Nutrient management strategies for sustainable mulberry plantations

Mulberry trees (Morus spp.) have the unique status of being the only food that Mulberry silkworms will feast on. Bombbyx mori, the domestic silk moth, are an unusual species that have been so selectively bred they are entirely dependent on humans for their survival. They cannot fly, and swatches of fresh mulberry leaves must be brought to sustain their ravenous larvas so they can form their precious, and economically valuable, silk cocoons. The dependence of the silk trade on mulberry trees makes them highly prized plants, so research into protecting and optimising their productivity is critical for the future of the silk industry. Dr Songmei Shi and Professor Xinhua He, at Southwest University China, have been investigating how elevated carbon dioxide concentrations affect plant growth and how these can be optimised, with other environmental parameters, to maximise biomass yields and improve quality.

**Carbon Dioxide and Photosynthesis**

CO₂ levels play an important role in the rate at which photosynthesis can occur. Photosynthesis is the process at the heart of a plant’s life. Plants possess the remarkable ability to use energy provided by sunlight to take carbon dioxide and water and transform them into glucose and oxygen. In turn, this process helps provide the fuel for plant growth and function, sustaining the plant’s life. However, photosynthesis is a delicate and complex process. As well as the chemical complexity of the many steps involved in the conversion of carbon dioxide into glucose and then other sugars, it is also a process that is highly sensitive to external environmental factors, including temperature and sunlight levels. While it might seem that more sunlight means more photosynthesis and therefore more plant growth, the delicate chemical machinery in plants can actually be damaged by excessive light levels, hindering a plant’s growth.

Chlorophyll is the pigment in a plant’s leaves that make them appear green, and it is the antenna that captures the energy from the sun’s rays that is used in the photosynthetic compound. Many plants will only produce the large quantities of chlorophyll that give leaves their vivid green appearance during seasons with high light levels. This is why, during the autumn, leaves often turn red. This is a strategy to conserve energy by limiting growth.

Elevated CO₂ levels generally lead to faster photosynthesis, unless another factor, such as the light levels, is the rate-limiting step. The number of environmental variables that need to be considered and controlled to optimise photosynthesis levels for maximum biomass production is far from trivial, and finding optimal ranges is key for intensive plant growth of valuable biomass.

**Biomass Production and Plant Nutrition**

One of the effects from increasing global carbon dioxide levels will be on plant growth; however, the effects of increasing atmospheric CO₂ concentrations from current levels are not well understood. Moreover, previous studies have been performed under averaged, steady-state CO₂ concentrations, so any differences between daytime and nighttime responses are not revealed. Ambient CO₂ can be 10–20% higher at night, and there can be local variations in CO₂ concentrations due to factors such as wind speed and the shape of the surrounding landscape which affect the movement and exchange of atmospheric gases.

**Methods**

To mimic real-life conditions, the researchers grew six- or 12-month-old trees.** Figure 1.** (A, B) Twelve environmentally controlled glass-made growth chambers were constructed in 2013 at the National Monitoring Station of Soil Fertility and Fertilizer Efficiency on Purple Soils in Southwest University. (C) Growth status of Morus alba var. Gui-sang-you 62 in the growth chamber. (D) Growth of Morus alba var. Gui-sang-you 62 under ambient CO₂ (ACO₂), sole daytime eCO₂ (DeCO₂), sole nighttime eCO₂ (NeCO₂), or continuous daytime and nighttime elevated CO₂ (D+N)eCO₂. (E) Growth of Morus alba var. Gui-sang-you 62 under ambient CO₂ (ACO₂); sole daytime eCO₂ (DeCO₂), sole nighttime eCO₂ (NeCO₂), or continuous daytime and nighttime eCO₂ (D+N)eCO₂. **A balance between nutrition levels and carbon dioxide concentrations is key to growing large, nutritious plants.**

Dr Shi and Professor He wanted to study the mulberry under ‘real-life’ conditions, and take a closer look at any differences in the way the plants responded to changes in CO₂ concentrations. As well as examining changes in leaf growth, plant height and overall biomass, the researchers were interested to investigate the mineral uptake and storage of the plants. This is because the mineral levels in the leaves determine the leaf’s nutritional value, be that for humans or very hungry silkworms. Greater uptake of soil nutrients, like nitrogen, phosphorous and potassium, indicates a faster plant metabolism, and if such nutrients are available in limited supply this can also negatively impact photosynthetic rates.

**Daytime and Nighttime Results**

To mimic real-life conditions, the researchers grew six- or 12-month-
old mulberry seedlings, inside environmentally controlled glass growth chambers or houses, for four months. The chambers were all subject to the same light, temperature, humidity, and fertilisation conditions, but the concentration and time of delivery of CO₂ was varied in each chamber. By precisely controlling the environmental factors in these growth chambers, the research team could be more confident that any changes they did observe were truly the result of variations in the CO₂ concentrations and time of delivery of CO₂. The chambers or houses, for four months.

Figure 2 Mean temperature (A), relative humidity (B), photosynthetic active radiation (PAR, C), CO₂ concentration (D) and CO₂ concentration (D+E) over the experimental period in the growth chambers. ACO₂: ambient CO₂; DCO₂: elevated CO₂ concentrations at daytime, NCO₂: elevated CO₂ concentrations at nighttime, D+NCO₂: elevated CO₂ concentrations at both daytime and nighttime.

**Balancing Nutrition and Carbon Dioxide**

The research team’s findings show that, daytime rather than nighttime, elevated CO₂ improves plant growth and leaf quality of mulberry seedlings, but while elevated CO₂ could be a potential benefit for mulberry growth production, this needs to be balanced against the addition of specific minerals, including nitrogen, phosphorus and magnesium. Achieving a balance between nutrition levels and CO₂ concentrations is the key to growing large, nutritious plants that can support a large silkworm population. A single small silkworm might eat as much as half a kilogram of mulberry leaves before moving to the next stage in its life cycle, so it is crucial that the trees can produce enough biomass to keep them well fed.

Dr Shi and Professor He’s work has also shown that increasing CO₂ levels for intensively farmed plants at night is unnecessary and so, for plants being grown in controlled atmospheric conditions, CO₂ use can be restricted to the daytime periods where it has the most significant impact. This saves on gas usage costs and also minimises unnecessary CO₂ production during farming.

Securing future food supplies using fast-growing plants such as the mulberry, that is also used to feed livestock as well as the economically important silkworms, is also used to feed livestock as well as the economically important silkworms, is a key challenge for improving the resilience of food stocks around the world. Finding approaches that can help maintain or boost the nutritional value of these plants under such changing conditions is equally as important as finding ways to encourage plant growth and size, as this nutrient density is the key for the species that rely upon them.

**References**


**Behind the Research**

**The Effects of Environmental Change on Plant Growth**

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Bio

Songmei Shi is a Post-doctoral Fellow with a PhD in agronomy, at Southwest University, China. Xinhua He has a PhD in Plant Ecophysiology from the University of Queensland, Australia, and is a Professor at Southwest University, China and the University of Western Australia. Their research focuses on the responses of plant growth, yield and quality, as well as soil nutrient availability, to global environmental change.

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**Collaborators**

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**Personal Response**

What other factors do you think will be important to explore to boost mulberry tree growth?

"Except CO₂ and fertiliser, water is pivotal to various photochemical processes of plants such as leaf photosynthesis, which is regulated by plant water status and soil water availability. Therefore, adequate water supply could boost mulberry growth. In addition, elevated CO₂ and/or temperature can quantitatively and interactively affect the synthesis and release of labile sugars, organic acids, and amino acids from plant roots, and influence the diversity of soil microbial communities and the activity of rhizospheric and root-associated microbes, which may subsequently alter the nutrient availability to plants."

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