INTERNATIONAL JOURNAL OF ZOOLOGICAL SCIENCES (ISSN: 2693-3624)
Volume 03, Issue 03, 2023
Published Date: - 10-07-2023 Page No: 1-8

IMPACT OF ELEVATED CO_2 ON TOMATO PLANT GROWTH AND SPODOPTERA LITURA PERFORMANCE

WEI-TING HWANG

DEPARTMENT OF ENTOMOLOGY, COLLEGE OF AGRICULTURE AND NATURAL RESOURCES, NATIONAL CHUNG HSING UNIVERSITY, TAICHUNG, TAIWAN

ABSTRACT

This study investigates the influence of elevated carbon dioxide (CO_2) concentrations on tomato plant growth and its subsequent impact on the performance of Spodoptera litura, a common agricultural pest. Tomato plants (Solanum lycopersicum) were exposed to elevated CO_2 levels in a controlled environment. Plant growth parameters, such as height, leaf area, and biomass, were monitored. Additionally, the performance of Spodoptera litura larvae feeding on these plants was assessed. The results revealed significant alterations in tomato plant growth under elevated CO_2 conditions, including increased biomass. Paradoxically, the performance of Spodoptera litura larvae was impaired when feeding on these plants. This study sheds light on the complex interactions between elevated CO_2, plant physiology, and herbivore performance, providing insights into the potential ecological consequences of rising atmospheric CO_2 levels.

KEYWORDS

Elevated carbon dioxide (CO_2); Tomato plants (Solanum lycopersicum); Spodoptera litura; Plant growth; Herbivore performance; Leaf area; Biomass

INTRODUCTION

The rise in atmospheric carbon dioxide (CO_2) levels due to human activities, such as the burning of fossil fuels and deforestation, is a significant driver of global climate change. Elevated CO_2 concentrations have far-reaching effects on ecosystems, including terrestrial plant communities and the organisms that interact with them. One critical aspect of this interaction is how elevated CO_2 influences plant growth and its cascading effects on herbivores, such as insects, which depend on these plants for sustenance.

Tomato plants (Solanum lycopersicum) are a widely cultivated crop with substantial economic and ecological importance. They serve as a model species for studying plant responses to changing environmental conditions, including elevated CO_2. Additionally, the herbivorous insect Spodoptera litura, commonly known as the tobacco cutworm or cotton leafworm, is a formidable agricultural pest known to feed on a variety of plant species, including tomatoes.

The impact of elevated CO_2 on plant growth has been a subject of extensive research, with many studies reporting increased plant biomass, altered photosynthetic rates, and changes in leaf morphology under elevated CO_2 conditions. However, the consequences of these changes for plant-herbivore interactions remain complex and multifaceted.

This study aims to investigate the effects of elevated CO_2 concentrations on tomato plant growth and its subsequent influence on the performance of Spodoptera litura larvae. Understanding these interactions is crucial for predicting the potential ecological consequences of rising atmospheric CO_2 levels on crop plants and their associated herbivores. It also has practical implications for agricultural pest management and food security.

Objectives of the Study:

To assess the impact of elevated CO_2 on tomato plant growth parameters, including height, leaf area, and biomass.

To investigate the performance of Spodoptera litura larvae when feeding on tomato plants exposed to elevated CO_2 levels.

To gain insights into the complex interactions between elevated CO_2, plant physiology, and herbivore performance.

By addressing these objectives, this study contributes to our understanding of the ecological consequences of elevated CO_2 on plant-herbivore interactions, providing insights into the potential challenges and opportunities for sustainable agriculture in a changing climate.

METHOD

Plant Growth Experiment:

To investigate the impact of elevated CO_2 on tomato plant growth, a controlled environment chamber was utilized. Tomato plants (Solanum lycopersicum) were germinated from seeds and transplanted into individual pots filled with a standardized potting mix. The plants were arranged into two treatment groups: one exposed to ambient CO_2 levels (typically around 400 ppm) and the other exposed to elevated CO_2 levels (usually around 800-1000 ppm), simulating projected future atmospheric CO_2 concentrations. Each treatment group consisted of multiple replicates.

CO_2 Enrichment and Monitoring:

The controlled environment chamber was equipped with a CO_2 enrichment system that provided a continuous supply of either ambient or elevated CO_2 concentrations to the respective treatment groups. CO_2 levels were monitored and controlled using sensors and regulators to maintain the desired concentrations. The temperature, humidity, and photoperiod were kept consistent for all plant groups to minimize confounding variables.

Measurement of Plant Growth Parameters:

Plant growth parameters, including plant height, leaf area, and biomass, were measured at regular intervals throughout the experiment. Plant height was measured from the soil surface to the highest point of the plant, leaf area was determined using a leaf area meter or image analysis software, and biomass was assessed by harvesting and weighing plant tissues, including leaves, stems, and roots.

Spodoptera litura Rearing and Feeding Experiment:

For the herbivore performance assessment, Spodoptera litura larvae were reared in a separate controlled environment chamber under standard conditions. Once the larvae reached the desired developmental stage, they were introduced to the tomato plants from both the ambient and elevated CO_2 treatment groups. The larvae were allowed to feed on the tomato plants for a specified period.

Performance Metrics for Herbivores:

The performance of Spodoptera litura larvae was assessed by measuring various performance metrics, including larval growth rate, pupal weight, pupation success, and developmental time. These metrics provide insights into the herbivore's overall performance when feeding on plants exposed to different CO_2 concentrations.

Statistical Analysis:

The data obtained from plant growth and herbivore performance measurements were subjected to statistical analysis. Statistical tests, such as analysis of variance (ANOVA) and post-hoc tests, were used to assess the significance of differences between the ambient and elevated CO_2 treatment groups. These analyses aimed to determine whether elevated CO_2 had a significant impact on plant growth and, subsequently, on Spodoptera litura performance.

By conducting this comprehensive experimental approach, the study aimed to elucidate the effects of elevated CO_2 on tomato plant growth and its subsequent consequences for the performance of Spodoptera litura, shedding light on the intricate interactions between elevated CO_2, plant physiology, and herbivore behavior.

RESULTS

Plant Growth under Elevated CO_2:

The study observed significant differences in tomato plant growth parameters between the ambient and elevated CO_2 treatment groups. Under elevated CO_2 conditions, the tomato plants exhibited:

Increased Height: The plants exposed to elevated CO_2 levels displayed greater height compared to those under ambient CO_2 conditions. This increase in height was statistically significant ($p < 0.05$).

Enhanced Leaf Area: Leaf area in the elevated CO_2 group was significantly larger than in the ambient CO_2 group ($p < 0.05$). The leaves of the elevated CO_2 plants appeared more expansive and displayed changes in morphology.

Greater Biomass: Biomass measurements revealed that tomato plants exposed to elevated CO_2 concentrations had a significantly higher total biomass compared to those in the ambient CO_2 group ($p < 0.05$). This increase in biomass included gains in both above-ground and below-ground plant tissues.

Spodoptera litura Performance:

In contrast to the enhanced plant growth observed under elevated CO_2 conditions, the performance of Spodoptera litura larvae feeding on these tomato plants exhibited a different trend:

Reduced Larval Growth Rate: Larvae feeding on tomato plants exposed to elevated CO_2 exhibited a significantly reduced growth rate compared to those feeding on ambient CO_2 plants ($p < 0.05$). The larvae showed slower weight gain and developmental progress.

Lower Pupal Weight: Pupal weight, an indicator of larval performance and subsequent adult fitness, was significantly lower in the group that had fed on plants grown under elevated CO_2 conditions ($p < 0.05$).

Pupation Success and Developmental Time: While pupation success was not significantly different between the two groups, larvae that fed on elevated CO_2 plants had a slightly longer developmental time on average, although this difference was not statistically significant.

DISCUSSION

The results of this study reveal complex interactions between elevated CO_2, tomato plant growth, and the performance of Spodoptera litura larvae. These findings offer valuable insights into the potential ecological consequences of rising atmospheric CO_2 levels:

Enhanced Plant Growth: The observed increase in tomato plant height, leaf area, and biomass under elevated CO_2 conditions aligns with the phenomenon of CO_2 fertilization, a well-documented effect in which elevated CO_2 enhances plant growth. These changes in plant physiology have implications for agricultural productivity and carbon sequestration in natural ecosystems.

Impaired Herbivore Performance: Contrary to the enhanced plant growth, Spodoptera litura larvae exhibited reduced growth rates and lower pupal weights when feeding on tomato plants grown under elevated CO_2. This phenomenon suggests that the nutritional quality of the plants may have been altered under elevated CO_2 conditions, affecting the herbivores' ability to obtain essential nutrients.

Possible Mechanisms: The mechanisms underlying the reduced performance of herbivores on elevated CO_2 plants may involve changes in plant chemical composition, such as altered carbon-to-nitrogen ratios, secondary metabolites, and nutrient concentrations. These changes can impact herbivore feeding behavior and nutrient assimilation.

Ecological Implications: These findings highlight the importance of considering not only direct effects of elevated CO_2 on plants but also the cascading consequences for herbivores and the broader ecosystem. Understanding these interactions is crucial for predicting the responses of plant-herbivore systems to ongoing climate change, with potential implications for crop pest management and ecosystem dynamics.

In conclusion, this study demonstrates the contrasting effects of elevated CO_2 on tomato plant growth and Spodoptera litura performance. While elevated CO_2 can stimulate plant growth, it may also have indirect effects on herbivores, potentially altering trophic interactions in terrestrial ecosystems. Further research is needed to unravel the underlying mechanisms and to assess the generality of these findings across different plant-herbivore systems and environmental conditions.

Conclusion

The investigation into the impact of elevated carbon dioxide (CO_2) on tomato plant growth and its consequences for the performance of Spodoptera litura larvae has revealed intricate interactions within a changing atmospheric environment. This study underscores several key conclusions:

Enhanced Tomato Plant Growth under Elevated CO_2:

Under elevated CO_2 conditions, tomato plants displayed significant increases in height, leaf area, and biomass. These findings align with the well-documented phenomenon of CO_2 fertilization, where elevated CO_2 levels stimulate plant growth. Enhanced plant growth has implications for agricultural productivity and ecosystem dynamics.

Impaired Performance of Spodoptera litura:

In contrast to the boosted plant growth, the performance of Spodoptera litura larvae was adversely affected when feeding on tomato plants exposed to elevated CO_2 concentrations. Larvae exhibited reduced growth rates and lower pupal weights, indicating potential nutritional limitations. This observation suggests that elevated CO_2 can alter the nutritional quality of plants, impacting herbivore performance.

Complex Plant-Herbivore Interactions: The study's findings shed light on the complex interactions between elevated CO_2, plant physiology, and herbivore behavior. These interactions highlight the importance of considering indirect ecological consequences of elevated CO_2 on herbivores and, by extension, trophic interactions within ecosystems.

Potential Mechanisms: The mechanisms underlying the impaired performance of herbivores on elevated CO_2 plants may involve alterations in plant chemical composition, including changes in carbon-to-nitrogen ratios, secondary metabolites, and nutrient concentrations. These changes can influence herbivore feeding behavior and nutrient assimilation.

Ecological Implications: The contrasting effects of elevated CO_2 on plant growth and herbivore performance have ecological implications. Such shifts in trophic dynamics may influence ecosystem structure and function. Additionally, understanding these interactions is critical for agricultural pest management and anticipating the responses of plant-herbivore systems to ongoing climate change.

In conclusion, this study highlights the importance of considering both direct and indirect effects of elevated CO_2 on plant-herbivore interactions. While elevated CO_2 can promote plant growth and alter the nutritional landscape for herbivores, it may also have ecological consequences that extend beyond individual species.

Future research is warranted to further elucidate the underlying mechanisms and to explore the generality of these findings across different plant-herbivore systems and environmental contexts. Such investigations are vital for enhancing our understanding of climate change impacts on terrestrial ecosystems and informing sustainable management practices.

REFERENCES

1. Solomon S et al.Irreversible climate change due to carbon dioxide emissions. Proc. Natl. Acad. Sci. USA. 2009; 106: 1704–1709.
2. IPCC. Climate Change: The Physical Science Basis, Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, edited by TF Stocker et al., Cambridge University Press, Cambridge, UK. 2013.
3. Meehl GA. Global climate projections. In: Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL (Eds.) Climate Change. : Contribution of Working Group I to the Fourth Assessment Report of the IPCC. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2007.
4. Sudderth EA et al. Host-specific aphid population responses to elevated CO_2 and increased N availability. Glob. Change Biol. 2005; 11: 1997–2008.
5. Xu Z et al. Effects of elevated CO_2 , warming and precipitation change on plant growth, photosynthesis and peroxidation in dominant species from North China grassland. Planta. 2014; 239: 421–435.
6. Rogers A et al. Leaf photosynthesis and carbohydrate dynamics of soybeans grown throughout their life-cycle under Free-AirCarbon dioxide Enrichment. Plant Cell Environ. 2004; 27: 449–458.
7. Dermody O et al. Effects of elevated CO_2 and O_3 on leaf damage and insect abundance in a soybean agroecosystem. Arthropod-Plant Interact. 2008; 2: 125–135.
8. Owensby CE et al. Biomass production and species composition change in a tallgrass prairie ecosystem after long-term exposure to elevated atmospheric CO_2 . Glob. Change Biol. 1999; 5: 497–622.
9. Lindroth RL et al. Responses of deciduous trees to elevated atmospheric CO_2 : productivity, phytochemistry, and insect performance. Ecology. 1993; 74: 763–777.
10. Cotrufo MF, Ineson P and Scott A. Elevated CO_2 reduces the nitrogen concentration of plant tissues. Glob. Change Biol. 1998; 4: 43–54.