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Study on the Future Climate Change and Its Influence on the Growth Stage and Yield of Wheat in Weifang City

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Abstract In order to study the trend of climate change in the future in Weifang, and analyze the impact of climate change on the local wheat production, the air temperature and precipitation in Weifang from 2021 to 2050 were simulated by using the regional climate model PRECIS. And then put the meteorological data into the crop model to simulate the growth of wheat under climate change conditions in the future. The results showed that there would be a trend of rising temperature and increasing precipitation in Weifang in the future. Climate warming would result in growth period of wheat to be ahead of schedule and yield reduction. If taking into account the effect of CO_2, the yield of wheat would increase.

Key words Climate change, Wheat, Growth stage, Yield, Impact

1 Introduction

In recent years, the global warming has not stopped, and the impact of climate warming can not be ignored. The summary of policymakers in the First Working Group of the Fifth Assessment Report of Intergovernmental Panel on Climate Change (IPCC)[1] pointed out that over the past 130 years, global temperatures have increased by 0.85 ℃, and the global warming degree may exceed 1.5 ℃ in the 21st century. The past climate trend of Weifang City was consistent with global climate trend, and over the past 30 years, the annual average temperature has increased by 0.5℃ every 10 years[2]. Wheat is the main food crop in Weifang City, and it is found that the climate change over the past 30 years has had an impact on the growth stage and yield of wheat[3-4], so on the basis of analyzing future climate change trends, this paper analyzes its effects on the growth and yield of wheat, which can provide a scientific basis for reducing the climate change vulnerability and ensure the food security and rapid economic development in Weifang City.

2 Materials and methods

In this study, we use the climate scenario data from PRECIS[5] to analyze the future climate change trends. The future weather data from PRECIS are embedded into CERES-Wheat model[6] to simulate the wheat production during 2021 -2050, and analyze future trends of the growth stage and yield of wheat in Weifang City during 2021 -2050.

2.1 Introduction to climate models and climate scenarios

PRECIS (Providing Regional Climate for Impacts Studies) is developed at the Hadley Centre at the UK Met Office, PRECIS is a regional climate modelling system designed to run on a Linux based PC. PRECIS can be applied to any area of the globe to generate detailed climate change projections. PRECIS is a regional climate model (RCM) ported to run on a Linux PC with a simple user interface, so that experiments can easily be set up over any region of the globe. PRECIS is designed for researchers (with a focus on developing countries) to construct high-resolution climate change scenarios for their region of interest. The horizontal resolution is 50km × 50km, and it is vertically divided into 19 layers. It has a friendly interface, and it can be set up in any region of the world for regional downscaling. Xu Yinlong *et al.*[7-10] verify the simulation capability of PRECIS model in China and carry out the simulation verification at the site level[11]. This paper uses SRES A_2 and B_2 scenarios[12]. According to China's national conditions, it should pay equal attention to economic development and environmental protection in the future, which is closest to B_2 scenario (namely the regional sustainable scenario). A_2 scenario considers the rapid population growth, greatly different from China's population growth, but as a hypothetical high-emission scenario, it can be used to assess the possible impact of climate change in the worst situation of development.

2.2 Crop model CERES-Wheat model was a user-oriented crop growth simulation model developed by the United States for the actual production. It consists of three parts: input module of climate, soil, crop genetic parameters and crop cultivation and management; simulation module of main physiological processes; output and analysis module of simulation results. CERES -Wheat mode has been extensively verified at the site level in China[13-16].

3 Results and analysis

3.1 The future climate trends in Weifang City

3.1.1 Temperature trend. As can be seen from Fig. 1, under A_2 and B_2 scenarios, the temperature showed a rising trend in Weifang City during 2021 - 2050, and the increasing extent of temperature in A_2 is greater than in B_2. Under A_2 scenario, the annu-

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al average temperature will rise by 0.9 ℃; under B_2 scenario, the annual average temperature will rise by 0.6 ℃.

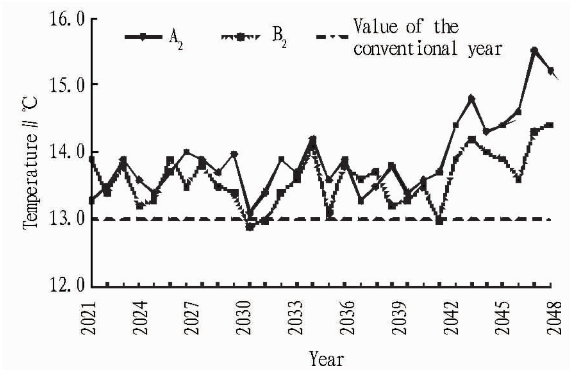

Fig. 1 The annual average temperature trends in Weifang City in the future climate change scenarios

From the inter-annual average temperature change (Table 1), the average temperature in the 2030s will be lower than in the period before and after the 2030s under A_2 and B_2 scenarios. Under A_2 scenario, the temperature at each stage shows an upward trend, and the temperature rise in the 2030s is slower than in the 2020s but the temperature sharply rises in the 2040s. Under B_2 scenario, the temperature shows a downward trend in the 2020s, and it rises in the following 20 years, and the temperature rise in the 2040s is faster than in the 2030s.

3.1.2 Precipitation trends. Under A_2 and B_2 scenarios, the precipitation shows an increasing trend in Weifang City over the next 30 years, and the precipitation in B_2 scenario is slightly more than in A_2 scenario (Fig. 2). Under A_2 scenario, the average annual precipitation increases by 17.9% in Weifang City over the next 30 years; under B_2 scenario, the average annual precipitation increases by 21.3%.

Table 1 The average temperature anomaly and climate tendency rate in Weifang City during 2021 – 2050

Year	A_2 scenario		B_2 scenario	
	The average temperature anomaly // ℃	Climate tendency rate // ℃/10a	The average temperature anomaly // ℃	Climate tendency rate // ℃/10a
2021 – 2030	0.7	0.54	0.6	−0.13
2031 – 2040	0.6	0.24	0.4	0.49
2041 – 2050	1.7	2.03	0.8	1.10

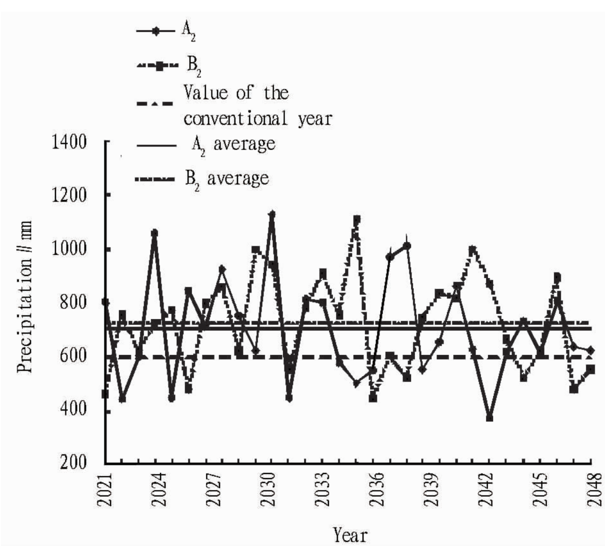

Fig. 2 The annual average precipitation trends in Weifang City in the future climate change scenarios

From the inter-annual precipitation changes (Table 2), under A_2 and B_2 scenarios, the average precipitation at three stages is higher than at other stages, and the precipitation in the 2030s goes through the largest increase. Under A_2 scenario, during 2021 – 2030, the precipitation shows an increasing trend, and during 2031 – 2040, 2041 – 2050, the precipitation shows a decreasing trend. During 2031 – 2040, 2041 – 2050, the precipitation falls more sharply. The precipitation trend under B_2 scenario is consistent with the precipitation trend under A_2 scenario, and the difference is that the precipitation during 2041 – 2050 falls much faster than during 2031 – 2040.

3.2 The impact of future climate change on the growth stage and yield of wheat Assuming wheat varieties and management mode remain unchanged, we input the meteorological data under A_2 and B_2 scenarios in Weifang City during 2021 – 2050 into crop model, to simulate the future wheat growth and development and evaluate the impact of future climate change on the growth stage and yield of wheat.

Table 2 The precipitation anomaly percentage and climate tendency rate in Weifang City during 2021 – 2050

Year	A_2 scenario		B_2 scenario	
	The average temperature anomaly // ℃	Climate tendency rate // ℃/10a	The average temperature anomaly // ℃	Climate tendency rate // ℃/10a
2021 – 2030	20.9	92.37	18.9	302.3
2031 – 2040	23.1	−75.76	23.4	−234.4
2041 – 2050	9.8	−7.79	21.6	−381.6

3.2.1 The impact on the growth stage. The changes in growth stage affect the biomass accumulation. In this study, by simulating the wheat growth under future climate change scenarios, we analyze the impact of climate change on the growth stage of wheat. By simulating the main growth stages (flowering and maturity) of wheat, it can be found that: (i) under A_2 and B_2 scenarios, the flowering and maturity stages of wheat in Weifang City during 2021 – 2050 are earlier than usual (under A_2 scenario, flowering and maturity stages of wheat are 5, 7 days earlier than usual, respectively; under B_2 scenario, flowering and maturity stages of wheat are 3, 5 days earlier than usual, respectively); (ii) flowering and maturity stages under A_2 scenario are much earlier than under B_2 scenario, mainly because the temperature under A_2 scenario is higher than under B_2 scenario, and the higher the temperature, the shorter the phenophase duration of wheat.

Table 3 The flowering and maturity stages of wheat under different future climate scenarios

	1981 – 2000	2021 – 2050	
		A_2	B_2
Flowering stage (d)	129	124	126
Maturity stage (d)	160	153	155

3.2.2 The impact on yield. Both A_2 and B_2 scenarios consider the change in the concentration of CO_2, and the rising concentration of CO_2 has a fertilization effect on the growth of agricultural crops[17 – 19], so when evaluating the impact of future climate change on wheat yield, this paper studies two cases (without considering CO_2 fertilization effect and considering CO_2 fertilization effect) (Table 4). As can be seen from the simulation results, if we keep the existing variety and field management model and do not consider the CO_2 fertilization effect on wheat yield, then under A_2 and B_2 scenarios, the future wheat production in Weifang City shows a downward trend, and the magnitude under A_2 is larger than under B_2. This is mainly due to the rising temperature which dominates the future climate trends, and the rising temperature will accelerate the growth of wheat, shorten the growth period, reduce the dry matter accumulation time, and lower the yield. When considering the CO_2 fertilization effect on wheat, the CO_2 fertilization effect partially offsets the negative impact of rising temperature, and the future wheat yield in Weifang City will be significantly increased.

Table 4 The changes in wheat yield under the future climate change scenarios

	A_2	B_2
Without considering CO_2 fertilization effect	–1.7%	–0.9%
Considering CO_2 fertilization effect	+5.4%	+3.2%

4 Conclusions and discussions

(i) In the context of global climate change, the temperature and precipitation will increase in Weifang City in the future. The temperature will rise by 0.6 – 0.9 ℃ and the precipitation will increase by 17.9% – 21.3% in 2050. (ii) The future climate change will advance the growth stages of wheat. In 2050, the flowering period of wheat in Weifang City will be advanced by 3 to 5 days and the maturity period will be advanced by 5 to 7 days. (iii) When considering the CO_2 fertilization effect, the future wheat yield will show an upward trend, an increase of 3.2% – 5.4%; when we do not consider the CO_2 fertilization effect, the future wheat yield will show a downward trend, a decrease of 0.9% – 1.7%. (iv) When this study considers the CO_2 fertilization effect to simulate the growth of wheat, it is assumed that the conditions of irrigation and fertilization for wheat are fully satisfied, and the other conditions are very suitable for growing wheat, but in the actual planting process, there are still great difficulties in fully achieving this ideal standard. Thus, when evaluating the impact of future climate change on wheat yield, the assessment of CO_2 fertilization effect is merely for reference. (v) The site selected in this study is irrigated arable land, so when using the crop model to simulate the wheat growth, it is assumed that the conditions of irrigation and fertilization for wheat are fully satisfied, and the impact of pests and diseases is not considered, but there are still some difficulties in achieving such conditions in real production, so the results in this paper are only for reference, and there is a need to perform specific analysis in the production.

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(To page 98)

3 Software design

3.1 Wireless gateway The data exchange between the network based on TCP protocol and the protocol stack based on ZigBee is completed mainly via ZigBee wireless gateway[3]. The Zigbee wireless gateway can send the data in common Ethernet to Zigbee network, and it can also send the data in Zigbee network to the Ethernet based on TCP protocol, in order to achieve network interconnection. After the ZigBee wireless gateway is opened, other RFD nodes will automatically contact it, and quickly enter the wireless network. Thus, all nodes are dominated by ZigBee wireless network. The program flow chart is shown in Fig. 3.

3.2 Data collection The reference nodes and wireless gateway in the ZigBee network act as the coordinator or router device. The sensor device records the temperature and battery energy readings and sends them to the wireless gateway. After the wireless gateway is started or joins a network, it must be placed under the mode of allowing binding in response to the binding request sent from the sensor device. The program flow chart is shown in Fig. 4.

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(From page 84)

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