production of carbohydrates. Many of these carbohydrates will be exported from leaves to ultimately provide energy or carbon skeletons to facilitate further plant growth, after which any remaining carbohydrates are generally converted into starch and stored within leaves or roots for future use.

**46. Tannins** – Numerous studies indicate that elevated concentrations of atmospheric  $\text{CO}_2$  tend to increase leaf and fine-root tannin concentrations of plants, and that this phenomenon tends to (1) protect the plants' foliage from predation by voracious insect herbivores, (2) protect the plants' roots from soil-borne pathogens and herbivores, (3) enhance the sequestration of carbon in forest soils, and (4) reduce methane emissions from ruminants that might nibble on the plants' foliage.



**47. Temperature Stress** – The optimum temperature for plant growth and development typically rises with increasing concentrations of atmospheric  $\text{CO}_2$ . This response, coupled with

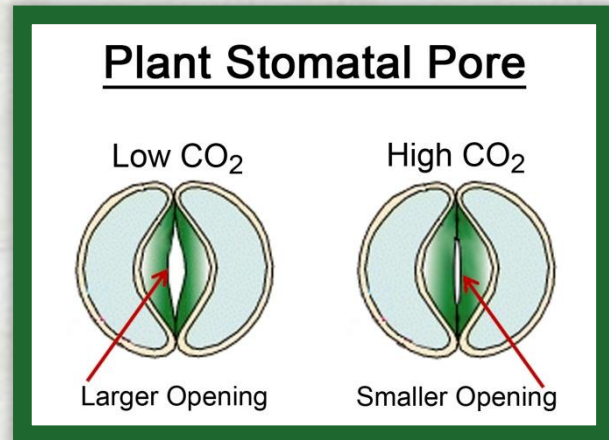


expected increases in plant photosynthetic rates from the concomitant rise in the air's  $\text{CO}_2$  concentration, is **more** than enough to **totally compensate** for any temperature-induced plant stress that might be caused by most scenarios of climate-model-predicted  $\text{CO}_2$ -induced global warming.

**48. Thylakoid Membranes** – The results of several studies suggest that atmospheric  $\text{CO}_2$  enrichment may be a powerful "treatment" for all sorts of environmental ailments that afflict earth's plants and have their origin in stress-induced problems associated with the thylakoid membranes of chloroplasts.

**49. Transpiration** – Under conditions of atmospheric  $\text{CO}_2$  enrichment, stomatal apertures typically decrease, thereby reducing stomatal conductance and transpirational water losses from plants.

**50. UV-B Radiation Stress** – The ongoing rise in the air's  $\text{CO}_2$  content is a powerful antidote for the deleterious biological impacts that might be caused by an increase in the flux of UV-B radiation at the surface of the earth due to any further depletion of the planet's stratospheric ozone layer.



**51. Vegetative Storage Proteins** – In  $\text{CO}_2$ -enriched air, these special nitrogen-storing proteins are created in greater amounts in the leaves of perennial plants, where they are stored over winter and from whence they are transferred to newly-developing second-year leaves to give them a huge boost in their initial development.



**52. Water Stress** – When plants are growing under less-than-optimal conditions of soil water availability, the percent growth enhancement due to atmospheric  $\text{CO}_2$  enrichment is generally greater than it is when water is readily available to them. Elevated levels of  $\text{CO}_2$  thus tend to compensate for less-than-optimal water supplies; and they help plants recover, both more quickly and more completely, when they have experienced a period of severe water stress.

**53. Water-Use Efficiency** – With higher concentrations of  $\text{CO}_2$  in the air, greater photosynthetic carbon uptake typically occurs. In addition, less water is lost via transpiration, as many plants exhibit decreased stomatal conductances at elevated  $\text{CO}_2$ . Hence, the amount of carbon gained per unit of water lost via transpiration – or water-use efficiency – generally increases substantially with atmospheric  $\text{CO}_2$  enrichment, sometimes even doubling with a doubling of the air's  $\text{CO}_2$  content.



**54. Weeds** – Elevated  $CO_2$  typically stimulates the growth of nearly all plant species in monoculture, including those deemed undesirable by humans, i.e., weeds. Consequently, it is important to determine how future increases in the air's  $CO_2$  content may influence relationships between weeds and non-weeds when they grow competitively in mixed-species stands. Fortunately, the results of several such studies suggest that the ongoing rise in the air's  $CO_2$  content likely will **not** favor the growth of weedy species over that of crops and native plants. In fact, it may well provide non-weeds **greater** protection against weed-induced decreases in their productivity and growth. Thus, future increases in the air's  $CO_2$  content may actually increase the competitiveness of non-weeds over weeds, which would be a great boon to agriculture.



**55. Wood Density** – Elevated  $CO_2$  often increases wood density in trees, thereby increasing a number of strength properties of their branches and trunks.



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Air Pollution Stress (Non–Ozone)  
Air Pollution Stress (Ozone)  
Avoiding Human Starvation and  
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Bacteria  
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Biogenic Volatile Organic Compounds  
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C<sub>4</sub> Plants  
CAM Plants  
Carbon Sequestration  
Diseases of Plants  
Early Growth  
Earthworms  
Evolution  
Flowers  
Fluctuating Asymmetry  
Glomalin  
Health-Promoting Substances  
Herbivory  
Hormones  
Human Longevity  
Human Mortality (All Causes)  
Human Mortality (Cardiovascular)  
Human Mortality (Respiratory)  
Iodocompounds  
Isoprene  
Light Stress  
Lipids  
Medicinal Plants  
Monoterpenes  
Nectar  
Net Primary Productivity  
Nitrogen Fixation  
Nutrient Acquisition  
Phosphorus Acquisition  
Photosynthesis  
Progressive Nitrogen Limitation  
Reactive Oxygen Species  
Root Exudation  
Root Production  
Salinity Stress  
Seeds  
Soil Erosion  
Soil Toxicity  
Starch  
Tannins  
Temperature Stress  
Thylakoid Membranes  
Transpiration  
UV-B Radiation Stress  
Vegetative Storage Proteins  
Water Stress  
Water-Use Efficiency  
Weeds  
Wood Density



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