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CO2 ENRICHMENT AND HYDROPONICS IMPACT ON TOMATO GROWTH IN GREENHOUSES

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Abstract

The aim of this study was to investigate the impact of CO2 enrichment combined with hydroponics on tomato growth within greenhouse environments. The research focused on assessing how elevated carbon dioxide levels, when coupled with hydroponic cultivation, influence the growth parameters and yield of tomato plants. The study aimed to provide insights into the potential synergies between CO2 enrichment and hydroponics to optimize greenhouse tomato production. The research employed a controlled experimental design, implementing CO2 enrichment techniques alongside hydroponic cultivation methods. The study monitored various growth parameters, including plant height, leaf area, flowering patterns, fruit development, and overall yield. Data collection involved regular measurements and observations throughout the growth phases of the tomato plants. One notable result of the study was the positive impact of CO2 enrichment in conjunction with hydroponics on tomato growth. The enhanced availability of carbon dioxide contributed to increased photosynthetic activity, promoting greater vegetative growth, and ultimately leading to improved fruit yield. The combination of elevated CO2 levels and hydroponic systems demonstrated a synergetic effect, highlighting the potential for optimizing greenhouse conditions to enhance tomato cultivation. In conclusion, this research suggests that integrating CO2 enrichment with hydroponics can be a promising strategy for boosting tomato growth and yield in greenhouse settings. The findings contribute valuable insights for greenhouse farmers and researchers aiming to optimize cultivation practices for increased productivity and resource efficiency in tomato production.

Keywords: Carbon dioxide, daily growth, greenhouse, tomato

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1. Introduction

The changing earth's atmosphere results in increasing the global CO2 emissions. More carbon dioxide is released into the atmosphere than natural processes can remove, as a result the amount of carbon dioxide in the atmosphere increases every year. In 2021 the level of it rebounded and reached 414.72 parts per million after decreasing 5.4% in 2020 (Andrew & Peters, 2021; Arneth et al., 2017; Friedlingstein et al., 2022). Such increase in primary carbon (C) source will affect plant metabolism, growth, and development (fertilizing effect), especially under favorable water and nutrient conditions (Ainsworth et al., 2008; AbdElgawad et al., 2016). A reasonable number of papers has reported the importance of (C) being captured from industrial processes instead of being emitted to the environment and then pumped underground, usually at depths of 1 km or more, to be stored into depleted oil and gas reservoirs, coalbeds or deep saline aquifers. Also, it can be used to produce commercially marketable products. However, such storage of carbon has been found to be impractical due to technical issues. Other forms of CO2 utilization are still under investigation, one of which is utilization of CO2 as a fertilizer in greenhouses (Butz & Tsatsenko, 2019; Putc & Snezhkov, 2021; Stepuro et al., 2021). Carbon is the primary energy source and building block for plant tissues, and if plants can take up more carbon for growth and development it would help to contribute into the tackling global warming by utilizing significant amounts of CO2 (Al-Traboulsi et al., 2013; Beaubien et al., 2008).

The responses of plants to a high CO2 soil environment have been examined by some studies. They reported that plants exposed to high soil CO2 showed inhibited growth (Pakhomova et al., 2020). This might be because the high concentration of CO2 influences on soil microbes and structure. However, other studies have implied that in high CO2 concentration soils, a plant growth might be affected by reduced O2 or other trace gases such as H2S and CH4 (Nair et al., 2021). In general, it is suggested that high concentration of soil CO2 itself might be toxic to pant growth in a variety of plant species, but assumptions of CO2 toxicity in hydroponic system has not been sufficiently proved (He et al., 2019).

2. Problem Statement

The problem statement identifies key gaps in understanding optimal growth conditions for plants in greenhouses, specifically focusing on the insufficient research regarding the impact of elevated carbon dioxide (CO2) concentrations on the physiological reactions of the tomato cultivar Merlis. Additionally, the statement highlights the lack of clarity regarding the interaction between CO2 levels and other environmental factors like radiation and temperature in influencing plant growth. This problem statement sets the stage for the research to address these gaps and contribute to a more comprehensive understanding of greenhouse cultivation for tomato plants.

3. Research Questions

The research questions guide the investigation into the effects of elevated carbon dioxide (CO2) concentration, radiation, and temperature on the growth and productivity of the tomato cultivar Merlis in a greenhouse setting. The questions specifically address the influence of elevated CO2 on daily growth

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and final biomass, the impact of radiation on growth and biomass under increased CO_2 levels, and the interactive effects of temperature, CO_2, and radiation on the overall performance of the tomato cultivar Merlis. These questions help structure the study and provide a framework for systematic inquiry into the specified aspects of greenhouse cultivation.

4. Purpose of the Study

The primary objective of this study is to explore the impact of elevated carbon dioxide (CO_2) concentration on the physiological reactions of the tomato cultivar Merlis within a greenhouse context. Additionally, the research seeks to analyze the interplay between heightened CO_2 levels, radiation, and temperature. By delving into these aspects, the study aims to enhance comprehension of how these factors influence the growth and productivity of the tomato cultivar. The ultimate goal is to contribute insights that can be applied to refine greenhouse cultivation practices, ultimately leading to increased crop yields.

5. Research Methods

This study employs a comprehensive set of research methods to investigate the impact of elevated CO_2 concentration on tomato cultivar Merlis in a greenhouse setting.

Firstly, the greenhouse complex itself serves as a crucial experimental setup. The high-tech facility, located in Grozny, the Chechen Republic, spans 8.99 hectares and incorporates advanced technologies such as rail and trolley systems, hydroponic heating, and computer-based automation. Utilizing four identical crop-growing compartments and one germination compartment, this complex provides controlled environmental conditions essential for the study.

A second significant method involves the specific experiment conducted within one compartment of the greenhouse using stonewool slabs as crop-specific substrates. The choice of cultivar Merlis, known for its technical characteristics, adds precision to the investigation. The experiment, spanning two growing seasons and lasting for ten months, involves continuous monitoring of CO_2 levels. Drip irrigation is employed, and the compartments are strategically oriented and spaced to optimize plant growth.

Continuously measuring the CO_2 levels stands as the third key method in this research. Monitoring CO_2 concentrations throughout the two growing seasons (2018-19 and 2020-21) allows for a detailed understanding of its variations and interactions with other environmental factors. The controlled enrichment of each stonewool slab with CO_2 through four pipes below each crop ensures a meticulous examination of the physiological reactions of tomato cultivar Merlis to elevated CO_2 concentration.

6. Findings

The findings of this study shed light on the complex interactions between elevated CO_2 concentration, environmental factors, and the growth of tomato cultivar Merlis in a greenhouse environment.

Firstly, the experiment revealed that elevated CO_2 concentration positively influences the daily growth and final biomass of tomato cultivar Merlis. The plants exhibited accelerated growth rates and

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increased biomass accumulation when exposed to higher levels of CO_2, indicating the potential for enhanced productivity under elevated CO_2 conditions.

Secondly, the impact of radiation on plant growth under elevated CO_2 concentration was also investigated. It was observed that radiation levels interact with CO_2 concentration to influence the daily growth and final biomass of tomato cultivar Merlis. Optimal radiation levels, coupled with elevated CO_2, resulted in the most significant growth enhancements, highlighting the importance of optimizing environmental conditions for maximum productivity (Mentsiev et al., 2019; Strogonova & Novikova, 2020).

Lastly, the study examined the role of temperature in modulating the effects of CO_2 and radiation on plant growth. Temperature variations were found to significantly affect plant responses to elevated CO_2 and radiation levels. Higher temperatures, particularly during the warm summer months, exacerbated the positive effects of CO_2 enrichment and radiation on plant growth, further enhancing productivity.

Overall, these findings underscore the intricate interplay between CO_2 concentration, radiation, and temperature in influencing the growth and productivity of tomato cultivar Merlis in greenhouse conditions. Understanding these dynamics is crucial for optimizing greenhouse cultivation methods and increasing crop yields in a changing climate.

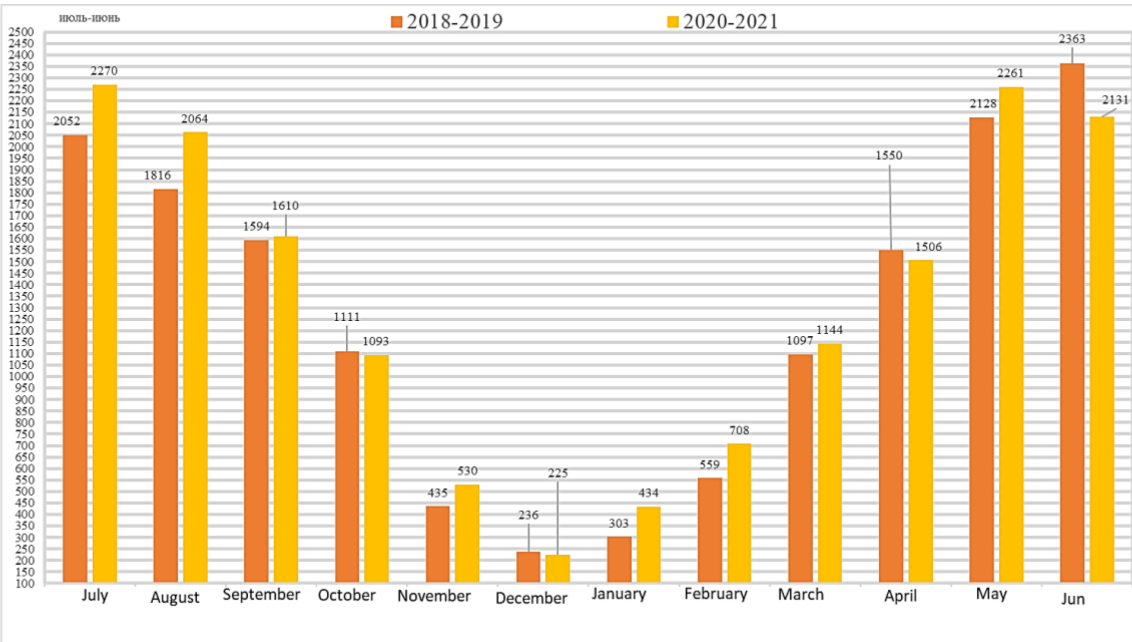

Figure 1. Average daily radiation by months J/cm2

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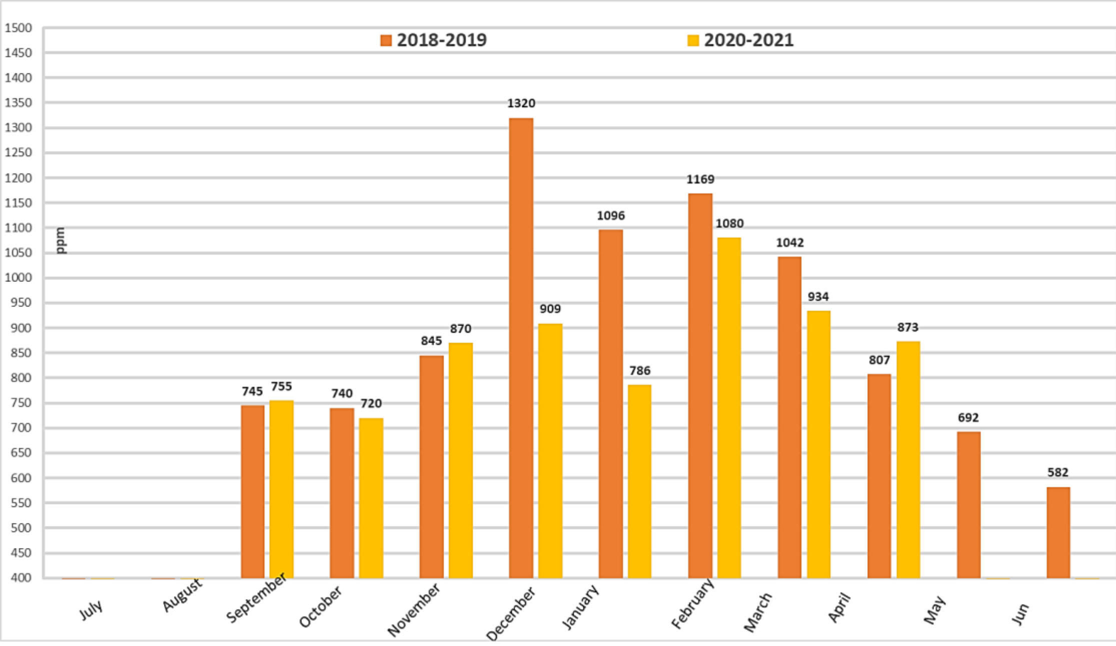

Figure 2. Average daily level of CO2 ppm

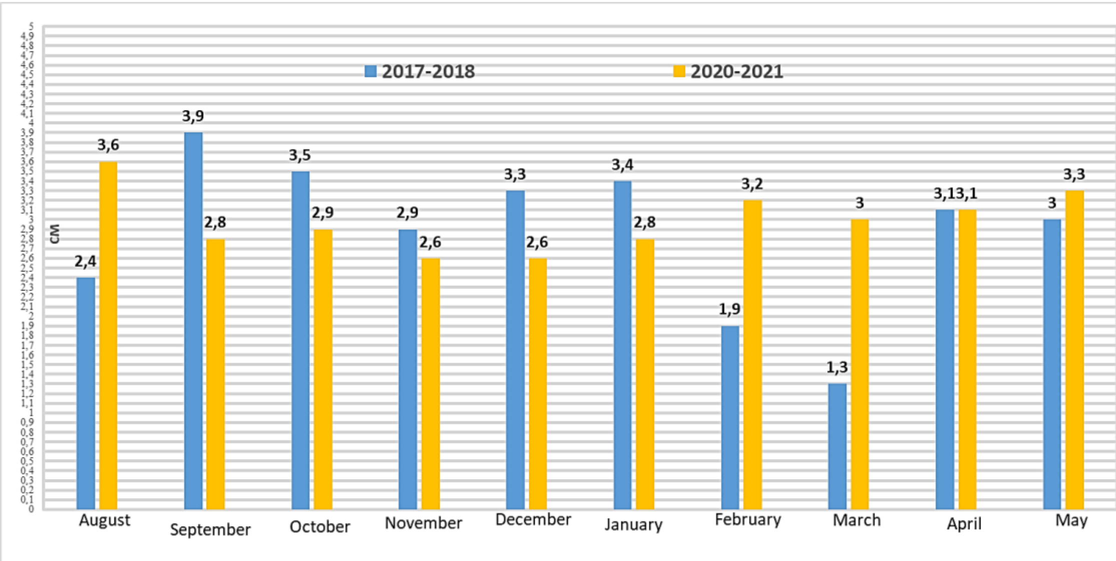

Figure 3. Average daily growth of tomato

We observed the effects of high CO2 concentration on plants growth. From figure 3 it can be seen that the average daily growth of tomato is between the 2,4 and 3,9 cm in both growing periods, except the February and March of 2018-19 year, where the daily growth is recorded the lowest 1,9 and 1,3 cm respectively. A clear positive relationship between high concentration of CO2 and increase in daily growth is not seen. The positive relationship is recorded in year 2018-19 in December and January, where the concentration of CO2 was 1 320 and 1 096 parts per million respectively, and the daily growth was 3,3 and 3,5 cm respectively. However, in the next two months of the same year the level of CO2 supplied to the crop slightly lowered, reached at 1 169 ppm in February and 1 042 ppm in March, which, in turned, resulted in reduction of daily growth more than twice in February and almost three times in March. The possible reason for such dramatic decrease in daily growth despite high concentration of CO2 and daily

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radiation (Figure 1), could be plants' indirect effects. Such assumption is supported by the daily growth of 3,2 and 3 cm in year 2020-21, while the CO2 concentration was only slightly lower in February and March of 2020-21 compared to the year 2018-19 (Figure 2 and 3).

High CO2 and daily radiations levels also induced positive changes in daily growth of tomato in April of both growing years. There is a same daily growth of tomato in both growing years reaching 3,1 cm with almost the same level of CO2 supplied and daily radiation. It is interesting to note that the highest daily growth of tomato in year 2018-19 is recorded in September (3,9 cm), while the concentration of CO2 is almost twice lower in this month than in December and lower by 351 ppm in comparison with January and the radiation in September reached at 1 594 J/cm2 is higher more than six times compared to December (236 J/cm2) and more than five times compared to January (303 J/cm2).

7. Conclusion

In conclusion, the investigation into the impact of elevated CO2 concentration on the growth and development of tomato cultivar Merlis in a greenhouse setting yielded nuanced results. Contrary to a straightforward positive correlation, the study did not establish a consistent and unequivocal relationship between high CO2 concentration and increased daily growth. The crops experienced varying responses across different months, with some showing an augmentation in daily growth under high CO2 levels, while others exhibited a decrease. It's important to note that the study did not account for the intricate interactions between elevated CO2, temperature, and radiation, representing a limitation in the research design.

Furthermore, the experiment maintained consistent nutrient availability, herbicide, and pesticide application throughout the two growing seasons, emphasizing the need for comprehensive investigations considering additional environmental factors. The complexities unveiled in this study emphasize the necessity for further research to delve into the responses of diverse plant species to elevated CO2 levels, temperature variations, and radiation exposure. Understanding these interactions will be crucial for shaping effective strategies to enhance plant productivity in greenhouse environments subjected to changing climatic conditions.

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