Effects of Ultraviolet-B Radiation and Its Interactions with Climate Change Factors on Agricultural Crop Growth and Yield

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Abstract Crops are often exposed to multiple factors of climate change including: (1) enhanced ultraviolet-B (UV-B) radiation, (2) elevated carbon dioxide concentrations (CO\textsubscript{2}), and (3) episodes of elevated temperatures and water stress during critical stages of crop development. Our understanding of crop responses to individual climate change stress factors has significantly advanced in recent years. However, crop responses to a combination of stress factors are less understood and need attention. In addition to direct effects on various physiological, growth, and yield traits of plants, the interaction of plants with biotic factors (particularly insects and pathogens) will play an important role in determining crop productivity. The objective of this chapter is to provide a summary of crop responses to UV-B, CO\textsubscript{2}, temperature, drought, and a combination of multiple stresses. Exposure to above ambient UV-B radiation decreases crop productivity through negative effects on photosynthesis, growth, dry matter production, yield, and grain quality. Elevated CO\textsubscript{2} often improves photosynthesis, growth, and yield of most crop species. Alternatively, exposure to both above optimum temperatures and water stress significantly decreases crop productivity and quality, particularly when stress occurs during sensitive stages (reproductive phase) of crop development. The positive effects of elevated (CO\textsubscript{2}) on photosynthesis and growth do not generally overcome the negative effects of UV-B radiation, elevated temperatures, or water stress on productivity and quality of grain crops. Crop species and cultivars within crop species vary in their responses to both individual and a combination of stress factors, suggesting a scope for genetic improvement. Further research should be focused on breeding for tolerance to multiple stresses of regional and local importance. An increased knowledge of crop responses to multiple stresses and genetics
may also improve crop simulation models resulting in a better understanding, prediction and management of crops in a changing environment.

**Keywords** climate change, crop growth and yield, drought stress, genetic variability, multiple abiotic stresses, temperature

### 14.1 Introduction

The growing population of today’s world (6.7 billion, U.S. Census Bureau, 2008) faces great challenges due to limited resources for the production of adequate amounts of food, fiber, feed, industrial products, and ecosystem services. As the global population increases by nearly 80 million each year, policies must be developed to ensure the needs of a future population of 8 billion by 2025 and more than 12 billion by 2050 (U.N. Population Division, 2008) are met. About 84% of this growth is expected to occur in developing countries. Since there is essentially no new arable land that can be cultivated, the increased food supply must primarily come from more intensive cultivation of existing arable land. Furthermore, with intensive agriculture, soil degradation will become a major concern. The world’s water resource is also finite, and the increased demands will result in reduced availability of water for agriculture. Urban communities do not generally give high priority to the preservation of agricultural resources, such as land and water. In many highly populated countries, food and fiber needs are being met by irrigating up to 75% of the arable land and introducing high yielding cultivars of most grain crops that have higher input use efficiency thus maximizing production. In addition, the benefits humans derive from natural ecosystems, such as marketable products and goods (i.e., timber, fish, pharmaceuticals), recreational opportunities (i.e., camping, boating, hunting, hiking, fishing), maintaining biodiversity, aesthetic and spiritual experiences, and other services (i.e., erosion control, water purification, carbon sequestration, oxygen production), are being threatened by the growing human population through habitat destruction and air and water pollution. In addition to these stresses, there is a threat of global climate change due to increased greenhouse gas concentrations in the atmosphere and the depletion of the ozone layer assumedly due to anthropogenic activities.

Climate change is not a new phenomenon. The planet’s climate has changed tremendously over geological time, and the changes are still occurring. However, what appears to be different is the possibility of a new driving force and the cause of the climate change. Changes that were observed over a geological time period now occur over a shorter time span, particularly since the beginning of the industrial revolution. Apparently, human activities are causing climate change. Concentrations of key anthropogenic greenhouse gases, such as carbon dioxide (CO$_2$), methane (CH$_4$), nitrous oxide (N$_2$O), and tropospheric ozone (O$_3$) have