WORKSHOP 06

Research Progress and Application of NAU-CropGrow Model

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I. Introduction

China experienced explosive economic growth in recent decades, but with only 7% of the world's arable land available to feed 22% of the world's population (Tong *et al.*, 2003). Crop simulation models are powerful tools for evaluating the potential impacts of climate change on agro-ecosystems and assessing the long term changes in crop potential productivity under future climate scenarios (White *et al.*, 2011). Our objectives were (1) to improve the model algorithms for the simulation of rice and wheat phenology and productivity under post-anthesis heat stress based on the original model RiceGrow (Tang *et al.*, 2009) and WheatGrow (Cao *et al.*, 2002; Yan *et al.*, 2000); (2) to study on regional patterns of rice and wheat productivity changes in the past decades and future scenarios by using RiceGrow and WheatGrow; (3) to propose agricultural solutions on mitigating and adapting the impacts of climate change on crops in china.

II. Materials and Methods

2.1. Experiments for model development

Temperature-controlled wheat and rice experiments were conducted during 2011-2013 in phytotron at Nanjing Agricultural University, Nanjing, China (32.04°N, 118.78°E). Two cultivars were used in each experiment. At anthesis and early filling stage, pots were transferred to four phytotron rooms severally with the four temperature levels under natural daylight conditions. Durations of high-temperature under different high-temperature levels were designed as 2 d (D1), 4 d (D2) and 6 d (D3).

2.2. Datasets for model applications

The study region of rice involved 4 main rice production areas mentioned in the High

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Yield Technical Specifications of Rice for the main rice growing region of China (Ministry of Agriculture, P.R. China, 2009). The study region of wheat involved 10 main wheat production provinces, including Heibei, Henan, Shandong, Jiangsu, Anhui, Shanxi, Shaanxi, Ganshu, Hubei, and Sichuan. The daily meteorological data, selected from 700 weather stations during 1960-2010.

III. Results

3.1. Modeling the effects of short-term heat stress on phenology

Significant positive correlations were observed between the shortened grain growing days from anthesis to maturity (GD_{AM}) and heat degree-days (HDD).The impact of post-anthesis heat stress on phenology was quantified by adding thermal effectiveness of heat stress to the original model. Performance of the improved model was tested with phenological data from different cultivars under post-anthesis heat stress of phytotron environments and field conditions (Fig. 1).

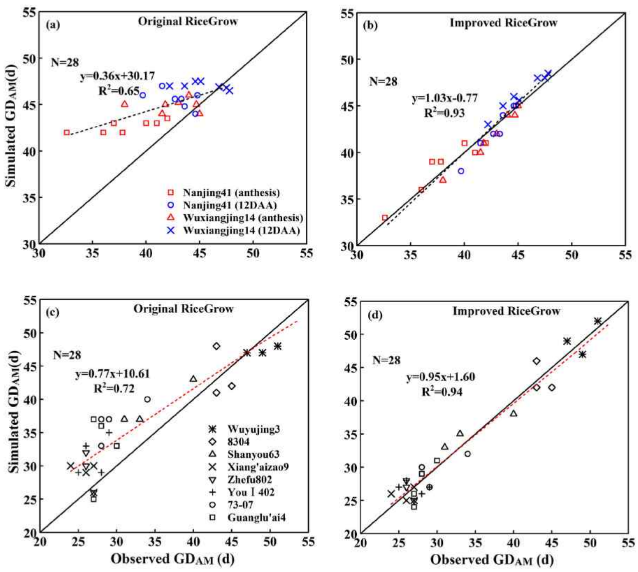

Fig. 1. Comparison of validation results between the observed and simulated growing days from anthesis to maturity (GD_{AM}) under different high temperatures in phytotron (a and b) and field conditions (c and b). 12DAA indicates temperature treatment at 12 days after anthesis.

3.2. Regional yield predictions under future climate change scenarios for rice and wheat

Whether considering direct effect of CO_2 fertilization or not, the yields in most of Southern China decreased by comparing with baseline scenario. The yields of high attitude mountain area in Sichuan, Yunnan, and Guizhou Province increased compared with baseline scenario. The increased yield areas were enlarged after considering direct effect of CO_2 fertilization. Moreover, north of Jiangsu and south to Yangtze River showed yield increased (Fig. 2).

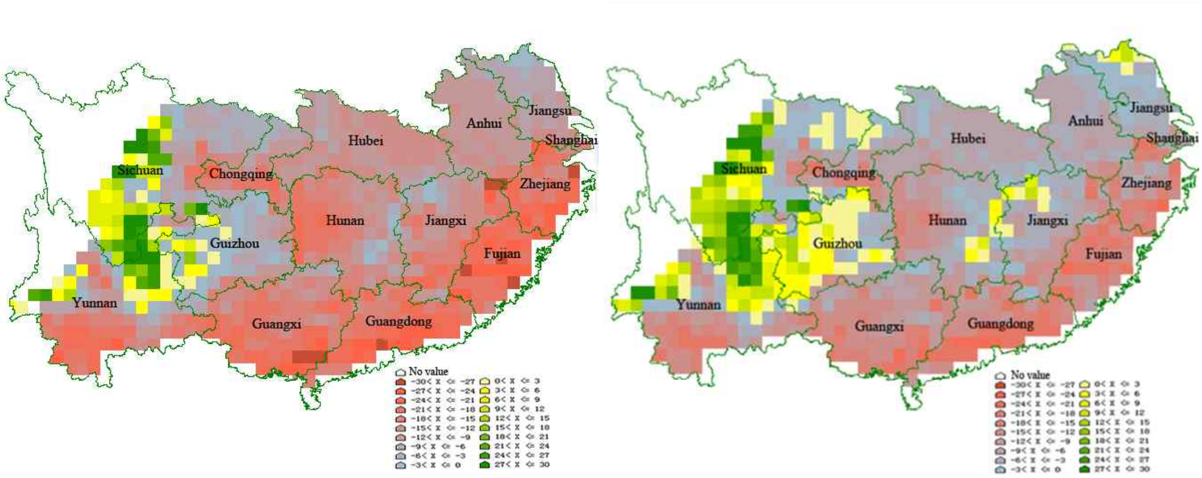

Fig. 2. Spatial distributions of changes in rice yields for climate change scenario in 2050 (A : without direct effect of CO_2 elevation ; B : with direct effect of CO_2 elevation).

The rain-fed wheat yields under A2 and B2 scenarios (without direct effect of CO_2 elevation) in 2080s were decreased in most areas of in Huang-huai-hai region in China (Fig. 3), which decreased by 7.34% and 6.05% by comparing with baseline value, respectively. The yield increased, especially significantly under A2 scenarios in some areas of Henan and Hebei Province where have less precipitation under baseline scenario. The two future climate scenarios increased the precipitation which causes rain-fed wheat yields increased.

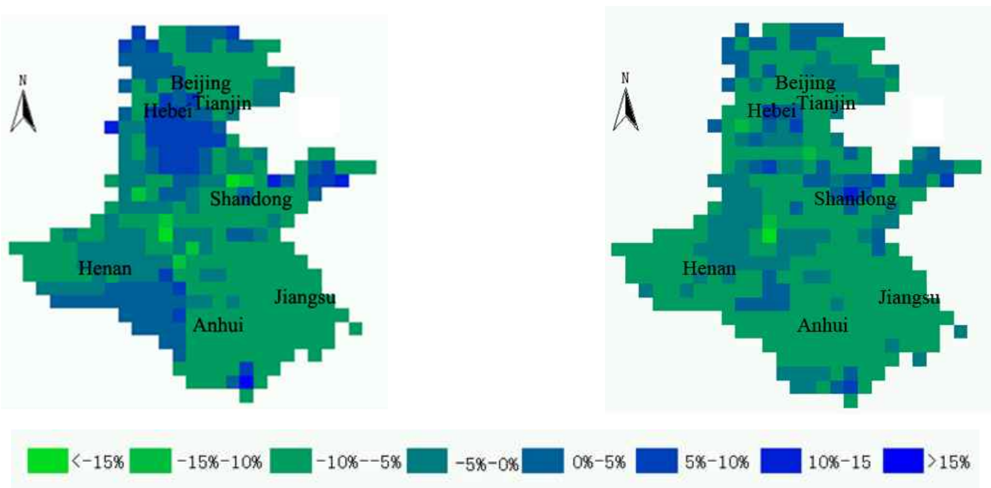

Fig. 3. Spatial distribution of yield changes of rained wheat in Huang-huai-hai plain under A2 and B2 scenarios in 2080s (without direct effect of CO_2 elevation).

IV. Discussion

4.1. Model improvement for short-term heat stress on phenology

The phenology response of crop models to climate warming has attracted increasing attentions in recent years, especially under heat stress conditions. Previous studies have noticed the poor pre-dictions and systematic errors for current phenology models under heat stress conditions (Alderman *et al.*, 2013; Van Oort *et al.*, 2011; Zhang *et al.*, 2008). Researchers put more emphasis on the better calibration for phenological parameters under heat stress, while relatively little work has been done on simulating the response of crop phenology to heat stress. Our study reported an increasing development rate above the threshold temperature of heat stress (Th= 35°C) after anthesis in the improved model, which gave better prediction than the original model with a constant development rate above the threshold temperature of heat stress.

4.2. Agricultural solutions on mitigation and adaptation

Three solutions for mitigation and adaptation of crop production under future climate change are proposed: (1) adjustment of cropping system; (2) adjustment of sowing date (Fig. 4); (3) breeding new crop varieties.

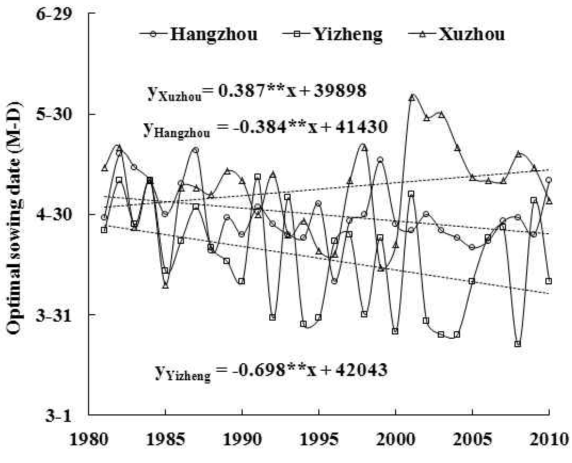

Fig. 4. Optimal sowing date with highest yield from 1981 to 2010 in Xuzhou (30.1°N, 119.9°E), Yizheng (132.3°N, 19.2°E) and Hangzhou (30.1°N, 119.9°E).

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