Climate Changes Impacts on Agriculture in China*
- By top-down and bottom-up

Songcai You

(1, Institute of Environment and Sustainable Development in Agriculture, the Chinese Academy of Agricultural Sciences, Beijing 100081;)

1. Foreword

Climate change is a major global issue of common concern to the international community. It is an issue involving both environment and development, but it is ultimately an issue of development. As a developing country of responsibility, China attaches great importance to the issue of climate change.

2. Climate Changes in China

Many observations in recent 100 years show that the earth's climate is now experiencing significant change characterized by global warming. And the trend of climate change in China is generally consistent with that of global climate change.

2.1 Observed Climate Changes in China

The Third Assessment Report of IPCC has clearly indicated that most of the global warming observed over the past 50 years was likely induced by the increase in concentrations of greenhouse gases (GHGs), such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), due to human activities.

2.1.1 Changes in Past 100 Years

In the context of global warming, climate in China has experienced noticeable changes over the past 100 years as well. The major observed evidence of climate change in China includes the following:

(1) Temperature

Annual average air temperature has increased by 0.5~0.8 during the past 100 years, which was slightly larger than the average global temperature rise. Most of the temperature rise was observed over the last 50 years. The regional distribution of the temperature changes shows that the warming trend was more significant in western, eastern and northern China than in the south of the Yangtze River. The seasonal distribution of the temperature changes shows that the most significant temperature increase occurred in winter, and 20 consecutive warm winters were observed nationwide from 1986 to 2005;

(2) Precipitation

In the past 100 years, there was no obvious trend of change in annual precipitation in China, but there exists considerable variation among regions. The annual precipitation decreased gradually since 1950s with an average rate of 2.9 mm/10a, although it

* yousc@ieda.org.cn, No.12, South Zhongguancun Street, Haidian District, Beijing 100081, Tel: +86(0)10-8210-9571 ext. 3227

increased slightly during the period of 1991 ~ 2000. The regional distribution of precipitation shows that the decrease in annual precipitation was significant in most of northern China, eastern part of the northwest, and northeastern China, averaging 20~40 mm/10a, with decrease in northern China being most severe; while precipitation significantly increased in southern China and southwestern China, averaging 20~60 mm/10a.

2.1.2 Changes in Past 50 Years

Based on the 1961-2007 ground surface meteorological data from 558 meteorological stations in China, the differences of agricultural climate resources in China different regions were analyzed, and the change characteristics of the agricultural climate resources in 1961- 1980 (period I) and 1981-2007 (period II) were compared, taking the year 1981 as the time node. As compared with period I, the mean annual temperature in China in period II increased by 0.6 ℃, the highest increment occurred in Northeast China. The annual sunshine hours decreased by 125.7h, the highest decrement occurred in the middle and lower reaches of Yangtze River, and followed by the North China; Both precipitation and reference crop evapotranspiration showed a decreasing trend, with the largest decrement of precipitation in North China and of reference crop evapotranspiration in the middle and lower reaches of Yangtze River.

Table 1 Observed climate changes from 1961-2007 in China

Climate element		SW China	Middle and Lower Yangtze River	South China	NW China	North China	NE China	China
Annual mean temperature	(℃)	0.4	0.4	0.4	0.7	0.7	1.0	0.6
	(%)	2.9	2.5	1.9	11.8	7.1	24.4	5.5
Annual sunshine hours	(h)	-93.9	-199.1	-159.1	-67.3	-174.3	-101.9	-125.7
	(%)	-5.0	-10.3	-8.5	-2.3	-6.5	-3.8	-5.3
Annual precipitation	(mm)	-13.7	46.6	22.8	3.4	-41.4	5.0	3.1
	(%)	-1.4	3.7	1.4	1.3	-7.2	0.9	0.4
Annual reference crop evapotranspiration	(mm)	-22.1	-34.5	-22.3	-30.9	-33.3	-11.6	-26.4
	(%)	-2.2	-3.4	-1.9	-2.9	-3.2	-1.4	-2.6

2.1.3 Changes of Agro-Climate in past 50 years in China

Also, based on the 1961-2007 ground surface meteorological data from 558 meteorological stations in China, the change characteristics of the agricultural climate resources in 1961- 1980 (period I) and 1981-2007 (period II) were compared. As compared with period I, the ≥0℃ active accumulated temperature representing the growth periods of chimonophilous crops and the ≥10℃ active accumulated temperature representing the growth periods of thermophilic crops increased averagely by 123.3 ℃·d and 125.9 ℃·d, respectively. The ≥10℃ active accumulated temperature increased most in South China. In sunshine hours in the growth periods of chimonophilous crops and of thermophilic crops in period II decreased by 32.2 h and 53.6h, respectively, compared with those in period I. Both the precipitation and the reference crop evapotranspiration in China all showed a decreasing trend, with the largest decrement in North China; the largest decrement in the reference crop evapotranspiration in the growth periods of thermophilic crops and of chimonophilous crops occurred in the middle and lower reaches of Yangtze River and in Northwest China, respectively.

Table 2 Observed agro-climate changes from 1961-2007 in China

Agricultural climate element			Southwest China	Middle and lower Yangtze River	South China	Northwest China	North China	Northeast China	China
Item	During the period of daily temperature	Unit							
Accumulated temperature	≥0℃	(℃.d)	-	-	-	120.0	118.1	-	123.3
		(%)	-	-	-	3.7	2.9	-	3.5
	≥10℃	(℃.d)	100.9	123.5	178.2	105.2	131.5	140.4	125.9
		(%)	2.6	2.4	2.5	4.0	3.6	5.2	3.2
Precipitation	≥0℃	(mm)	-	-	-	1.2	-33.9	-	-9.9
		(%)	-	-	-	0.5	-7.4	-	-3.0
	≥10℃	(mm)	-13.6	16.6	6.6	6.1	-30.3	7.7	-0.6
		(%)	-1.6	1.6	0.4	4.0	-7.3	1.7	-0.1
Sunshine hours	≥0℃	(h)	-	-	-	-3.1	-93.6	-	-32.2
		(%)	-	-	-	-0.2	-4.9	-	-1.7
	≥10℃	(h)	-46.9	-114.6	-115.5	-1.4	-69.4	-18.7	-53.6
		(%)	-4.4	-8.1	-6.8	-0.1	-4.8	-1.6	-4.1
Reference crop evapotranspiration	≥0℃	(mm)	-	-	-	-20.0	-15.9	-	-19.2
		(%)	-	-	-	-2.2	-1.8	-	-2.1
	≥10℃	(mm)	-6.5	-21.6	-9.4	-13.0	-8.0	2.4	-10.7
		(%)	-0.9	-2.6	-0.9	-1.9	-1.1	0.6	-1.4

"-" meant no data

2.1.4 Changes of Water Resources

Climate change has already caused the changes of water resources distribution over China. A decreasing trend in runoff was observed during the past 40 years in the six main rivers, namely Haihe River, Huaihe River, Yellow River, Songhuajiang River, Yangtze River, and Pearl River. Meanwhile, there is evidence for an increase in frequency of hydrological extreme events, such as drought in North and flood in South. The Haihe-Luanhe River basin is the most vulnerable region to climate change, followed by Huaihe River basin and Yellow River basin. The arid continental river basins are particularly vulnerable to climate change. In the future, climate change will have a significant impact on water resources over China: in the next 50-100 years, the mean annual runoff is likely to decrease evidently in some northern arid provinces, such as Ningxia Autonomous Region and Gansu Province, while it seems to increase remarkably in a few already water-abundant southern provinces, such as Hubei and Hunan provinces, indicating an increase of flood and drought events due to climate change; the situation of water scarcity tends to continue in the northern China, especially in Ningxia Autonomous Region and Gansu Province, where water resource per capita are likely to further decrease in future 50-100 years; providing that water resources are exploited and utilized in a sustainable manner, for most provinces, water supply and demand would be basically in balance in future 50-100 years. However, gap between water resource supply and demand might be expanded in Inner Mongolia Autonomous Region, Xinjiang Autonomous Region, Gansu, and Ningxia Autonomous Region.

Table 3 Linear trends in basin-averaged annual and seasonal precipitation (mm) over ten major river catchments and China 1956-2002

Watershed	Winter	Spring	Summer	Fall	Yearly
Songhuajiang River	-0.08	-0.01	-0.03	-0.11	-0.06
Liaohe River	-0.09	0.03	-0.12	-0.12	-0.15*
Haihe River	-0.07	0.01	-0.16*	-0.08	-0.17*
Huaihe River	0.07	-0.07	-0.11*	-0.13	-0.14*
Yellow River	0.02	-0.05	-0.10	-0.11	-0.14*
Yangtze River	0.06	-0.03	0.06	-0.04	0.03
Rivers in Southeast region	0.07	0.00	0.19**	-0.09	0.11
Rivers in Northwest Region	-0.02	0.03	0.08*	0.07	0.10*
Rivers in Southwest Region	0.05	0.15**	-0.02	0.09*	0.09**
Pearl River	0.08	0.04	0.05	-0.02	0.08
China	0.01	0.01	0.02	-0.02	0.01

Note: ** and * stand for the test passing at 0.01 level and 0.05 level, respectively.

2.1.5 Changes of Extreme Climate Events

The frequency and intensity of extreme climate/weather events throughout China have experienced obvious changes during the last 50 years. Drought in northern and northeastern China, and flood in the middle and lower reaches of the Yangtze River and southeastern China have become more severe. The annual precipitation in most years since 1990 has been larger than normal, with the precipitation pattern being a dipole, corresponding to frequent disasters in the North and flood in the South; the frozen occurred in South China in 2008 caused serious damage. According to survey, the direct damage to agriculture and forest is nearly 200 billions RMB Yuan, of which, the damage to food crops occupied one third. Nearly 80 millions livestock died from the cold.

Table 4 Damaged area of food crops and economic crops (in 1000 ha)

	Food crops	Rape	Vegetable	Fruit	Tea	Sugar cane*
Area with 10%-30% decrease of yield	14667	3891	3189	1930	439	755
Area with 30%-70% decrease of yield	8000	2149	1583	801	185	491
Area with over 70% decrease of yield	2051	375	583	232	25	71

* only the damage in Guangxi Zhuangzu Autonomous Region

2.1.6 Identification of Adaptation Strategies in Specific Region

The MOST of China set up a special sector of climate change impact study in National 973 program. Besides, the MOA, Bureau of Forest of China also raised special fund to support the studies on climate change impacts. The research area covers the Carbon sources and sink, the mechanism of climate change, impacts of climate change on agriculture, forestry, livestock, fishery, human being, etc. special attentions have been paid to the vulnerable areas such as coastal area, the environment fragile areas. As water shortage is the key problem in China, and over 70% of water resources is used by agricultural sector. It attracted the attention of scientists from domestic and abroad.

The most widely used adaptation strategies include water saving techniques in agriculture, sustainable management of water resources, limitation of underground water exploitation, change planting date, etc..

Table 5 Case studies for testing the adaptation assessment and management framework

Case Study Area	Objectives	Existing Problems	Sponsor	Identified Strategies
Huaihe River Watershed	To reduce the damages from flooding disaster	Flooding disaster	World Bank and Ministry of Water Resources	1, enhance the construction of drainage system in lowland area; 2, increase water holding capacity 3, establish the flooding forecast system and water resource management system.
Miyun Reservoir, located in Haihe River Watershed	Sustainable water supply to Beijing	Continued reduction of inflow water	Ministry of Environment Protection, Ministry of Water Resources, World Bank, Global Environment Fund, the government of Beijing	1, Transform the irrigated cultivation to rain fed cultivation in upper reach of Miyun Reservoir; 2, Financial compensation to the farmers in the upper reach 3, Increase the inflow water by constructing a water transporting channel from Luanhe River to Chaohe River in the upper reach of Miyun Reservoir;

				4, Increase water use efficiency by reusing the waster water.
Haihe River Watershed	Agricultural water resources and policies	Decreasing underground water level, ground subsidence, degradation of water quality.	Ministry of Water Resources, World Bank	1, Raise water price, 2, Increase investment on irrigation and drainage system.
Shiyanghe river watershed	Sustainable management of water resources	Oasis disappear due to Environmental degradation	Management Bureau of Shiyanghe river watershed	1, Increase investment on water saving project 2, transfer water from Yellow river to Shiyanghe river, 3, Financial compensation to lose caused by limiting the underground water exploitation.

2.2 Trend of Climate Change in China

The trend of climate warming in China will further intensify in the future. The projections by Chinese scientists indicate that:

(1) Temperature

The nationwide annual mean air temperature would increase by 1.3~2.1C in 2020 and 2.3~3.3C in 2050 as compared with that in 2000. The warming magnitude would increase from south to north in China, particularly in northwestern and northeastern China where significant temperature rise is projected. It is estimated that by 2030, the annual temperature would likely increase by 1.9~2.3C in northwestern China, 1.6~2.0C in southwestern China, and 2.2~2.6C in the Qinghai-Tibetan Plateau;

(2) Precipitation

It would possibly increase during the next 50 years in China, with a projected nationwide increase of 2~3 percent by 2020 and 5~7 percent by 2050. The most significant increase might be experienced in southeastern coastal regions;

(3) Extreme climate/weather events

The possibility of more frequent occurrence of extreme weather/climate events would increase in China, which will have immense impacts on the socio-economic development and people's living;

(4) Desertification

The arid area in China would probably become larger and the risk of desertification might increase;

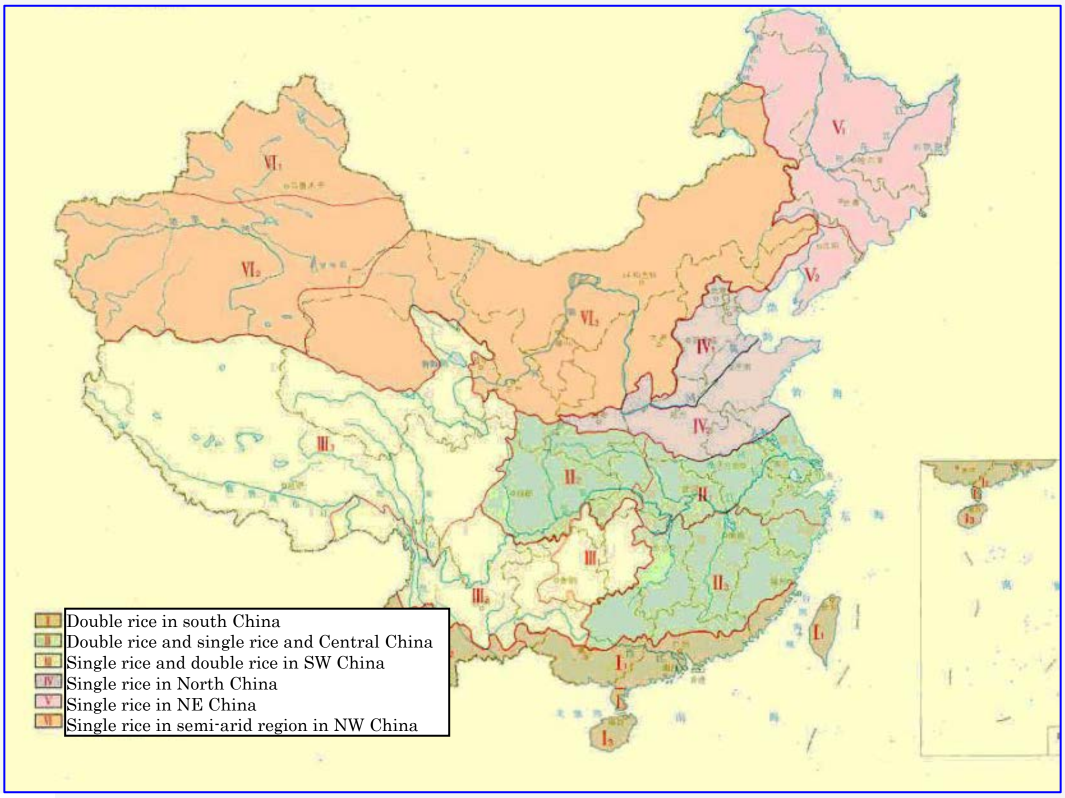
3. Climate Change Impacts on Rice, Wheat and Corn in China

There are many researches on climate changes impacts on crops. Here, I would like to introduce two newly launched research projects which I participated in.

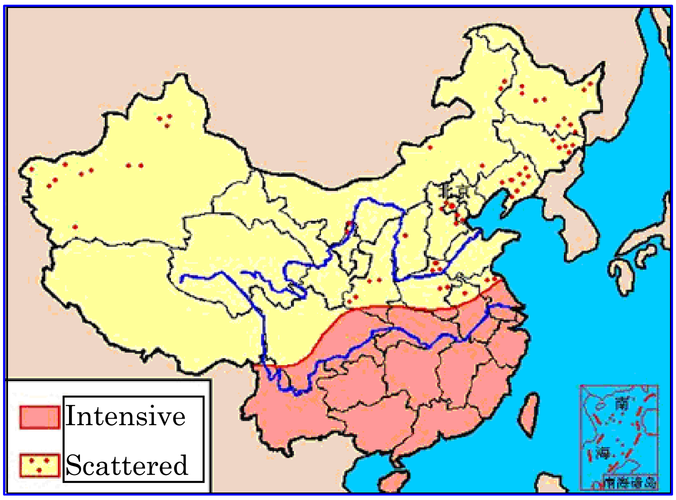
(1) Sensitivity, vulnerability of rice in south China under climate change

This is one of tasks of project, launched in 2011 and entitled The influence of global change on vulnerability and adaptivity of major terrestrial ecosystems in China, funded by The National Basic Research Program (also called 973 Program). The Preliminary output are as followings.

- The distribution of rice cropping system: region I is for double rice in the coastal area of south China; region II and III are for single rice and double rice in the other part of south China and central China, the difference between two regions is region III with high elevation. Region IV, V and VI are for single rice.



- The spatial distribution of rice area. Most of rice cultivation is in the south of Yangtze rive and area along the north bank of Yangtze river



- Experiment site: Jingzhou, Hubei province, located in Jianghan plain in Central China.



- Three treatments, each with three replicates. Treatment I: CK; Treatment II: increasing temperature by 2℃; Treatment III: increasing temperature by 2℃ and CO_2 by 60 ppm.




- Results of different treatment

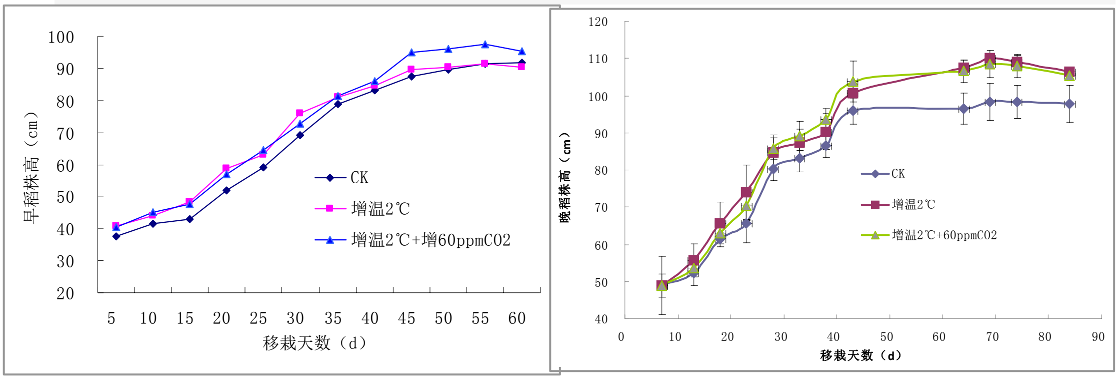


Figure 1 growth days and height (left, early rice; right, late rice)

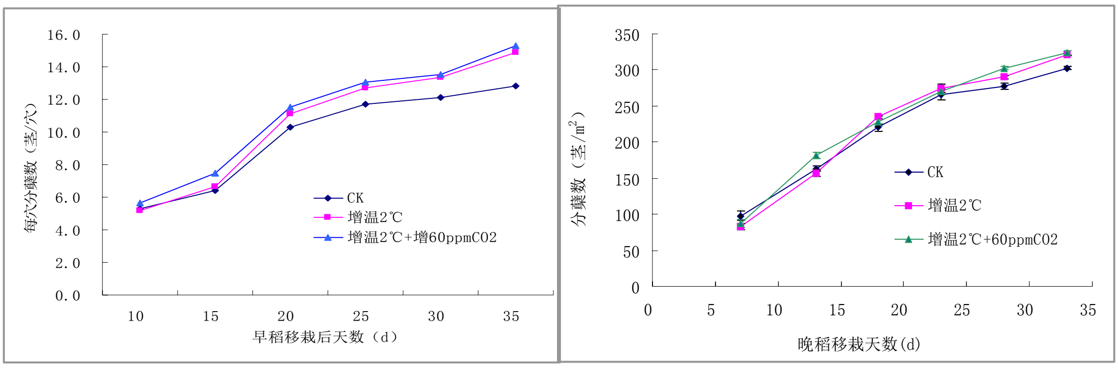


Figure 2 growth days and Number of tillers (left, early rice; right, late rice)

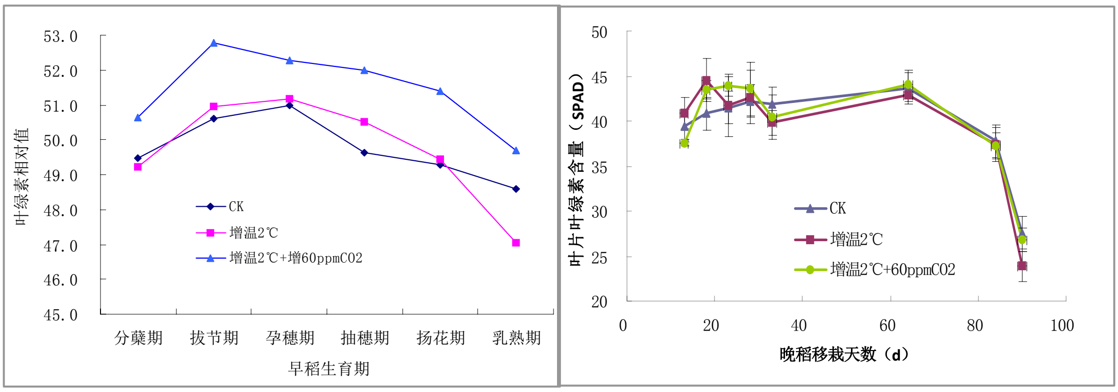


Figure 3 growth days and Chlorophyll content (left, early rice; right, late rice)

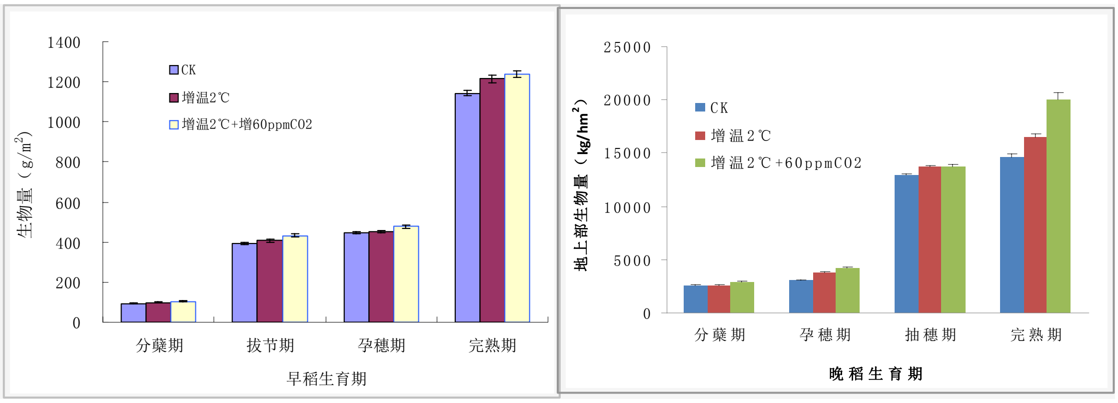


Figure 4 growth days and biomass (left, early rice; right, late rice)

Table 6 Properties of Yield

	CK	+2℃	+2 ℃ +60ppmCO2	CK	+2℃	+2℃ +60ppmCO2
Tillers	**12.7**	**13.9**	**13.7**	**16.1**	**15.7**	**18.8**
Spike rate(%)	**95.8**	**95.7**	**97.1**	**85.8**	**95.3**	**95.2**
Grains per spike	**131.2**	**142.4**	**138.7**	**193.0**	**202.4**	**201.7**

Empty husks rate(%)	**4.7**	**11.8**	**9.3**	**23.8**	**21.5**	**24.4**
Spike length (cm)	**21.4**	**21.9**	**22.3**	**26.2**	**27.3**	**26.8**
1000-seed weight (g)	**22.2**	**23.0**	**22.6**	**22.3**	**22.1**	**22.3**
Yield (kg/hm2)	**6697.2**	**7585**	**7477.9**	**8243.4**	**9530**	**11072.9**

(2) Forecast and mitigation techniques to high temperature damage to rice, wheat and corn in China.

This task is funded by the MOA, the research period is from Jan. 2012 to Dec. 2015. the purposes are: to identify the high temperature tolerance species of three crops, totally, 1000 species will be identified, of which, 350 species of rice, 430 species of wheat and 220 species of corn; and to set up a warning system of heat wave for winter wheat and of high temperature for rice and corn.