forests

Editorial

Abiotic and Biotic Stress Cascades in the Era of Climate Change Pose a Challenge to Genetic Improvements in Plants

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Citation: Xiao, Y.; Wang, M.; Song, Y. Abiotic and Biotic Stress Cascades in the Era of Climate Change Pose a Challenge to Genetic Improvements in Plants. *Forests* **2022**, *13*, 780. https://doi.org/10.3390/f13050780

Received: 30 April 2022
Accepted: 14 May 2022
Published: 18 May 2022

Forest ecosystems are vast, second in expanse only to marine ecosystems. Prior to widespread deforestation, forests covered two-thirds of the Earth's surface. Forest ecosystems have high biological productivity and have the potential to maintain carbon and oxygen balances and mitigate the temperature increases associated with global climate change. However, climate change, which is primarily driven by anthropogenic greenhouse gas emissions, poses a severe challenge to such ecosystems [1]. The Intergovernmental Panel on Climate Change's (IPCC) Sixth Assessment Report (AR6) indicated that CO_2 concentrations have risen from approximately 280 ppm prior to the industrial revolution to approximately 410 ppm in 2019, and average temperatures between 2011 and 2020 were 1.09 °C higher than those of the preindustrial period (1850–1900). The frequency and intensity of extreme thermal events will significantly increase with each 0.5 °C increase in temperature. In addition, each 0.5 °C of warming will significantly alter precipitation regimes, increasing agricultural and ecological drought in some regions [1]. As climate risks continue to increase, forest ecosystems will reach their limits.

The effects of climate change are most apparent in terms of CO_2 concentrations, temperature, rainfall intensity, and the probability of extreme weather events. In particular, extreme heat, extreme drought and intense rainfall will become more frequent and widespread. In addition, a growing population will also contribute to the need to reduce the damage of low temperatures and saline–alkali to trees by using high latitude and saline–alkali lands. Of course, researchers have investigated the means by which trees resist such abiotic stresses. Stress alters numerous physiological processes, including photosynthesis and transpiration, as well as chlorophyll content, and plants transmit signals through ABA-dependent and ABA-independent pathways to synthesize transcription factors and promote the expression of stress-resistance genes. For example, MYB transcription factors are induced, and DREB transcription factors are produced under drought, salt, and low-temperature stress, thus enhancing resistance to these stresses. The analysis of molecular mechanisms in plants under stress has great practical value for improving stress resistance in trees. Nevertheless, studies need to consider the compound effects of such stresses in conjunction with climate change, as abiotic stresses operate at longer and more intense time scales. Although CO_2 policies have been introduced, they have not been effective. However, from the perspective of improving plant photosynthesis, higher CO_2 concentrations are not entirely negative, and the effects of changes in CO_2 concentrations may be particularly complex in perennial woody plants. Hence, it is important to better understand the regulatory mechanisms forest trees employ in response to multiple concurrent stresses. In addition, low-carbon energy policies have spurred the development of new energy sources, which may produce heavy metals (HMs), plastics, and radionuclides (Figure 1). Researchers have proposed using plants to absorb HMs from soil and have pointed to genetic improvements in perennial woody plants that can enhance such remediation efforts. Food safety is currently the subject of much attention, as plastic waste is released and degrades into microplastics and nanoplastics that accumulate in plants. One study explored the uptake and accumulation of nanoplastics in Arabidopsis thaliana and demonstrated that these contaminants inhibit plant growth [2]. How the accumulation of microplastics and nanoplastics may affect forests and the underlying physiological and molecular mechanisms involved have yet to be studied. Moreover, the effects of radionuclides on forest growth and development can be severe and lead to die offs. This is a topic that requires further research.

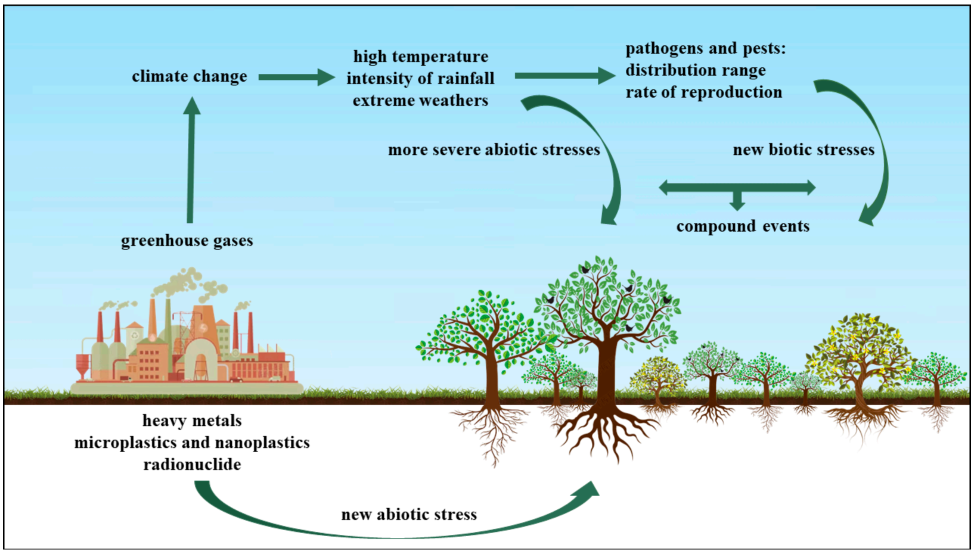

Figure 1. This picture shows the impact of human activities on climate change and new stresses. Climate change will affect temperature, intensify of rainfall and extreme weather, and environmental change will further affect the distribution range and reproduction rate of pathogens and pests. There may also be multiple abiotic stresses simultaneous compound events or biotic and abiotic stress simultaneous compound events.

Biotic stresses, such as pathogen and pest infestations, are also affected by changes in temperature and humidity. Warmer, more humid conditions tend to accelerate the development of pests and facilitate range expansions. Range expansions of beneficial rhizosphere microorganisms can benefit plants by improving their stress resistance and remediating polluted soils. However, the spread of pests is concerning. Adverse climatic conditions have preceded spruce budworm outbreak episodes, leading to tree mortality [3]. This implies that new pathogens and pests could emerge in areas where they have not previously occurred, increasing damage to trees. In addition, extreme weather events can trigger outbreaks of pathogens and pests. Models developed to predict future disease outbreaks [4,5] can be used to proactively plan for such events. When pathogenic bacteria infect plants, they release effectors into host cells that inhibit defense responses. However, plants can recognize these effectors and initiate an immune response, but the process by which the effectors target the host is not fully understood. The combined effects of abiotic and biotic stresses could cause massive mortality events. Essentially, interactions among multiple phenomena are expected to be more harmful to trees than a single phenomenon or event. Hence, it is important to understand the resistance mechanisms trees have to cope with concurrent biotic and abiotic stresses.

Global climate change will substantially impact forest ecosystems, which, as the largest carbon pool on Earth, plays a critical role in mitigating climate change. It is crucial to understand how climate change affects the growth and development of trees, how multiple concurrent stresses affect their regulatory mechanisms, and how trees regulate the effects of novel stresses. Exploring these issues requires ongoing work on forest genomes and the understanding of their complex regulatory network. Furthermore, new techniques can be applied to this end. For example, the bioaccumulation and transport of microplastics and nanoplastics have been studied in vegetables and other crops using europium chelate Eu-β-diketonate doped polystyrene particles with a diameter of 200 nm [6]; this tracer technique can also be used to study the effects of such plastics on perennial woody plants. In the future, such new technologies should be used to study tree stress to better understand how forests may respond to future challenges.

Author Contributions: Conceptualization, Y.S.; Investigation, Y.S.; writing—original draft preparation, Y.X.; Writing—Review and Editing, Y.S. and M.W.; Visualization, Y.X. and Y.S.; Supervision, Y.S.; All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest: The author declares no conflict of interest.

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