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Numerous experiments for the impact of warming climate on the phenology and grain yield of winter wheat

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Abstract—Based on the environmental and crop data at Zhenjiang City, in Jiangsu Province, middle east of China, the growing process of winter wheat was simulated by CERES-Wheat model assuming the daily average temperature is 1°C to 2°C higher than at the present, which are mostly possible for the change of climate because of enrichment of greenhouse gases in the atmosphere. The simulation results show that warming climate can promote development rate and shorten phenological stages of wheat, and the grain yield will be higher than present. Its impact on the kernel weight and grains per square meter were different for the plantings of various sowing dates. The results of this study suggest that substantial changes in agricultural production and management practices are needed to respond to the climatic changes expected to take place in China.

Keywords: greenhouse gases; warming climate; winter wheat; climatic change; phenology.

INTRODUCTION

Appreciable global climatic change responses to increasing level of atmospheric CO_2 and other trace gases are expected to take place over the next 50 to 80 years. Although there is substantial disagreement on the climatic change scenarioes for doubled levels of atmospheric CO_2, all agree that a warmer trend is expected and it was estimated that the global average temperature will be 1.5°C higher (Bert, 1986) and the temperature in China will be 2.69°C warmer than at present. Agricultural production is very sensitive to climate change, and which can threaten the subsistence of human being. There were some studies on the climatic change impact on agriculture by crop models or combination them with climate models (Liverman, 1986; Ellen, 1990), most of them were developed in the United States and Europe.

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Winter wheat is one of principal grain crops in China and estimation its variation of growing process and grain yield are of very important for farmers and policy makers adaptation to climatic change. In this study, the phenological stages and grain yield structural elements are concerned for impact analysis of warming climate. Zhenjiang (32.2°N, 112.5°E) is selected as a case study because of the field experimental data were taken there.

METHODOLOGY

The crop model selected for this analysis is the Crop Environment Resources and Environmental Synthesis Model for wheat (CERES-Wheat), developed by an international and interdisciplinary team of scientists over a period of several years. Dr.Joe T.Ritchie of Michigan State University, and formerly of the United States Department of Agriculture-Agricultural Research Service (USDA-ARS), Temples, Texas have coordinated development of the model. The nitrogen sub-model was primarily developed by the modelers at the International Fertilizer Development Center (IFDC). CERES-Wheat has been incorporated into the International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT) project. Full model documentation can be found in technical reports of IBSNAT projects (Godwin, 1989).

CERES-Wheat model is a user-oriented crop process simulation model on daily time step. The model simulates interactions between environmental factors and many plant growth processes including photosynthesis, respiration, phenology, leaf initiation and growth, stem growth, root growth, soil water extraction, evapotranspiration, nitrogen movement, grain initiation and growth. Simulated elements include phenology, end-of-season grain yield, grains per square meter, leaf area index, biomass production and so on. In some degree, CERES-Wheat re-exhibited the growth process of wheat in computer.

Some limitations of CERES-Wheat must be addressed before the model being used for climatic change impact analysis. First, the model does not consider catastrophic weather events, pests and weeds. Secondly the direct effect of CO_2 on photosynthesis and other bio-processes is not considered. But the influence of temperature on crop and other environmental factors are somewhat fully described. Temperature impacted processes in the model include plant development, the initiation and growth of leaf, tillers and ears, photosynthesis and respiration, cold hardiness, potential evaporation (which is the base of soil water output), and mineralization, nitrification and denitrification and so on. And considering the relative agreement with the estimation of the climatic change because of greenhouse gases enrichment in atmosphere, daily average temperature promotes by 1°C to 2°C are as simple climatic change scenarioes and which will be used to analyze crop impact by CERES-Wheat model.

The site of field experiment is at Zhenjiang City. CERES-Wheat model was validated by field experimental data of four plantings sowing on various dates (sowing dates are Oct.20, Oct.31, Nov.10 and Nov.20 in 1984, represented as planting No.1, No.2, No.3 and No.4, respectively), and the genetic parameters needed for the input of the model were determined and validated as well. The actual experimental results were taken as the initial condition.

RESULTS ANALYSIS

The impact of warming climate on the phenological stages of winter wheat

The growing circle of winter wheat, from sowing, emergence, tillering, heading, anthesis to maturity, spends about 210 days. The phenology of winter wheat, especially for the strong springness winter wheat, is mainly determined by temperature and which can be expressed approximately by thermal accumulation theory. High temperature can promote development rate and shorten phenological periods. Table 1 gives the phenological changes of winter wheat simulated under the condition of daily average temperature increase 1°C to 2°C in the whole growing circle (from Oct.1, 1984 to Jun.30, 1985).

Table 1 The impact of temperature increases 1°C to 2°C on the phenological periods of winter wheat

	Planting No.	Initial condition, day	Controlled condition, day			
			+1°C	Shorten	+2°C	Shorten
Sowing to anthesis	1	174	164	10	152	22
	2	173	165	8	157	16
	3	170	163	7	157	16
	4	166	160	6	153	13
Anthesis to maturity	1	37	39	-2	43	-6
	2	35	34	1	35	0
	3	34	33	1	32	2
	4	34	33	1	32	2
Sowing to maturity	1	211	203	8	195	16
	2	208	199	9	192	16
	3	204	106	8	189	15
	4	200	193	7	185	15

Table 1 shows that high temperature shortens the durations of periods of development from sowing to anthesis and from anthesis to maturity. For each 1°C warmer, the period from sowing to anthesis shortens 6 to 11 days and from sowing to maturity shortens 7 to 8 days. For different sowing dates, this shortening impact are different.

The climatic conditions of some development stages, such as grain filling, are changed because of the ahead of prior development stages, and by this the phenology and yield of crop are strongly impacted in turn. Table 2 shows the temperature condition of grain filling of initial and controlled situations, which also can be used to explain why the grain filling period of No.1 planting is longer than the initial.

Table 2 The temperature condition of grain filling of initial and controlled situations

Planting No.	Treatment	Ahthesis data	The average temp. after anthesis 10 to 30 days, °C
1	Initial condition	Apr.12	19.7
	Controlled +1°C	Apr.2	17.7
	condition +2°C	Mar.21	13.2
2	Initial condition	May 3	20.4
	Controlled +1°C	Apr.25	21.0
	condition +2°C	Apr.17	22.3

The impact of warming climate on the grain yield

Temperature sensitive bio-processes such as photosynthesis, respiration, biomass production, the initiation and development of leaf, stem tillers and ears, soil water and nitrogen balance, phenology and so on in some degree, all impact the end-of-season grain yield, and which is most concerned by farmers and policy makers. The impact of warmer climate of various periods on grain yield are shown in Fig.1 (A and B for 1°C and 2°C higher temperature treatment respectively). The horizontal axis represents the end months of temperature treatment periods and all of them begin from Oct.1, 1984. The vertical axis represents the variation of grain yield compared with the initial condition.

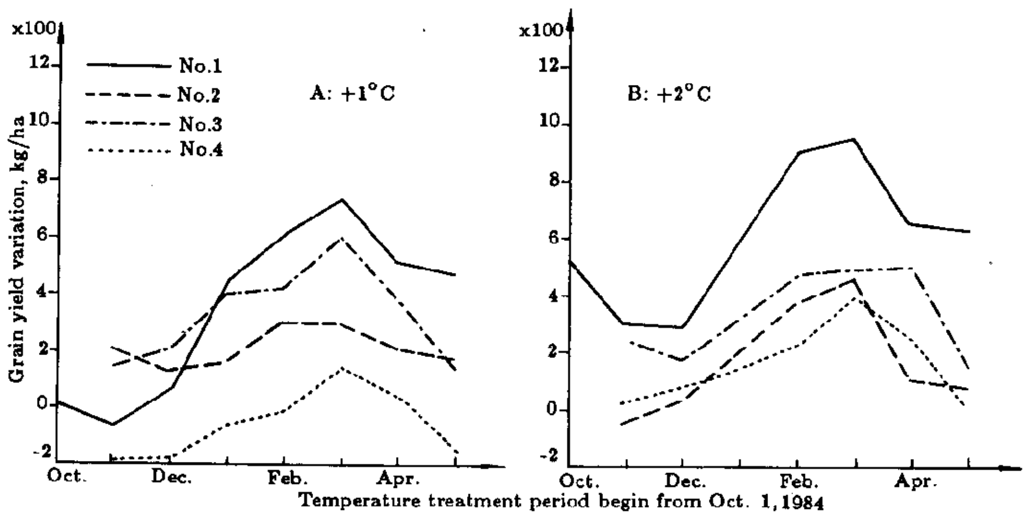

Fig. 1 The impact of temperature treatment of various periods on the end-of-season grain yield of wheat

Fig.1 shows that warming climate favors the promotion of grain yield, especially for higher and longer temperature treatment and earlier sowing plantings such as planting No.1. This may be a good news for the impact of climatic change on agricultural production. That is mainly because high temperature greatly improves the wintering condition of wheat and facilities crop escape the harmful hot influence of summer on grain filling by aheading anthesis. In otherwise, higher temperature treatment in later crop development stages, such as in May and June, is unfavorable for the anthesis and grain filling of wheat, which is shown by the later stage decline trend of curves in Fig.1.

The impact of temperature treatment on kernel weight can be positive and negative for different planting dates (Fig.2). High temperature favors the increase of kernel weight of earlier plantings such as No.1 and No.2, but is unfavorable for later plantings such as No.3 and No.4. These phenomena are mainly because of the change of the duration and conditions of grain filling of wheat.

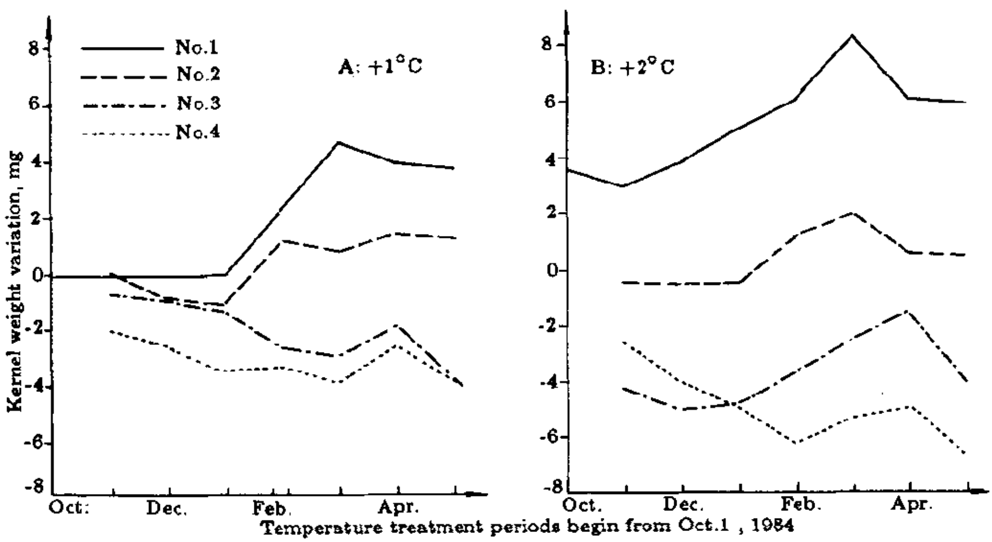

Fig. 2 The impact of temperature treatment of various periods on the kernel weight

Another grain yield structural element is grains per square metre, which is determined by canopy density and grains per ear. The impact of temperature treatment on it is shown in Fig.3. High temperature treatment is almost favorable for the increase of grains per square metre for all plantings, but the quantities of the impact are somewhat complex for different sowing dates. Temperature treatments in the early growing period of wheat such as from Oct.1, 1984 to Nov.30, Dec.31, 1984 and Jan.31, 1985, their impacts on the grains per square metre are stronger than that on kernel weight, which may be attributed to the relation between the grains per square metre and the canopy density, and which is determined before heading.

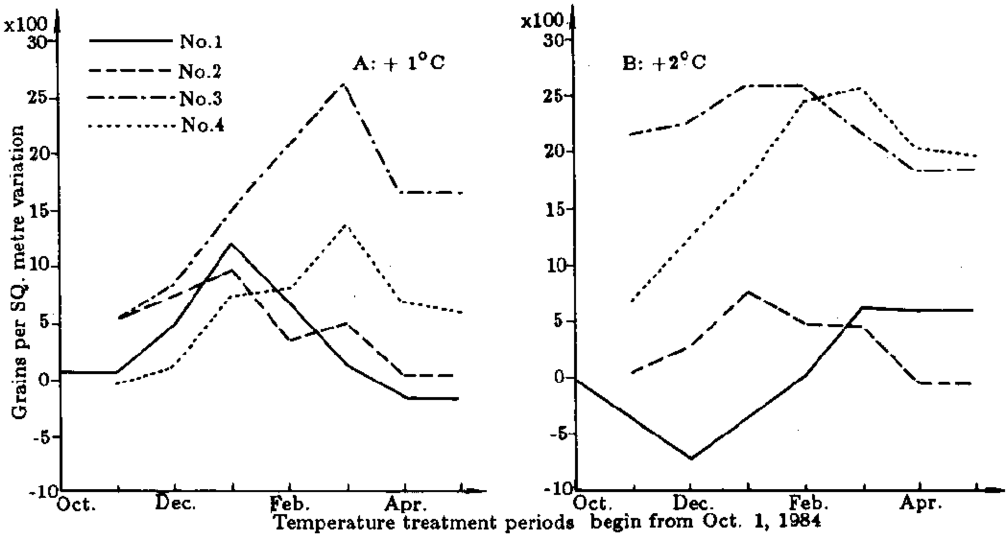

Fig. 3 The impact to temperature treatment of various periods on the grains per square metre

Fig.1, 2 and 3 show that the impacts of warming climate on grain yield and its structural elements are very different for the plantings of various sowing dates, it suggests that adjusting agricultural production practices such as sowing data, planting density and altering variety and so on are necessary when the climate is warming.

DISCUSSION AND CONCLUSION

The present analysis indicates that under warming climate conditions, causing by greenhouse effect of increasing contents of CO_2 and other trace gases in the atmosphere, the phenology and grain yield of wheat will be strongly impacted. The development process will be promoted and phenological stages will be shortened, the end-of-season grain yield will be increased frequently. It suggests that substantial adjustment in agricultural practices are needed to respond to the climatic change.

This study attempts to provide some information to decision makers and agricultural researchers to adapt to the climatic change actively. Model generated results are quantitative but must be used with caution in light of the limitations of crop model, assumptions for the climatic change scenarioes, and the constraints of field experiment data. More case studies will be needed to enlarge this case study and a vast area analysis will be more reasonable to persuade the decision makers.

REFERENCES

Bert Bolin *et al.*, Scope, 1986, 29:363

Ellen J.Cooter, Climatic Change, 1990, 16:1

Godwin D. *et al.*, A User's Guide to CERES-Wheat, 1989, 2:10

Liverman, D.M. *et al.*, Climatic Change, 1986, 9:327