

Climate Change Impacts on Secondary Metabolites of Plants

(Image: <https://elements.envato.com/school-laboratory-with-microscope-and-green-plants-7GBD5JF>)

Overview

As an **Undergraduate Biological Sciences** teacher, you can use this set of computer based tools to enable students in developing a comprehensive understanding about the core topics of **plant pathology**, **mycology**, **plant response to biotic stress** and **medicinal botany**. Plants being immobile, synthesize a diversity of chemical compounds predominantly for their protection against predators and microbes. These compounds are either secreted or accumulated within the biosynthetic cells; and are classified as **primary and secondary metabolites**.

Primary metabolites are essential for basic photosynthesis, growth and development of plants whereas, secondary metabolites include pigments, antibiotics, toxins, alkaloids, scents that are synthesized in different parts of the plants according to their utilization. They play an important role in defense mechanisms, act as important signaling molecules under different environmental stresses and thus play a crucial role in adaptation of plants to changing climatic conditions. A rapid alteration in climate affected the biosynthesis and accumulation of secondary metabolites in plants.

This lesson will help students understand the importance of **secondary metabolites**, its **biosynthesis** and their role in plant defense responses. Secondary metabolites are not only important for plants to defend, but are highly useful to humans for their medicinal uses such as anti-diabetic, anti-cancerous, and anti-viral compounds; anti-ageing properties, anthelmintic properties, immunosuppressant attributes, cholesterol lowering effects and many more. Students will also learn how climate change disrupts the delicate balance of the ecosystems, altering the temperature and precipitation patterns; thereby, affecting the production of secondary metabolites in plants. These compounds, critical for defense and adaptation, may undergo shifts, potentially impacting plant resilience and their interaction with other organisms.

Thus, the use of this lesson plan allows you to integrate the teaching of a climate science topic with a core topic in the **Biological Sciences**.

Learning Outcomes

The tools in this lesson plan will enable students to:

1. Understand and comprehend the definition of secondary metabolites in plants and how they contribute to various ecological and physiological functions.
2. Identify key environmental factors affected by climate change such as temperature, light, water availability and nutrients that can influence the synthesis of secondary metabolites.
3. Analyze the intricate interactions between climate change factors and CO₂ levels.
4. Understand and predict potential outcomes of these interactions on plant health, defense mechanisms and interactions with other organisms considering the broader ecological implications.
5. Connect with broader themes such as biodiversity loss, ecosystem resilience.
6. Apply gained knowledge to real world scenarios by assessing the impact of climate change on specific plant species and their secondary metabolite profiles, fostering critical thinking and problem solving skills.
7. Develop skills for understanding the importance of secondary metabolites in the plant world, for their essential survival, growth and developmental patterns.
8. Engage in discussions on possible strategies for the mitigation of negative effects of climate change on secondary metabolite production, promoting a proactive approach to environmental challenges and sustainable management.
9. Foster a sense of responsibility towards environmental stewardship.

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About

Grade Level	Undergraduate, Graduate
Discipline	Biological Sciences
Topic(s) in Discipline	Life Sciences, Botany, Photosynthesis, Biotic Stress, Plant Defense Mechanism, Mycology, Medicinal Botany, plant response to Biotic stress
Climate Topic	Climate Change and Food Security; Climate and the Biosphere
Location	Global
Access	Online
Language(s)	English
Approximate Time Required	55-60 minutes
Mapped Sustainable Development Goal(s), apart from 4 and 13	15: Life on Land

Step-by-step User Guide

Here is a step-by-step guide to using this lesson plan in the classroom/laboratory. We have suggested these steps as a possible plan of action. You may customize the lesson plan according to your preferences and requirements.

1	<p>Introduce the topic through a video lecture</p> <p>Video (17 mins)</p>	<p>Use the video titled “Plants Secondary Metabolites” by Bio Minerals Technologies, Inc. to introduce students to the basics of plant pigments and its types – as primary and secondary metabolites. This video describes secondary metabolites in detail as organic compounds synthesized by the plants that are not only essential for their immediate growth and reproduction, but also play a crucial role in defense mechanisms against herbivores, pathogens and environmental stressors. It also provides details about alkaloids, terpenoids, phenolics and sulfated amino acids; their subdivisions; and provides sufficient examples. The students will also gain understating about their medicinal and economic value in flavor, fragrance and pharmaceutical industries.</p> <p>This can be accessed here.</p>
2	<p>Introduce the impact of CO₂ rise on Secondary Metabolites in Plants</p> <p>Reading (15 mins)</p>	<p>Use the reading titled, "Influence of Carbon Dioxide Enrichment on Accumulation of Secondary Metabolites in Plants" by Shahram Sharafzadeh and Kourosh Ordoorkhani of the Islamic Azad University, Iran to discuss the effects of CO₂ levels in the accumulation of secondary metabolites. This review paper states that the CO₂ levels have been increasing after the industrial revolution. Increased CO₂ concentration increases the rate of photosynthesis and activity of Rubisco enzyme. The paper highlights many conclusions stated by various researchers, that the effect of CO₂ on plant biomass, stomatal conductance, and various secondary metabolites of a</p>

		<p>particular plant. The paper concludes that the concentration of secondary metabolites is influenced by various environmental factors such as light, temperature, soil water and nutrients as they may interact with CO₂ levels. It suggested that the concentration of secondary metabolites in plants is intricately shaped by an interplay of environmental factors. Light intensity and quality dictate the rate of photosynthesis, affecting the production of precursors for these compounds. Temperature fluctuations can modify enzymatic activity, either boosting or inhibiting the synthesis of specific metabolites. Soil water availability and nutrients content influence a plant's metabolic pathways, indirectly influencing secondary metabolite production. Importantly, these environmental cues can synergize with atmospheric CO₂ levels, potentially altering the balance of metabolite synthesis due to CO₂ role in photosynthetic and metabolic processes.</p> <p>This can be accessed here.</p>
3	<p>Further discuss the impact of Climate Change on Plants Secondary Metabolites</p> <p>Reading (20 mins)</p>	<p>Use the reading titled “Climate Change Effects on Secondary Compounds of Forest Trees in the Northern Hemisphere” by Jarmo K. Holopainen, et al. to discuss the effects of climatic changes on plant secondary metabolites. The reading states that secondary metabolites are produced by several metabolic pathways and many of them are specific for a few plant genera or families. In forest ecosystems the full-grown trees constitute the majority of plant biomass and are capable of producing significant amounts of secondary metabolites. There was strong evidence that major climate change factors, such as CO₂ increase and warming, have contradictory effects on the main groups of secondary metabolites for example CO₂ increases phenolic compounds in foliage, but limits terpenoids in foliage and emissions; however warming decreases phenolic compounds in foliage but increases terpenoids foliage and emissions. The secondary metabolites may help trees to adapt to a changing climate and to pressure from current and invasive pests and pathogens.</p> <p>This can be accessed here.</p>

Questions

Use this Lesson Plan to help the students to understand and find answers to:

1. What are plant metabolites? What are different types of metabolites available in plants?
2. What are different chemical classes of plant secondary metabolites?
3. Write explanatory notes on
 - a. Alkaloids
 - b. Terpenes
 - c. Defense responses in plants
 - d. Organic compounds in plants
 - e. Flavonoids
4. Differentiate between primary and secondary metabolites of plants?
5. Explain various pathways governing the synthesis of metabolites in plants?
6. What are different direct and indirect climate change ways of affecting the productivity of secondary metabolites?
7. How fluctuating climatic conditions are impacting the productivity of secondary metabolites in plants?
8. What are the threats to plants for their survival due to changing climate patterns?

Additional Resources

1.	Reading (Time – 20 min)	The reading material highlights the interactive effects of heat shock and elevated carbon levels on the isoprene secondary metabolism in <i>Salix</i> sp This can be accessed here .
2.	Reading (Time – 15 min)	The book chapter discusses the different classes of secondary metabolites produced by plants, their classification in different families and their importance in medicinal plants. This can be accessed here .
3.	Reading (Time – 15 min)	The book chapter discusses the altered expression of secondary metabolites and its correlation with plant evolution. It also focuses on the environmental factors triggering the evolutionary response along with the ecological roles of each metabolite in plants. This can be accessed here .

Credits

1.	Video “17 Plant Secondary Metabolites”	Bio Minerals Technologies, Inc. , Youtube
2.	Reading "Influence of Carbon Dioxide Enrichment on Accumulation of Secondary Metabolites in Plants"	By Shahram Sharafzadeh and Kouros Ordoookhani, Islamic Azad University
3.	Reading “Climate Change Effects On Secondary Compounds Of forest In Trees In Northern Hemisphere”	By Jarmo K. Holopainen, Virpi Virjamo , Rajendra P. Ghimire , James D. Blande , Riitta Julkunen-Tiitto and Minna Kivimäenpää https://doi.org/10.3389/fpls.2018.01445
4.	Additional resources	Frontiers , intechopen.com
5.	Additional Resources	Science Direct, by Akhileshwar Kumar Shrivastava, Pragyan Mishra and Amit Kumar Mishra 2021.