

World Climate Declaration: Exhaled Carbon Dioxide Promotes Plant Development

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ABSTRACT

The British Naturalist Alfred Russel Wallace (1823–1913), who was born 200 years ago, argued in a popular book of 1903 that carbon dioxide (CO₂) is enriched in exhaled air of humans, and bad for our health, but essential to plant development. With reference to the 2023 *World Climate Declaration*, we document that exhaled CO₂ drastically promotes the growth of a representative land plant. Using regenerated cuttings of *Tradescantia geniculata*, raised in moist soil, we show that, within 21 days of growth in a day-/night-cycle, CO₂-enrichment (ca. 4 vol. % vs. 0.04 vol. % in the control) exerts the following effects: Average stem length is doubled, a three-fold enhancement in the number of branches occurs, and adventitious roots, plus flowers, develop. This CO₂-fertilisation-phenomenon, documented as large increase in plant biomass since ca. 1850. We also address negative effects of further rising CO₂-levels in the atmosphere on the global environment in the ongoing Anthropocene. Finally, we point out that A. R. Wallace was not only a theorizing explorer of nature, but also an expert in animal- and plant physiology.

Keywords: Alfred Russel Wallace, Carbon dioxide, Global Greening, Photosynthesis, World Climate Declaration.

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I. INTRODUCTION

On February 18, 2023, the World Climate Declaration published an updated version of their document “There is no climate emergency” (GCIG 2023) [1]. The first author of this article signed the declaration as “Scientist from Germany / no. 35”. In the present study, we discuss point four of this document, stating that “CO₂ is plant food, the basis of all life on Earth”. Specifically, we agree with the GCIG 2023 argument that “CO₂ is not a pollutant. It is essential to all life on Earth. More CO₂ is favorable for nature, greening our planet. Additional CO₂ in the air has promoted growth in global plant biomass. It is also profitable for agriculture, increasing the yields of crops worldwide” [1].

This “CO₂-fertilisation phenomenon”, known under the term “Global Greening of the Earth,” has been studied extensively, using Infrared gas-analyzers and additional sophisticated equipment, by Kutschera *et al.* [2], [3] and other scientists.

However, the broader context of this contribution is the 200th anniversary of the birth of the British naturalist Alfred Russel Wallace (1823–1913), who argued in his popular book *Man's Place in the Universe* [4] that carbon dioxide is essential for plant growth (Fig. 1). Moreover, with reference to the pertinent literature of his time, Wallace wrote that, in the exhaled air of humans, CO₂ is enriched, leading to poor air quality in badly ventilated buildings. This topic has recently been discussed in this journal [5].

In a comprehensive bio-historical account on the discovery of carbon dioxide (CO₂)-mediated “Global Greening”, it is

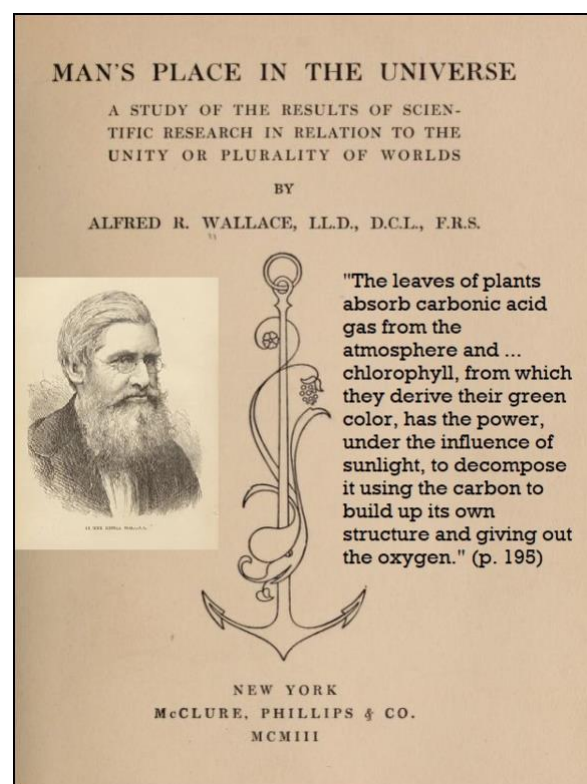


Fig. 1. Title page of Alfred Russel Wallace's popular book *Man's Place in the Universe* (1903), with a portrait of the author and his definition of photosynthesis as sunlight-driven-CO₂-assimilation.

documented that the German plant physiologist Wilhelm Pfeffer (1845–1920) was the first to demonstrate that CO₂ is a limiting factor for vegetative growth of crop-species, such

as raspberries and horn beans [6]. The aim of the present investigation was to answer the question to what extent exhaled air of a human being is able to promote the growth of a representative flowering plant. We will discuss our findings with reference to Wallace [4], who was one of the first scientists to argue that, on the one hand, CO₂ is essential to plants but, on the other hand, may be bad for human health [5].

II. MATERIALS AND METHODS

We have experimentally analyzed the effect of CO₂-enrichment of the atmosphere in a model plant used rarely in this context: cuttings of *Tradescantia geniculata* Jacq. (family Commelinaceae), also known as Tahitian Bridal Veil (Origin: Mexico to South America; it is a partial shade plant). Individuals of *T. geniculata* were raised in moist soil (pots with a diameter of 12 cm) in a glasshouse (Fig. 2). Excised tips of selected single shoots (length: ca. 2.5–5.0 cm) were treated for 7 days in rooting medium (Chryzopon 0.25 %; purchased from the company Rhizopon, The Netherlands). The rooted cuttings were planted into moist garden soil in small plastic pots (diameter: 6 cm). Developing plantlets were raised in a glasshouse under a natural sunlight/dark-regime (temperature: ca. 26/21 °C; 25 % relative humidity: ca. 99 %; max. photon fluence during the day: ca. 800 μmol m⁻² s⁻¹).



Fig. 2. Adult individual of a *Tradescantia geniculata*-plant with ca. 50 stems. Vegetative tips with “growth potential” were excised as indicated and treated with rooting medium. Rooted cuttings of average size were used for all experiments.

Based on the fact that the current CO₂-level in the atmosphere is ca. 0.04 vol. %, whereas human breath contains ca. 100-fold more carbon dioxide (approx. 4.0 vol. %) [7], the experiments shown in Fig. 3 and 4 were designed. Pairs of *T. geniculata* plantlets were raised in transparent plastic boxes (15×15×15 cm) (Fig. 3). For ventilation and air-exchange, two plastic tubes, diameter ca. 3 mm, were placed into the cover of the box and arranged as indicated. Distilled water

was added to the bottom of the boxes to create an atmosphere of 100 % rel. humidity. For the next 21 days (natural daylight/dark-regime, photon fluence, and temperature as described above), the control was left without further treatment (ca. 0.04 vol. % CO₂). For experimental CO₂-enrichment of the air, the exhaled breath of a male human being (lung volume ca. 5.0 l) was applied twice per day for ca. 0.5 min (6 AM and 6 PM, respectively) to the second box. After 21 days of growth under these +/- CO₂-enrichment conditions, both *T. geniculata*-plantlets were taken out of the containers, photographed and analyzed with respect to stem-high, number of shoots, adventitious roots, and flowering organs. In control experiments, cuttings were treated with pure carbon dioxide gas, resulting in a concentration in the enclosed air of ca. 4.0 vol. % CO₂. All experiments were repeated four times with similar results.

III. RESULTS

Fig. 3 shows a scheme indicating the basic design of our study. In addition, the scheme shows that CO₂ and H₂O, molecules composed of three atoms each absorb Infrared (IR)-light and hence act as greenhouse gases. It should be noted that the cuttings were raised in moist garden soil that contained a natural mixture of mineral salts. The only growth-limiting factor was the CO₂-level in the surrounding air. In Fig. 4, a representative sample of two *T. geniculata*-plants that were raised for 21 days in plastic boxes, with or without CO₂-enrichment caused by exhaled air of a human being, is shown. At the start of the experiment, the stems of the rooted cuttings (plantlets) were ca. 2.8 to 4.8 cm long. At the end of the treatment, average stem lengths were 9.6 vs. 19.5 cm in the control vs. CO₂-treated samples, respectively. In ambient air, 4 side branches developed, whereas in the CO₂-enriched plantlets, 12 additional branches were counted. The average length of the leaves was 2–3 cm in both kinds of plants. However, due to the enhanced number of side branches, more leaves per plant developed: from six at day zero to 23 vs. 43 in the control and CO₂-treated samples, respectively. In addition, Fig. 4 also shows that, in the carbon dioxide-enriched plants, adventitious roots were prominent, but these organs were not detectable in the controls. Moreover, the development of flowers was drastically promoted under the influence of the applied extra-CO₂.

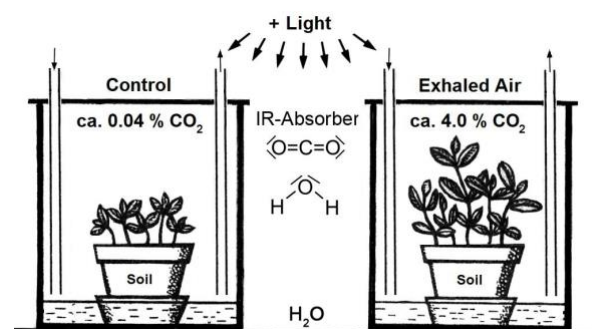


Fig. 3. Experimental set-up to study the effects of CO₂-enrichment of the atmosphere in rooted shoots of *Tradescantia geniculata*. One pot with moist garden soil was placed into a transparent plastic-box (water level ca. 5 mm). Airflow from outside the box was achieved via two narrow tubes. In the right box, the atmosphere was enriched with exhaled air of a male human being. The action of CO₂- and H₂O-gas as Infra Red (IR)-absorbers is indicated.

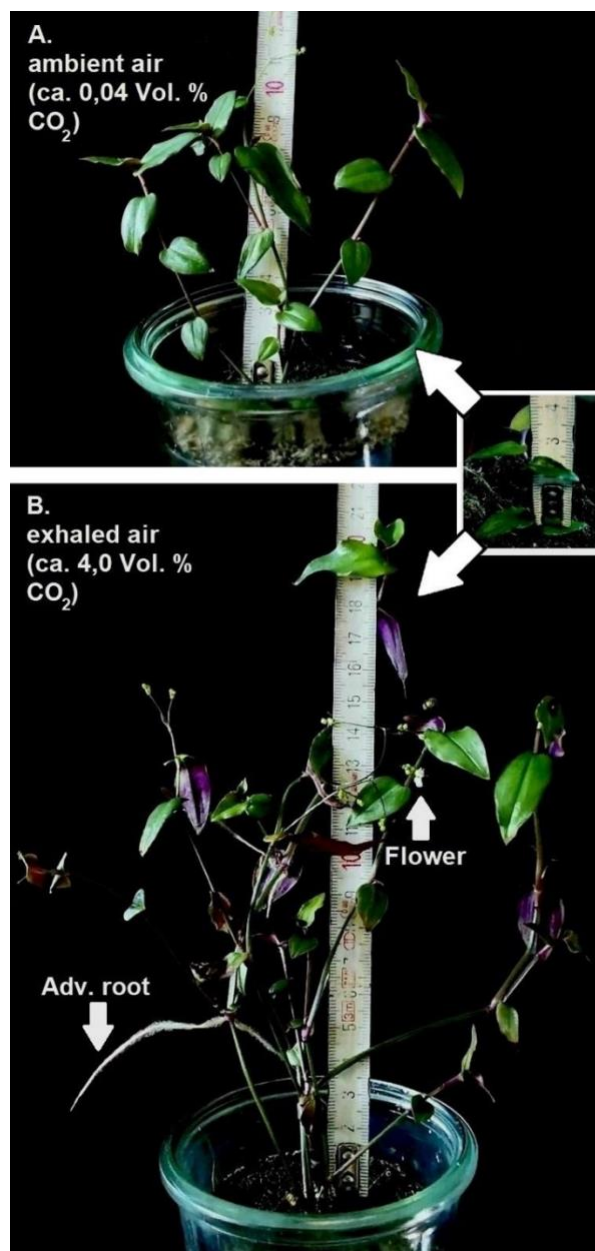


Fig. 4. Representative result after a carbon dioxide enrichment-period of 21 days under experimental conditions as shown in Fig. 3 (natural daylight/dark-cycle). Control (A); sample plus extra-CO₂ (B) Note that, in the right plant (100-fold enrichment of atmospheric CO₂, B), not only stem length is drastically promoted. In addition, flowers and adventitious roots developed under the influence of the exhaled air of a human being.

In the next step, we investigated root and flower development in more detail. As shown in Fig. 4, control plantlets displayed no adventitious roots upon close examination. In contrast, we observed in all four independent CO₂-enrichment experiments adventitious roots originating at the nodes of the lower part of the stem (lengths of 1 up to 5 cm). Since these roots developed in moist air, root hairs were visible in all samples studied. With respect to flower development, we were surprised to discover that this key parameter of plant development was drastically promoted by the exhaled CO₂-enriched air (Fig. 4). Compared with the controls, the CO₂-treated samples displayed larger, more fully developed flowering organs. In some cases, sexually mature, white flowers with diameters of up to 3 mm were observed.

As mentioned above, the exhaled air of an adult human being contains ca. 4 vol. % CO₂ [7]. It is logical to assume

that the growth-promoting effect observed in our study is caused by carbon dioxide-enrichment. To corroborate this interpretation, we repeated the experiment shown in Fig. 3 and Fig. 4 by applying pure CO₂ provided by a commercially available carbon dioxide gas bottle. When ca. 4 vol. % CO₂ was applied to the developing *T. geniculata* plants, under the same experimental conditions, the results obtained by application of exhaled air were reproduced (unpublished results). This “pure CO₂-enrichment-effect” is currently under investigation, with a focus on the time-course of adventitious root and flower development.

IV. DISCUSSION

One hundred and twenty years ago, Wallace published his influential book *Man's Place in the Universe* [4]. In this popular text, the British naturalist not only championed the emerging discipline of Astrobiology [8], but also, as shown in Fig. 1, argued that CO₂ is an essential trace gas for light-driven carbon-assimilation (photo-synthesis). As it was common at that time, Wallace [4] interpreted this process as “de-composition of carbonic acid gas.”

Decades later, it was discovered that the oxygen released during carbon assimilation is not created by the “sunlight-induced de-composition of CO₂”, but via the hydrolysis of water (2 H₂O creates one O₂ molecule and four Hydrogen-units) [9]. With respect to the current “CO₂-atmospheric warming-discussion”, this insight, i.e., that carbon dioxide is essential for plant life and all heterotrophic organisms on Earth, is of great importance. As mentioned in the introduction, the GCIG 2023-document stresses that CO₂ is not a pollutant but provides the basic carbon units for all green living beings that are labeled as “photoautotrophic organisms” capable of performing oxygenic photosynthesis (Cyanobacteria, Algae, Plants) [1], [9].

The German scientist Wilhelm Pfeffer was one of the first to argue that the then-current level of CO₂ in ambient air (ca. 0.028 vol. % in 1903) is suboptimal for plant growth and crop yield (with respect to C3-Plants) [6], [9].

However, to the best of our knowledge, it was the British naturalist Wallace [4] who, in addition to stressing the importance of CO₂ for vegetative growth (Fig. 1), argued that too much carbon dioxide is detrimental to human health. Wallace [4] complained about the poor air quality in closed rooms occupied by human beings and hence introduced the concept of “CO₂-poisoning” [5], [7]. These achievements of the co-discoverer of the “Darwinian” principle of “evolution by natural selection” and “father of biogeography” [10], [11], [12] have been ignored in the current literature on the relationship between human health risks and carbon dioxide-levels in the surrounding air.

In summary, our study documents that Wallace [4] was correct with his statements on carbon dioxide and plant vs. human life, published in his popular book *Man's Place in the Universe* –, i.e., the relationships between photoautotrophic vs. heterotrophic organisms of the bio-sphere.

This article may contribute to the acknowledgment that Wallace, “the man in the shadow of Darwin,” was not only a theorizing biologist with expertise in biodiversity research; He was also well aware of the scientific literature in plant- and animal physiology. We hope that the tarnished image of

the “naturalistic spiritualist” Wallace [12] can be corrected by pointing out and documenting his broad expertise, both as an explorer of nature and an expert in laboratory-based research studies.

Our simple experiment shown in this report may convince the broader scientific establishment that exhaled air of human beings, and hence CO₂-enrichment of the atmosphere, has beneficial effects on the “carbon dioxide-hungry” vegetation (C3-Plants), on which the life of all heterotrophic organisms, inclusive of our species, depends [9]. Finally, this study may illustrate and corroborate point 4 of the World Climate Declaration [1], i.e., that CO₂ is essential for plant development and the current anthropogenic “greening of the world” that resulted in a ca. 30 % increase in global plant biomass since 1850 [3], [13], [14]. However, despite the fact that we agree with the statement that “There is no climate emergency” [1], in the long run, a reduction in man-made CO₂-emissions is necessary because photosynthesis of the C3-vegetation (ca. 90 % of all plant species) will become carbon dioxide-saturated in the next decades. Then, negative effects of this trace gas may dominate (like water vapor, CO₂ acts as an Infra-Red absorber, see Fig. 3). Hence, CO₂-neutral “artificial photosynthesis energy systems” should be developed and employed by mankind in the ongoing era of the Anthropocene, a concept envisioned by the great scientist Wallace a long time ago [11], [12], [15], [16].

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