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THE EFFECTS OF CLIMATE CHANGE ON PLANT GROWTH: A REVIEW

Debarati Ghosh

Department of Botany, Midnapore College (Autonomous), Midnapore, Paschim Medinipur, West Bengal, Pin 721101, India.

Research Scholar, Dept. of Botany, CMJ University, G. S. Road, Jorabat, Ri-Bhoi District, Meghalaya, Pin-793101

Abstract:

Climate change refers to long-term changes in Earth's temperature trends and is mostly brought on by human activities like the burning of fossil fuels and deforestation. This phenomenon has negative effects on the environment and puts ecosystems through previously unheard-of challenges. Rising global temperatures are a consequence of greenhouse gas emissions, which have a number of negative effects on the ecosystem. A few of these changes include the polar ice caps melting, the sea level rising, the frequency and intensity of extreme weather events, and changes in precipitation patterns. Such alterations disturb a delicate ecological balance by harming several ecosystems and species. Climate change also contributes to the loss of biodiversity by shrinking and making many plants and animals' habitats less suitable. Recognising the urgency and magnitude of the actions required to decrease its consequences requires an understanding of the history of climate change and how it affects the ecosystem. By carefully examining the scientific evidence and taking into account the cascading effects of climate change, we can develop effective strategies to address this global problem.

Keywords: Climate Change, Plant Growth, biodiversity, environment, ecosystem, sustainable development.

Introduction

The burning of fossil fuels for transportation, energy generation, and industrial operations is one human activity that contributes to greenhouse gas emissions, primarily carbon dioxide (CO₂). These emissions cause the greenhouse effect by trapping heat in the atmosphere of the Earth. As a result, global temperatures have been steadily rising over the last century. The environmental implications of climate change are many and wide-ranging. One of the most noticeable repercussions is the melting of the polar ice caps and glaciers. Sea levels increase as a consequence, putting at risk populated coastal and low-lying regions as well as critical infrastructure. Seawater intrusion into freshwater sources, coastal erosion, and the loss of crucial coastal ecosystems like coral reefs and mangroves are some of the consequences that are related to one another. Extreme weather events including hurricanes, heatwaves, droughts, and heavy rain have become more frequent and more severe as a result of climate change. Both natural and human systems might be badly harmed by these events. Flooding and landslides result in the destruction of agricultural fields, the death and destruction of dwellings, and the disruption of essential services like water distribution and transportation.

variations in precipitation patterns brought on by climate change cause variations in the distribution of rainfall. Some regions have lengthier droughts while others see more rain and flooding. These changes may have a severe effect on ecosystems, affecting the availability of water resources for plants, animals, and human populations. Additionally, they disrupt the delicate ecological balance and have an impact on the variety, distribution, and migratory patterns of all plant and animal species. Climate change also poses a hazard to a range of ecosystems, including forests, grasslands, wetlands, and marine areas. Disrupting ecological relationships and species interdependencies leads to changes in species composition and abundance. Because of habitat loss and fragmentation caused on by shifting precipitation patterns and rising temperatures, many plant and animal species are in decline. This loss of biodiversity compromises ecosystems' ability to offer essentials like water purification, pollination, and carbon sequestration in addition to reducing their adaptability and resilience. Understanding the history of climate change and its consequences on the environment is crucial for the development of efficient mitigation and adaptation methods. A thorough analysis of scientific research and data is required to gauge the severity of the problem and identify the most vulnerable ecosystems and species. (Elmer, W. and White, J. C.; 2018) By comprehending the intricate web of interactions and feedback loops involved, policymakers, researchers, and communities can work together to develop sustainable practises, reduce greenhouse gas emissions, conserve natural resources, and foster resilience in the face of ongoing and upcoming environmental changes.

Importance of studying the effects of climate change on plant growth

In light of the many environmental issues facing the world today, research into how climate change affects plant development is of utmost importance. In addition to being necessary for preserving life as we know it on Earth, plants are also fundamental for maintaining ecological balance and delivering key ecosystem services. Temperature, precipitation, and atmospheric CO₂ concentrations are only a few of the components that climate change directly affects and are essential for plant development. It is crucial to comprehend the complex connections between climate change and plant development for a number of reasons. As primary producers and the backbone of the whole food chain, plants are the basis of terrestrial ecosystems. Climate changes have a big influence on plant physiology, phenology, and distribution, which ultimately affects how ecosystems are built and operate. Understanding these impacts may help us understand how ecosystem stability and biodiversity are impacted by how climate change changes species composition, interactions, and plant community dynamics. (Foyer, C. H. et al.; 2020)

Second, good plant development is crucial for the industries of horticulture, agriculture, and forestry. Changes in temperature, precipitation patterns, and severe weather brought on by climate change may have a significant impact on agricultural yields, food security, and economic stability. Researchers may identify susceptible crops, create adaption plans, and create sustainable agricultural practises by researching how climate change affects plant development, which will help to lessen its effects on food supply. Furthermore, determining carbon dynamics and mitigating climate change need a knowledge of how climatic change affects plant development. By storing carbon in their biomass and securing atmospheric CO₂ via photosynthesis, plants are essential components of the world's carbon cycle. The rate of carbon absorption and storage by plants may be impacted by changes in environmental factors such rising CO₂ levels, changed temperature patterns, and altered precipitation patterns. By analysing these impacts, scientists may develop more accurate models and forecasts of the trajectory of atmospheric CO₂ concentrations in the future, which will help them develop solutions for carbon sequestration and climate change mitigation. Additionally, researching how climate change affects plant development offers important insights into possible ecological feedback loops and cascading consequences on other creatures. Herbivores, pollinators, and other dependent species may be impacted by changes in plant growth patterns, which can disrupt ecological relationships and perhaps cause changes in community structure. (Fu, L. et al.; 2020) The operation of natural and agricultural ecosystems depends on ecosystem services including pollination, seed distribution, and soil fertility, all of which have wider ecological repercussions.

Overview of plant physiology and growth processes

Understanding the complex interplay between climate change and plant responses requires a basic understanding of plant physiology and growth mechanisms. The study of a plant's physiological activities, including photosynthesis, respiration, transpiration, and nutrient intake, is known as plant physiology. Through changed environmental circumstances, climate change affects various physiological functions. Temperature is one of the main elements impacted by climate change. Temperature increases may hasten plant metabolism, which may have an impact on growth rates, reproductive development, and general plant production. On the other hand, excessive heat events may cause heat stress, which weakens physiological processes and harms cellular structures. To forecast how climate change will affect plant growth and production, it is crucial to understand how temperature changes affect plant physiology.

The physiology of plants is significantly impacted by variations in precipitation patterns. For instance, drought conditions may cause water stress, which lowers plant transpiration rates and impairs nutrient absorption. Reduced plant growth, withering, and even plant death may result from this. Increased rainfall, on the other hand, may affect nutrient availability, root growth, and soil moisture levels. It is possible to learn more about plants' adaptation processes and the potential effects of climate change on plant growth and survival by examining the physiological reactions of plants to variations in precipitation patterns.

Additionally, changes in atmospheric CO₂ levels have an impact on plant physiology as a result of climate change. The "CO₂ fertilisation effect" is the capacity of elevated atmospheric CO₂ concentrations to stimulate photosynthesis and promote plant development. However, this reaction may differ depending on other environmental parameters like temperature and nutrient availability. The efficiency of water usage and stomatal conductance may both be impacted by high CO₂ levels, which can also have an impact on plant water relations and transpiration rates. (Dhankher, O.P. and Foyer, C.H.; 2018) Predicting the impacts of climate change on carbon dynamics and plant responses requires an understanding of the intricate relationships between atmospheric CO₂ concentrations and physiology.

Impact of temperature changes on plant growth

Understanding the effects of climate change on plant physiology requires taking into account the influence of temperature fluctuations on plant development. In order to shape plant development, metabolism, and general growth processes, temperature is a critical factor. It is critical to investigate how these changes impact plant physiological responses and subsequent growth patterns when global temperatures increase as a result of climate change.

Germination, blooming, fruiting, and photosynthesis are only a few of the crucial processes of plant growth and development that are influenced by temperature. Each of these processes has an ideal temperature range, and variations from these ranges may significantly affect plant performance. Increased growth rates and output may result from metabolic activities like respiration and photosynthesis being accelerated by warmer temperatures. However, excessive heat, particularly during high heat events, may cause plants to experience heat stress, which can lead to cellular damage, decreased photosynthetic efficiency, and slowed development. It is crucial to evaluate each plant species' unique reactions to temperature changes since different plant species display various levels of temperature sensitivity and tolerance. While certain plants may be adapted to flourish in warmer climates, others may find it difficult to withstand rising temperatures. To better understand how plants respond to temperature variations, whether they are resilient or vulnerable, it is important to look into the processes behind these reactions, such as modifications in gene expression, enzyme activity, and membrane integrity.

The timing and length of temperature fluctuations may also have a big effect on how quickly plants develop. For instance, changes in temperature regimes may have an impact on when plant life cycles like bud burst, blooming, and leaf senescence occur phenologically. Temperature variations may interfere with crucial ecological processes like pollinator availability and seed dissemination if they produce a mismatch between plant growth time and ambient circumstances. As a result, these disturbances could have a domino impact on ecosystem functioning, population dynamics, and plant reproductive success. In order to affect plant development, temperature also interacts with other environmental elements. For instance, temperature has an impact on plant transpiration and

evaporation rates, which in turn affect water availability and loss. Warmer temperatures have the potential to speed up evaporation, thereby aggravating plant water stress, especially in areas where climate change-related lower precipitation or protracted droughts are occurring. By affecting soil microbial activity, nutrient solubility, and root physiology, temperature changes may also have an impact on nutrient availability and absorption. As a result, changes in temperature regimes may have an indirect impact on plant development by changing the uptake and utilisation of nutrients. (Kukul, MS. and Irmak, S.; 2018)

Foreseeing the effects of climate change on agricultural output and ecosystem dynamics requires an understanding of how temperature fluctuations affect plant development. Depending on the precise temperature ranges and plant species involved, rising temperatures may affect plant development in both positive and negative ways. While in certain circumstances higher temperatures might promote faster growth and greater output, chronic exposure to high temperatures can also cause heat stress in plants and impair their ability to function. Changes in temperature regimes may also influence ecosystem services like pollination and seed distribution, disturb phenological synchronisation, change species diversity, and more. Once again, knowing the effects of temperature variations on plant development is crucial to understanding how climate change will affect plant physiology. Germination, blooming, and photosynthesis are just a few of the components of plant growth and development that may be impacted by variations in temperature regimes. Even while certain plants may have adaptations that allow them to flourish in warmer climates, too much heat can cause heat stress and impede plant development. Changes in temperature regimes may also impair vital ecological interactions and have a domino effect on ecosystem health and plant reproduction. (Melandri, G. et al.; 2020) We may learn more about how resilient or vulnerable plants are to climate change by examining the processes behind their responses to temperature changes. We can then design ways to lessen the negative impacts that climate change has on agricultural output and ecosystem stability.

Effects of altered precipitation patterns on plant growth

knowledge the repercussions of climate change on plant physiology requires a knowledge of how shifting precipitation patterns affect plant development. Plant water availability, nutrient transport, and general physiological functions are all significantly influenced by precipitation. It is crucial to consider how these differences impact plant growth and development when precipitation patterns, including changes in rainfall intensity, frequency, and distribution, are altered by climate change. The emergence of drought conditions is one of the main effects of changed precipitation patterns. Reduced precipitation, higher evaporation rates, or a combination of the two may all lead to drought stress. Photosynthesis, transpiration, and nutrient absorption are just a few of the physiological activities that plants need on a sufficient amount of water for. Reduced stomatal opening and transpiration rates under drought-like circumstances might affect a plant's capacity to absorb nutrients and perform photosynthesis. As a consequence, leaf withering may happen, plant development may be slowed, and overall output may be negatively impacted. On the other hand, changes to precipitation patterns may result in more rain and more intense precipitation events. Although an increase in rainfall might reduce water stress, too much precipitation can hinder plant development. Heavy rains may result in soil erosion, nitrogen loss, and waterlogging, all of which may hamper nutrient absorption and inhibit root activity. Long-term soil saturation may cause oxygen deprivation in root zones, which can harm roots and slow plant development. In addition, prolonged periods of heavy rain may result in increased runoff, which can remove important topsoil and minerals and harm plant development and soil fertility. Alterations to precipitation patterns may also affect when plants grow and mature. Numerous plant species have developed life cycles that coincide with regular rainfall patterns. This synchronisation may be broken by variations in precipitation timing, which results in a mismatch between plant phenology and the surrounding environment. For instance, if rainfall happens sooner or later than normal, it could not coincide with the best time for seed germination or blossoming, which might have an impact on the viability of reproduction. The availability of pollinators and seed dispersion, two ecological interactions that are essential for plant reproduction and species survival, may be affected in a cascade manner by these phenological variations. Furthermore, changes in precipitation patterns may have an impact on the availability and cycling of nutrients in ecosystems. Nutrients are transported from the atmosphere to the soil through precipitation, where they are then made accessible to plants. The delivery of nutrients to plants may be impacted by altered precipitation patterns, notably decreasing rainfall, which may result in nutritional imbalances

and deficits. In turn, this may have an effect on a plant's ability to grow, develop, and use nutrients generally. Predicting the impacts of climate change on ecosystems and agricultural systems requires an understanding of how shifting precipitation patterns affect plant development. The availability of water, the capacity to absorb nutrients, and the effectiveness of plant reproduction may all be significantly impacted by changes in precipitation regimes. Conditions of drought may cause water stress, stunted plant development, and even plant death. On the other side, an abundance of rain may cause root damage, nutrient loss, and soil erosion. Changes in precipitation timing may also affect ecological relationships and throw off phenological synchronisation. (Akrami, M. and Arzani, A.; 2019)

Researchers may learn more about how plants adapt to changes in precipitation patterns and how vulnerable they are to climate change by examining the physiological reactions of plants to these changes. Using this information, solutions for strengthening plant resilience may be developed, such as choosing drought-tolerant plant types, enhancing water management procedures, and putting soil conservation measures in place. Additionally, knowing how changed precipitation affects nitrogen availability may assist agricultural systems' nutrient management techniques be optimised. As a result, in the context of climate change and plant physiology, the consequences of changed precipitation patterns on plant development are important issues. Plant water availability, nitrogen uptake, phenology, and general plant growth and development may all be impacted by changes in precipitation regimes. Water stress and diminished growth are two effects of drought, whereas waterlogging and nutrient loss are two effects of excessive rains. Understanding these consequences is essential for creating mitigation plans for the negative effects of climate change on agricultural sustainability, ecosystem stability, and plant yield.

Influence of atmospheric CO₂ concentration on plant growth

When examining the effects of climate change on plant physiology, the impact of atmospheric CO₂ concentration on plant development is a crucial factor to take into account. The main substrate for photosynthesis, which is how plants turn CO₂ and sunlight into energy-dense carbohydrates, is CO₂. It is critical to investigate how rising atmospheric CO₂ levels impact plant growth and development as a result of human activities like the combustion of fossil fuels. The "CO₂ fertilisation effect," which is caused by increased CO₂ availability, which speeds up photosynthesis and increases plant biomass production, may have a fertilising impact on plant development. The bulk of agricultural crops and several plant species are C₃ plants, which are especially prone to this impact. C₄ plants, which are used to greater CO₂ concentrations, could not respond as strongly.

The impact of CO₂ fertilisation on plants may cause a number of physiological changes. Higher CO₂ levels allow plants to retain reduced stomatal conductance, which lowers transpirational water loss. Plants can preserve water under high CO₂ environments thanks to their higher water usage efficiency. Furthermore, increased CO₂ levels may have an impact on how nutrients are taken up and distributed by plants. Increased rates of photosynthetic activity and the synthesis of carbohydrates may affect nutritional requirements and change patterns of nutrient uptake. For instance, plants may allocate more nutrients to biomass above ground, such as leaves and stems, while decreasing the nutrients allocated to roots. Although the CO₂ fertilisation effect may promote plant development, there may be restrictions or trade-offs to take into account. Different plant species and environments might react differently to high CO₂ levels. According to several research, the CO₂ fertilisation impact weakens with time when other elements including nutrition availability and interactions with other environmental elements enter the picture. Additionally, other elements like temperature, the availability of water, and nutrient restrictions may have an impact on how plants react to high CO₂. (UNICEF, 2018)

Furthermore, not all plant species or environments may experience the same effects of increased CO₂ on plant development. The competitive interactions between plant species may be impacted by changes in plant growth, which might change the community's composition and species abundance. On the biodiversity and ecological dynamics, this may have a domino effect. It is essential to comprehend how atmospheric CO₂ concentration affects plant development in order to forecast how ecosystems, agriculture, and carbon dynamics will be impacted by climate change. The CO₂ fertilisation effect may have a big impact on how productive plants are, how secure our food supply is, and how much carbon is being sequestered. However, it is crucial to take into account the possible drawbacks and trade-offs connected to increasing CO₂, as well as how those factors interact

with other environmental factors. For the purpose of developing methods for the sustainable management of plant-based systems in the context of climate change, more study is required to better understand the long-term impacts of increasing CO₂ on plant growth and ecosystem functioning.

Plant Responses to Climate Change

There are many different ways that plants react to climate change, including phenological changes in their life cycles, changes in their geographic range and distribution, adjustments to their productivity and biomass, and changes to the richness and composition of their species. Plants adapt their phenology in response to changing climatic patterns, with changes seen in blooming, fruiting, and leaf senescence. Additionally, when different climatic conditions are adapted to, it is possible for plant species' geographic ranges and distributions to change. The dynamics and interconnections of ecosystems may be impacted by these shifts in plant distribution. Climate change may also affect the productivity and biomass of plants, with certain species having faster growth rates than others owing to things like water stress. Last but not least, changes in climate may affect the variety and composition of plant species, which may have an impact on how communities and ecosystems operate. In order to evaluate the effects of climate change on plant ecosystems and adopt efficient conservation and management measures, it is essential to comprehend these reactions.

Climate change exerts critical impacts on plant species, leading to extensive repercussions for ecosystem dynamics and biodiversity. Let's explore six examples that vividly illustrate these effects:

Range Constriction: Rising temperatures cause the contraction of the habitat range for alpine wildflowers, resulting in their diminished survival prospects as preferred habitats become unsuitable or vanish entirely.

Range Extension: Certain coastal plant species benefit from warmer temperatures and increased precipitation, allowing them to colonize new coastal regions with improved conditions, expanding their range and altering local biodiversity patterns.

Disrupted Ecological Interactions: Shifting plant distributions disrupt the interactions between alpine wildflowers and pollinators, jeopardizing the availability of food and shelter for dependent organisms and potentially leading to cascading effects on the composition and functioning of plant communities.

Phenological Shifts: Climate change alters the timing of critical life cycle events, such as blooming, fruiting, and leaf senescence. For instance, a species of fruit tree may experience a shift in blooming timing, affecting pollinator synchronization and reducing the availability of nutrients required for successful reproduction.

Reduced Health and Productivity: Variations in temperature and precipitation patterns negatively impact the health and productivity of plants. Examples include slower growth rates, heightened susceptibility to pests and diseases, and disrupted carbon and nitrogen cycling, all of which compromise the overall vitality of plant populations.

Cascading Effects on Ecosystem Resilience: The aforementioned impacts on plant species have far-reaching consequences for other organisms that rely on them for food, shelter, and pollination. The resulting disruption to plant communities directly affects ecosystem resilience and functioning, potentially leading to imbalances in biodiversity and reduced overall ecosystem stability.

Implications for Ecosystems and Agriculture

Numerous effects of climate change on ecosystems and agriculture must be carefully considered. Climate change may disturb biological relationships in natural ecosystems. For instance, variations in temperature and precipitation patterns may impact when plants blossom, influencing the number of pollinators available and perhaps causing pollination mismatches. Furthermore, changes in temperature might result in the loss of specialised habitats, jeopardising the species that rely on such areas. Furthermore, biodiversity is being threatened by climate change. Some species may find it difficult to adapt or move to better habitats when ecosystems change quickly, leading to population decreases or even extinctions. Loss of biodiversity may have a domino effect on an ecosystem's ability to cycle nutrients, transfer energy, and operate generally.

Climate change may have a significant impact on crop production and food security in agricultural systems. Crop growth and production may be impacted by variations in temperature, precipitation, and severe weather events. Droughts, floods, and heat waves may all harm crops, lower yields, and jeopardise food supply. These difficulties are especially worrisome in areas where agriculture is a vital source of subsistence and income. The effects of climate change on agriculture must be minimised, hence adaption measures are required. Improved irrigation methods, crop diversification, and the adoption of heat- and drought-tolerant crop types are some of the practises that farmers may employ. Furthermore, adopting sustainable farming methods that support soil health and water conservation may improve an agricultural system's adaptability to changing climatic circumstances. Therefore, climate change has significant effects on agriculture and ecosystems. The fragility of species and their habitats is highlighted by the disruption of ecological relationships and the decline in biodiversity in natural ecosystems. Crop yields and food security in agricultural systems are threatened by deteriorating climatic conditions. However, it is feasible to lessen the effects of climate change on agricultural systems by strategic adaptation strategies, such as the adoption of sustainable farming methods and the use of robust crop types. We may try to develop more resilient ecosystems and sustainable agriculture practises in the face of a changing climate by being aware of and addressing these concerns. (Bailey-Serres, J. et al.; 2019)

Mitigation and Adaptation Strategies

When it comes to tackling the effects of climate change on plant development and ecosystems, mitigation and adaptation techniques are essential. The purpose of mitigation strategies is to lower greenhouse gas emissions and lessen the effects of climate change. Carbon sequestration, which entails removing and storing carbon dioxide from the atmosphere, is one significant tactic. As carbon sinks and contributors to overall climate control, woods play a vital role in this respect. Agroforestry and sustainable agricultural methods also aid in lowering greenhouse gas emissions and promoting soil carbon storage. Sustainable land management practises. Building plant growth resilience in the face of shifting climatic circumstances is the main goal of adaptation techniques. A crucial strategy to improve plant adaptation is to breed robust plant types. In order to do this, crop types with characteristics like heat tolerance, drought resilience, and disease resistance must be chosen and developed. Farmers may lessen the hazards brought on by climate change by producing plants that can flourish in a variety of climatic conditions.

The use of precision agricultural methods is another adaptive option. This strategy makes use of cutting-edge technology to maximise agricultural output and optimise resource consumption, such as remote sensing, precision irrigation, and data-driven decision-making. Farmers may ensure effective resource utilisation and reduce the adverse effects of climate change on plant development by continuously monitoring soil moisture, nutrient levels, and plant health. This allows farmers to make educated choices and alter management practises.

We may endeavour to mitigate the negative impacts of climate change on plant growth and agriculture by combining mitigation techniques to reduce greenhouse gas emissions with adaptation tactics to improve plant resilience. These methods support food security and environmental sustainability in the face of climate change by fostering the development of sustainable and climate-resilient agricultural systems.

Conclusion

The vital functions that plants play in ecosystems, food supply, and environmental sustainability make it imperative to study how climate change affects plant development. Decision-making, adaption plans, and sustainable practises are all influenced by this information in order to lessen the effects of climate change. Changes in temperature have an effect on plant growth through affecting photosynthesis, blooming, and germination. Although some plants can adapt to greater temperatures, extreme heat may stress plants out and impede their development, which can harm ecological relationships and reproductive success. Water stress or nutrient loss may result from altered precipitation patterns because they have an impact on plant growth, fertiliser uptake, and water availability. Understanding these consequences is essential for reducing their negative implications on agricultural sustainability, ecological stability, and production. Crop yields, food security, and biodiversity are all under danger from climate change. However, these effects may be reduced by adaptation

strategies including robust crop types and sustainable agricultural techniques. Overall, being aware of how plants are affected by climate change makes it easier to design plans for a resilient and sustainable future.

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