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NATURAL DECARBONISATION IN CONTROLLED MICROCLIMATES IN THE CONCEPT OF NEUTRAL AGRICULTURE – REVIEW

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Abstract: In terms of emission absorption, agriculture, unlike other sectors, has the ability to fix the carbon in the atmosphere through the process of photosynthesis and sequester it in soil and biomass. In the context of climate change, outdoor agricultural production is usually subjected to uncertainty, obtaining random quantities from year to year, which leads to an increased demand for growing crops under controlled conditions. Due to the increased need for safe and deterministic food, the greenhouse is a protected space for food production that has its own microclimate. One of the most important objectives of a greenhouse is to maximize productivity by obtaining a competitive advantage, and an effective way to increase productivity is to fertilize plants with CO_2. In this paper will be presented various studies on the interest in enriching crops with CO_2 and its effect on crops.

Keywords: carbon dioxide, natural decarbonisation, controlled microclimates, neutral agriculture

INTRODUCTION

According to the 2015 Paris Agreement, the limit of 450 ppm of CO_2 in the atmosphere is approached as a protection limit (in a certain probability of validity) that must not be exceeded in order to avoid situations capable of causing irreversible problems. The current value of the CO_2 concentration is close to 417 ppm, and the upward trend is not in line with such a tight and strict limit. To keep the limit of the 450 ppm CO_2 limit could be achieved by sequestering CO_2 in the atmosphere *(Luan, H., Gao, W., et al, 2019 Wang, Y., Hu, N., et al, 2017; Xu, P., Zhu, J., et al, 2021)*.

Climate change is one of the biggest challenges facing humanity today, with the global economy as its main objective to increase the level of decarbonization. Agricultural activity is a source of greenhouse gases (GHGs), but also a sink, especially by storing carbon dioxide in soil organic matter and biomass. In terms of emission absorption, agriculture, unlike other sectors, has the ability to fix the carbon in the atmosphere through the process of photosynthesis and sequester it in soil and biomass. Also, biomass produced in agriculture and used for energy (energy from renewable sources) or as a raw material (biomaterials, plant chemistry) is another way to increase carbon biosequestration. Biochemists have shown that fertilizing the air with carbon dioxide is a great way to get high yields from different crops, plant growth can be stimulated by increasing CO_2. Thus, the interest in enriching crops with CO_2 is increasingly present in agriculture, in response to plant enrichment with CO_2, in different climatic conditions *(Runion, G. B., Finegan, H. M., et al, 2011 Liu, H., Zhang, J., et al, 2018; Liu K., Huang, J., et al, 2019)*.

Because horticultural plants are generally grown in containers without resource limitations (i.e., water and nutrients), increased root growth or mycorrhizal colonization may not become critical for survival and growth until after outplanting into the landscape. However, as a result of limited rooting space, growth in containers has been shown to dampen the response to CO2 enrichment. For plants to use a higher level of atmospheric CO2, they must have a means of storing the additional carbohydrates produced. Plants with a tuberous or woody root system tend to respond to CO2 enrichment to a greater degree than plants with smaller or more fibrous root systems *(Xu, X., Schaeffer, S. et al, 2020; Kallenbach, CM, et al, 2010)*.

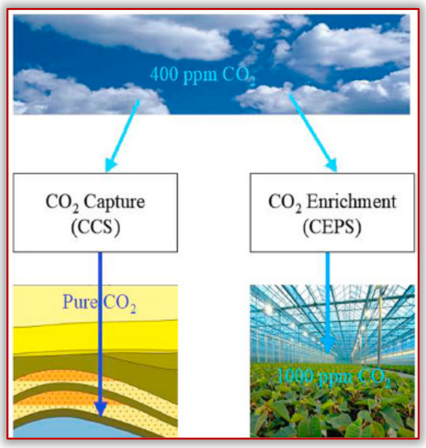

Figure 1 – Illustration of (a) CCS (Carbon Capture and Storage) and (b) CEPS (Carbon Enrichment for Plant Stimulation) processes (Baoa, J. et al., 2018)

Carbon dioxide links the atmosphere to the biosphere and is an essential substrate for photosynthesis. Elevated CO_2 stimulates photosynthesis leading to increased carbon (C) uptake and assimilation, thereby increasing plant growth. However, as a result of differences in CO_2 use during photosynthesis, plants with a C_3 photosynthetic pathway often exhibit greater growth response relative to those with a C_4 pathway *(Qiu, QY, Wu, LF, et al, 2016; Raheem, A, Zhang, J, et al, 2019)*.

In addition to the aforementioned effects of CO2 on photosynthesis and C allocation, increased CO2 can impact growth by improving plant water relations. Water is also a crucial resource in many horticultural production units, and its conservation is becoming an increasingly important issue. The fact that increased CO2 can increase plant WUE may indicate that plants can be watered less frequently as CO2 levels continue to rise. However, since these plants are generally grown with optimal nutrients, increased CO2 may increase the size of the plant to a point where watering frequency will need to be maintained at current levels or even increased. This interaction between high CO2 and resource availability is also extremely important for horticultural species after planting in the landscape, where periodic droughts can be relatively frequent *(Qaswar, M, Jing, H, et al, 2020)*.

MATERIALS AND METHODS

In the paper *(Prior, S. A.. et al., 2011)* a study was conducted on plant growth by CO2 stimulation. In this study, it was shown that applying more CO2 can increase the water use efficiency of the plant and lead to less water use.

The study *(Luan, H. et al., 2021)* aimed to appraise the changes of organic C stability within soil aggregates after eight years of fertilization (chemical vs. organic fertilization) in a greenhouse vegetable field in Tianjin, China. Changes in the stability of organic C in soil aggregates were evaluated by four methods, i.e., the modified Walkley–Black method (chemical method), 13C NMR spectroscopy (spectroscopic method), extracellular enzyme assay (biological method), and thermogravimetric analysis (thermogravimetric method). The aggregates were isolated and separated by a wet–sieving method into four fractions: large macroaggregates (>2 mm), small macroaggregates (0.25–2 mm), microaggregates (0.053–0.25 mm), and silt/clay fractions (<0.053 mm).

In the study *(Lin, S, et al., 2021)*, soil CO2 and CH4 fluxes under various fertilization treatments in tea soil were investigated during a 50–day period.The experiment consisted of five treatments: no fertilizer (CK), single nitrogen (urea, N), single oilseed rape cake fertilizer (R), nitrogen þ cake fertilizer (2:1, NR1), and nitrogen þ cake fertilizer (1:2, NR2).The fertilization proportion of NR1 and NR2 was determined by the nitrogen content of nitrogen fertilizer and cake fertilizer.

To hold global temperature rise below 2°C by 2050, global greenhouse gas emissions must be reduced by more than 80%. In this sense, in the study *(Baoa, J. et al., 2018)* was proposed develop a modern urban vertical farming system, i.e. greenhouses equipped with a Carbon Enrichment Plant Stimulation System (CEPS) to improve land use efficiency and thus increases food productivity and, at the same time, to sequester CO2 from the ambient air. The the implementation of such a CEPS system will have the potential to remove more than 500 million tons of CO2 from the air annually and increases the current food productivity more than 15 times than the open field operation.

In the paper *(Wanga, T.. et al., 2014)*, an integrated system combined direct air capture (DAC) (Figure 2) and greenhouse agriculture is proposed, in which moisture swing adsorption technology is used to concentrate CO2 from the atmosphere and then feed CO2 to the greenhouse. Allso, absorption isotherm study and desorption kinetic study have been achieved in the paper.

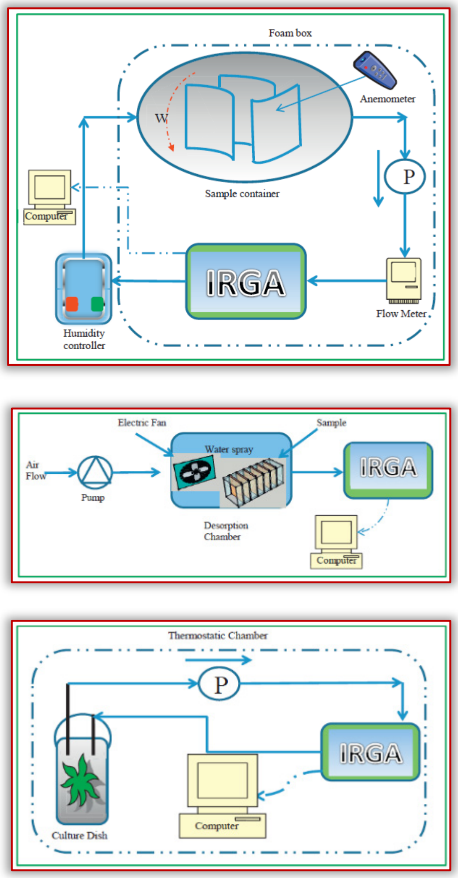

Figure 2 – Schematic of experimental system for absorption equilibrium study (Wanga, T.. et al., 2014)

(Stanghellini, C., et al., 2010) applied a simple model for estimating potential production loss, using data obtained in commercial greenhouses in Almería, Spain, and Sicily, Italy. They analysed the cost, potential benefits and consequences of bringing more CO2 into the greenhouse: either through increased ventilation, at the cost of lowering temperature, or through artificial supply. They

found that while the reduction in production caused by depletion is comparable to the reduction resulting from lower temperatures caused by ventilation to avoid depletion, compensating the effect of depletion is much cheaper than making up the loss by heating.

RESULTS

In the paper (*Prior, S.A.. et al., 2011*), after reviewing the available literature on CO2, a number of priority objectives for future research were provided regarding the need to breed or screen horticultural plant cultivars and species for increased drought tolerance; determination of the amount of carbon sequestered in soil by horticultural production practices to improve soil water holding capacity and help mitigate projected global climate change; determining the contribution of the horticultural industry to these projected changes by the flux of CO2 and other trace gases (ie nitrous oxide from fertilizer application and methane under anaerobic conditions) into the atmosphere; and determining how CO2–induced changes in plant growth and water relations will occur influences complex interactions with pests (weeds, insects and diseases).

Such data is necessary to develop best management strategies for the agriculture industry to adapt to future environmental conditions.

In the paper (*Luan, H. et al., 2021*), the results showed that organic amendments increased the organic C content and reduced the chemical, spectroscopic, thermogravimetric, and biological stability of organic C within soil aggregates relative to chemical fertilization alone. Within soil aggregates, the content of organic C was the highest in microaggregates and decreased in the order microaggregates > macroaggregates > silt / clay fractions. Meanwhile, organic C spectroscopic, thermogravimetric, and biological stability were the highest in silt/clay fractions, followed by macroaggregates and microaggregates. Moreover, the modified Walkley–Black method was not suitable for interpreting organic C stability at the aggregate scale due to the weak correlation between organic C chemical properties and other stability characteristics within the soil aggregates. This study showed that eight years of organic amendments improved the soil structure in a GVP system by inceasing the proportions of large macroaggregates and enhancing soil aggregate stability (MWD).

The results of paper (*Wanga, T.. et al., 2014*) show that the behaviour of membrane conforms to Langmuir model and its capacity reaches to 0.83 mol of CO2 per kilogram of sorbent. When the output CO2 concentration of the desorber is around 1000 ppm, desorption efficiency increases from 71.3% to 79.6% when the temperature is changed from 25°C to 40°C. Besides, based on the experiment of the uptake kinetics of plants under different light and different light intensity, energy consumption and techno–economic analysis of the system have been carried out.

In the study (*Lin, S, et al., 2021*), the results (Figure 3) revealed that the single application of nitrogen had no significant effect on soil CO2 flux. However, the addition of cake fertilizer significantly increased CO2 emissions through enhanced soil microbial biomass carbon (MBC). Additionally, CO2 emissions were directly proportional to the amount of carbon (C) in the fertilizer. All treatments were minor sinks for CH4 except for the treatment NR1. Specifically, the cumulative CH4 fluxes of NR1 and NR2 were significantly higher than rest of the three treatments, which implies that application of urea and oilseed rape cake reduced the capability of CH4 oxidation in tea soil. Structural equation models (Figure 4) indicated that soil CO2 flux is significantly and positively correlated with soil dissolved organic carbon, MBC and soil pH, while mineral nitrogen content was the main factor affecting CH4 flux. Overall, the application of oilseed rape cake increased the oxidation of CH4 and promoted soil C sequestration but inevitably increased the soil CO2 emissions.

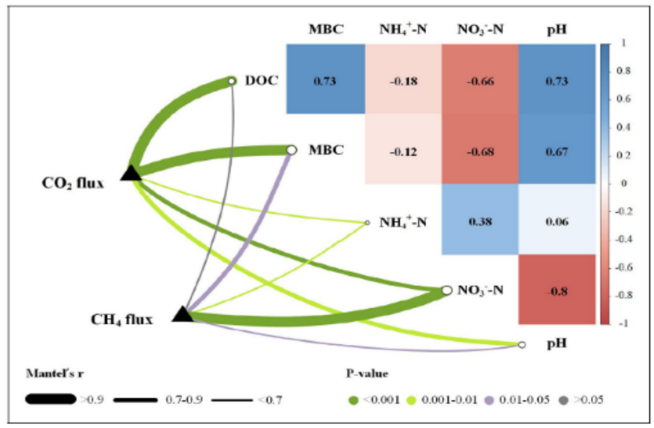

Figure 3 – Environmental drivers of CO2 and CH4 fluxes *(Lin, S, et al., 2021)*

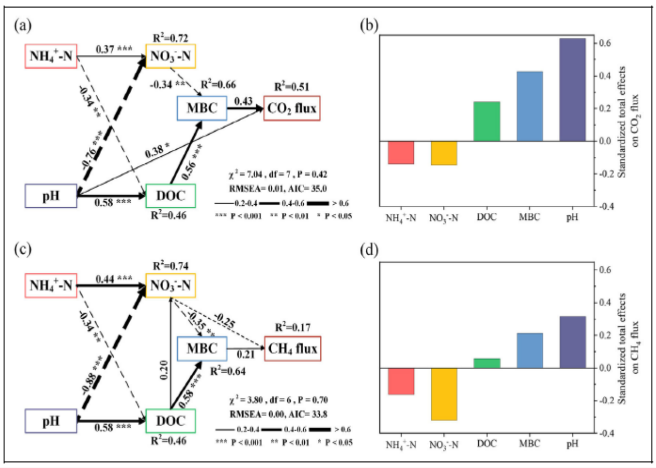

Figure 4 – The structural equation model (SEM) showing the effects of NH4 þ–N, NO3 –N, microbial biomass C (MBC), dissolved organic C (DOC), and pH on CO2 (A) and CH4 (C) fluxes (Lin, S, et al., 2021)

Pairwise comparisons of physicochemical property are shown, with a color gradient denoting Spearman's correlation coefficients. CO2 flux and CH4 flux were related to each environmental factor by partial (geographic distance–corrected) Mantel tests. Edge width corresponds to the Mantel's statistic for the corresponding distance correlations, and edge color denotes the statistical significance based on 9,999 permutations *(Lin, S, et al., 2021)*.

Standardized total effects of soil NH4 þ–N, NO3−–N, MBC, DOC, and pH on CO2 (B) and CH4 (D) fluxes as revealed by SEM. The width of the arrows indicates the strength of the standardized path coefficient. Solid lines represent positive path coefficients and dashed lines represent negative path coefficients. R2 values represent the proportion of the variance explained for each endogenous variable *(Lin, S, et al., 2021)*.

In the papier *(Baoa, J. et al., 2018)* the greenhouse gas emission reduction potential of CEPS technology for urban greenhouse industry consisted of two components: net CO2 sequestered from the air by plants through photosynthesis and CO2 displaced from the natural gas combustion source (Figure 5). For every ton of CO2 captured from the air, one CO2 from the natural gas combustion source will be displaced. A fraction of this ton of CO2 injected into the greenhouse will also be fixed by the plants, depending on the plant growth rate and the residence time of the air in the greenhouse. In general, more than one ton of net CO2 reduction will be achieved for each CO2 captured by the adsorption column. In order to quantify the net CO2 reduction, a full life cycle analysis will be carried out in the future.

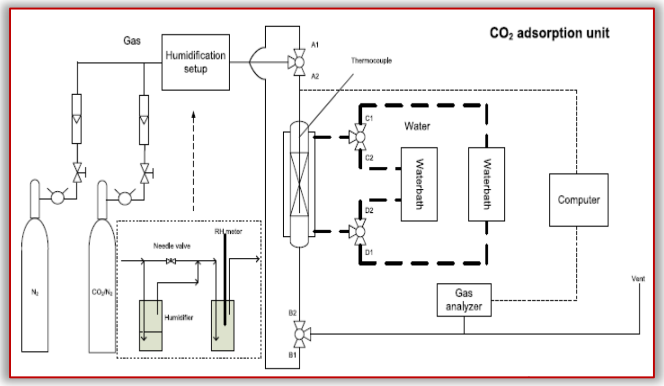

Figure 5 – Process diagram of CO2 adsorption and desorption unit with humidification unit (Baoa, J. et al., 2018)

In the papier *(Stanghellini, C., et al., 2010)*, they found that the optimal CO2 enrichment depends on the margin between crop growth value and cost of CO2 supply. Trying to determine the optimum concentration by experiment is not feasible because the economic value of enrichment is not constant but varies with solar radiation through photosynthesis rate and with the ventilation rate in the greenhouse through the loss of CO2. The optimal CO2 reference value depends on several influences: the effect of CO2 on photosynthetic assimilation rate, fruiting and to the vegetative structure, the distribution of photosynthate in subsequent harvests, and the price of fruit at those harvests, in addition to the amount of CO2 used, greenhouse ventilation rate and CO2 price.

CONCLUSIONS

In general, increased CO2 increases plant growth growth (both above and below ground) and improves plant water relations (reduces transpiration and increases WUE). Agricultural practices such as fertilization considerably influence soil greenhouse gas fluxes. Basic research on the response of various horticultural species to future levels of atmospheric CO2 may become crucial to breeding or screening horticultural plant cultivars and species for increased drought tolerance as a result of predicted changes in precipitation role models.

How CO2–induced changes in plant growth and water relations will affect complex interactions with pests (weeds, insects, and diseases) is an area of scarce research not only for horticulture, but for plants in general.

Moisture swing adsorption technology is used to capture CO2 from the atmosphere and provide it to the greenhouse. In the absence of artificial supplies of carbon dioxide in the greenhouse environment, the CO2 absorbed during photosynthesis must ultimately come from the external environment through the ventilation openings.

The concentration of CO2 within the greenhouse must be lower than that outside in order to obtain inward flow. Since potential assimilation is heavily dependent on carbon dioxide concentration, assimilation is reduced, whatever the light level or crop status.

The ventilation of the greenhouse implies a trade–off between ensuring inflow of CO2 and maintaining an adequate temperature within the greenhouse, particularly during sunny days.

All this information is necessary to develop at its best management strategies for the agricultural industry to successfully adapt to future environmental changes.

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