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Response of bean cultures' water use efficiency against climate warming in semiarid regions of China

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ABSTRACT

Farm crop growing and high efficiency water resource utilizing are directly influenced by global warming, and a new challenge will be given to food and water resource security. A simulation experiment by farm warming with infrared ray radiator was carried out, and the result showed photosynthesis of broad bean was significantly faster than transpiration during the seedling stage, ramifying stage, budding stage, blooming stage and podding stage when the temperate was increased by 0.5–1.5 °C. But broad bean transpiration was faster than photosynthesis during the budding stage, blooming stage and podding stage when the temperature was increased by 1.5 °C above. The number of grain per hill and hundred-grain weight were significantly increased when the temperature was increased by 0.5–1.0 °C. But they significantly dropped and finally the yield decreased when the temperature was increased by 1.0 °C above. The broad bean yield decreased by 39.2–88.4% when the temperature was increased by 1.5–2.0 °C. The broad bean water use efficiency increased and then decreased with temperature rising. The water use efficiency increased when the temperature was increased by 1.0 °C below, and it quickly decreased when the temperature was increased by 1.0 °C above. In all, global warming in the future will significantly influence the growth, yield and water use efficiency of bean cultures in China's semiarid regions.

In the recent half a century, the climate of semiarid regions in Northwest China has experienced changes of high temperature, arid, warm winter, etc, thus the air temperature significantly increased, the rainfall generally decreased, and warming with drought became more and more distinct. Especially in the recent 30 years, drought and water deficiency were enlarged and aggravated, and drought was so severe and long lasting in some regions that it had never happened before. Climate change affects agriculture and water resource more and more significantly and seriously (Du et al., 2012). In the coming 50 years, farm crop growing and high efficiency water resource utilizing are directly influenced by global warming, and a new challenge will be given to food and water resource security (Ding et al., 2009). The increasingly severe drought has brought the arid agriculture a critical problem in rainwater resource availability research for utilizing the limited rainwater resource effectively (Zhang et al., 2005; Singh et al., 2014). Improving the water use efficiency is a key factor for continuously increasing the crop yield in arid regions in Northwest China. A lot of research was made by Chinese and foreign scholars for the effect of climate change on crop water availability. Ogaya and Peuelas (2003) found crops in arid and semiarid regions maintained a higher water availability to reduce the effect of water deficiency and enhance the competitiveness for moisture in drought. Tenhunen et al. (2002) researched and found that climate warming accelerated crop transpiration and soil moisture evaporation, and influenced the crop water use efficiency in arid and semiarid regions. Water use efficiency in the crop ecological system drops with the decrease of soil moisture, and it means the crop photosynthesis changes down by some other factors besides the stomatal factor. Zhao et al. (2007) researched and found that the net photosynthesis and stomatal conductance of leaves of spring wheat during the grain filling stage and milk stage in semiarid regions dropped and the transpiration increased with air temperature rising, the photosynthesis and dry substance accumulation were inhibited by climate warming, as a result, the crop water use efficiency was degraded.

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The soil fertility in China's arid and semiarid regions is seriously poor. Planting bean cultures which can fertilize the soil by the nitrogen fixation of rhizobia is an effective way for promoting the crop growth and improving the grain yield in China's semiarid regions. Continuous cropping or interplanting with bean cultures and gramineous cultures is a key planting mode in China's semiarid regions as it obviously increases the yield and improves the soil nitrogen availability. Broad bean is a great annual bean culture commonly planted in China's semiarid regions as it has a series of favorable biological properties widely adapted to the environment against coldness, droughts, waterlogging, plant diseases and insect pests, and is rich in nutrition. This paper uses the large farm infrared radiator warming method to realize a research of warming effect on broad bean water use efficiency and provide a scientific reference for improving the broad bean climatic adaptation and control measures.

1. About the base station

The experiment was made in Guyuan Experimental Station in a typical China's semiarid region at N35.14″–36.38″ and E105.20″–106.58″. The annual air temperature during 1960–2014 was 6.3 °C–10.2 °C and the multi-year mean air temperature was 7.9 °C. The air temperature distinctly rose in the recent 50 years and especially after 1998 (Fig. 1). The annual rainfall volume during 1964–2014 was 282.1–765.7 mm and the multi-year mean rainfall was 450.0 mm. The rainfall volume in the recent 50 years was distinctly decreasing. Wheat, broad bean and corns, etc are main crops matured once per year, and the region is a typical semiarid rainfall farming area.

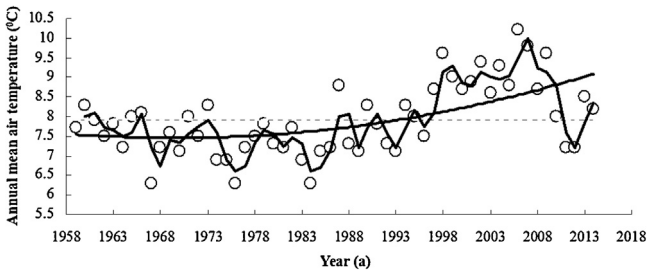

Fig. 1. Air temperature change in the semiarid Guyuan area during 1960–2014.

2. Experimental design and method

2.1. Simulated warming test

The research for warming effect on broad bean water use efficiency was done by field infrared radiator warming methods (Xiao et al., 2013). In December 2009 on the United Nations Climate Change Conference held in Copenhagen— the capital city of Denmark, it fixed target that the global warming amplitude in the coming 50 years will be controlled at 2.0–2.4 °C (Zheng, 2010). Therefore, the designed warming stages were 0 °C, 0.5 °C, 1.0 °C, 1.5 °C and 2.0 °C. Each plot in the experimental farm was 8 m^2 (2m × 4m) and plots were spaced for 3.0 m. Each plot was equipped with 2 infrared radiator warming tubes, and the support height was adjusted so that the warming pipe was spaced from the crop canopy height for 1.2 m. The warming pipe power was fixed according to the warming requirement and local air temperature. The infrared radiator warming pipe powers used in the experiment

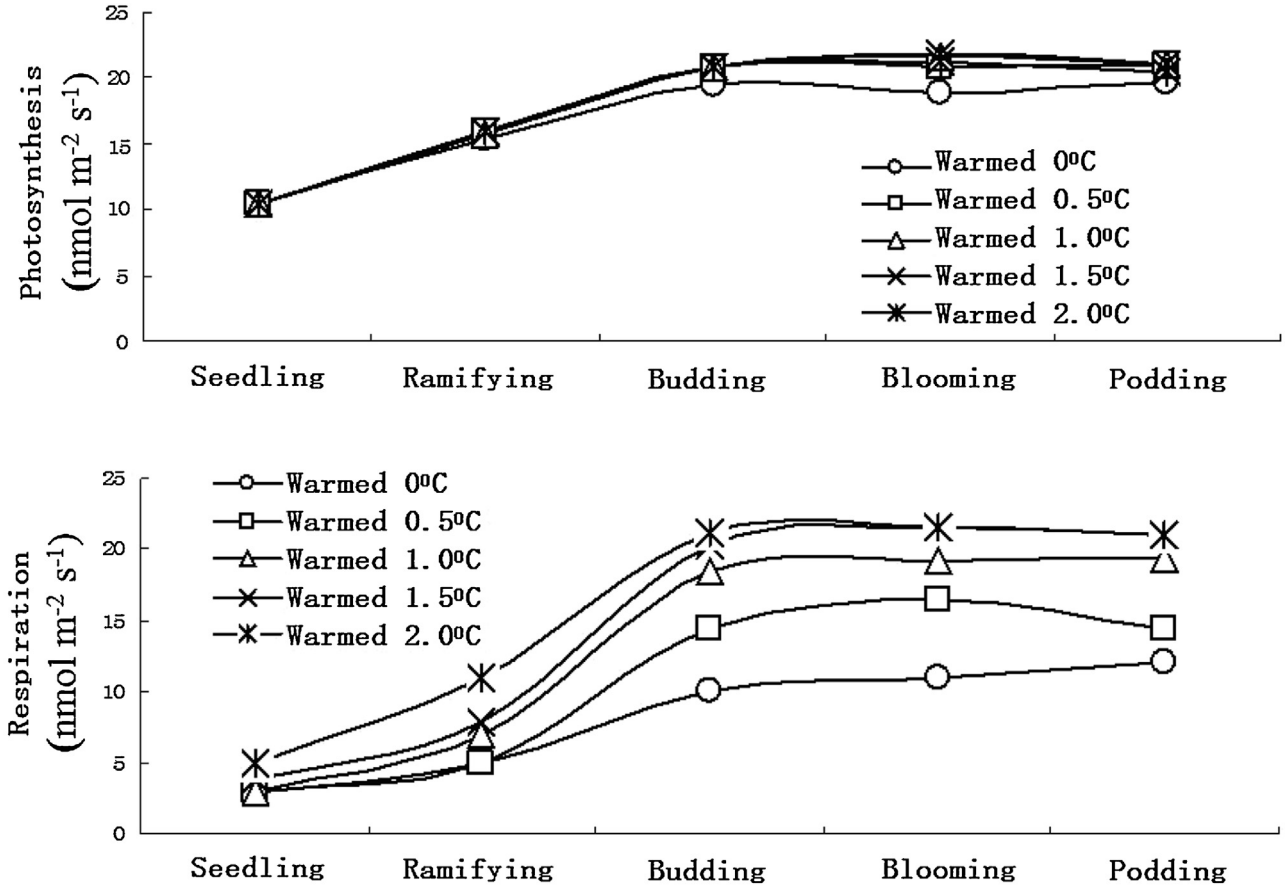

Fig. 2. Warming effect on broad bean photosynthesis and transpiration.