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Effects of temperature increase and elevated CO_2 concentration, with supplemental irrigation, on the yield of rain-fed spring wheat in a semiarid region of China

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Abstract

A field experiment on rain-fed spring wheat (*Triticum aestivum*) was conducted at the Haiyuan Experimental Station (36°34′N, 105°39′E), in a semiarid region of China, during 2001–2003. According to the experimental design, the CO_2 concentration increased by 90 μmol mol^{-1} (from 360 to 450 μmol mol^{-1}), while the mean daily temperature, during the whole growth stage, increased 0.8 °C (from 14.3 to 15.1 °C) and 1.8 °C (from 14.3 to 16.1 °C). The results showed that the combination of a 450 μmol mol^{-1} CO_2 concentration and a 0.8 °C temperature increase stimulated rain-fed spring wheat yield by ~5.3%. The combination of a 450 μmol mol^{-1} CO_2 concentration and a 1.8 °C temperature increase, however, reduced wheat yield by ~5.7%. This combined effect on wheat yield presents an image of the climatic result of global changes over the next 30 years in semiarid regions of China. As an agronomic practice, supplemental irrigation of 30 mm may compensate for any loss of yield caused by climatic changes in the future. Furthermore, 60 and 90 mm supplemental irrigation improved wheat yield 3.8 and 10.1%, respectively. Consequently, in

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this region, supplemental irrigation (from 30 to 90 mm) may play a crucial role in maintaining rain-fed spring wheat yield affected by global climatic changes.

Keywords: Elevated CO_2 concentration; Rain-fed spring wheat; Supplemental irrigation; Temperature increase; Yields

1. Introduction

The CO_2 concentration of the Earth's atmosphere was stable for thousands of years, at approximately 280 μmol mol^{-1}, until the 1800s, when it began increasing exponentially. CO_2 concentration has increased steadily from 315 μmol mol^{-1} in 1957 to 362 μmol mol^{-1} in 1994 (Schimel, 1994). It is expected that CO_2 concentration will reach 450 μmol mol^{-1} in 2030, and 700 μmol mol^{-1} in 2050 (IPCC, 2001).

Global mean surface temperatures have increased 0.3–0.6 °C since the late 19th century. Scientists expect that global average surface temperatures will increase 0.6–2.5 °C over the next 50 years, and 1.4–5.8 °C during the next century, with significantly regional variation (IPCC, 2001). In the latest 100 years, average surface temperatures in China have increased 0.4–0.5 °C. It is predicted that, in China, average surface temperatures will increase ~1.7 °C in the next 30 years, and 2.2 °C over the next 50 years (Qin, 2003).

Because of global climatic changes, the annual average rainfall is decreasing in certain regions of the world (Eban, 1995). In semiarid areas of China, annual average rainfall decreased about 60 mm in the 1990s, compared with 1950s; meanwhile, annual average temperature increased ~0.9 °C. Owing to the temperature increase, the loss of soil moisture through evaporation had increased by 35–45 mm from the 1950s to 1990s. In this case, the water supply of rain-fed spring wheat (*Triticum aestivum*), including natural rainfall and soil water, showed a total decline of about 100 mm in the 1990s, in comparison with the 1950s (Xiao and Gen, 1999). In semiarid regions of China, however, there is strong evidence that annual average rainfall will remain stable in the next 30–50 years, as a result of climatic changes (Ma et al., 2003).

China will benefit from global climatic changes and crop yields are predicted to increase by about 25% if CO_2 concentration in the atmosphere is doubled (Parry, 1994). Nevertheless, there is now evidence that crop yields will, in fact, decrease by 5–10% in the next 30 years in China, as a result of climatic changes. In particular, the yields of wheat, rice and maize will be greatly reduced (Fu and Wen, 2002; Qin et al., 2002). Results are contradictory; as a result, in semiarid regions of China, the role global climatic changes will play in rain-fed spring wheat production is still unknown. Therefore, it is essential to clarify the most probable outcome of global climatic changes.

In many studies of crop response to elevated CO_2 concentration, the plant physical environment was generally maintained at a level for optimum growth (in a controlled environment chamber) (Melkonian et al., 1998). In this work, however, a FACE (free-air CO_2 enrichment) experiment, i.e. growing rain-fed spring wheat in fluctuating environmental conditions with elevated CO_2 concentration, was used to study the interaction between temperature increase and elevated CO_2 concentration on wheat yield.