

Exploring the Introduction and Adaptability of Winter Rapeseed in Northern China

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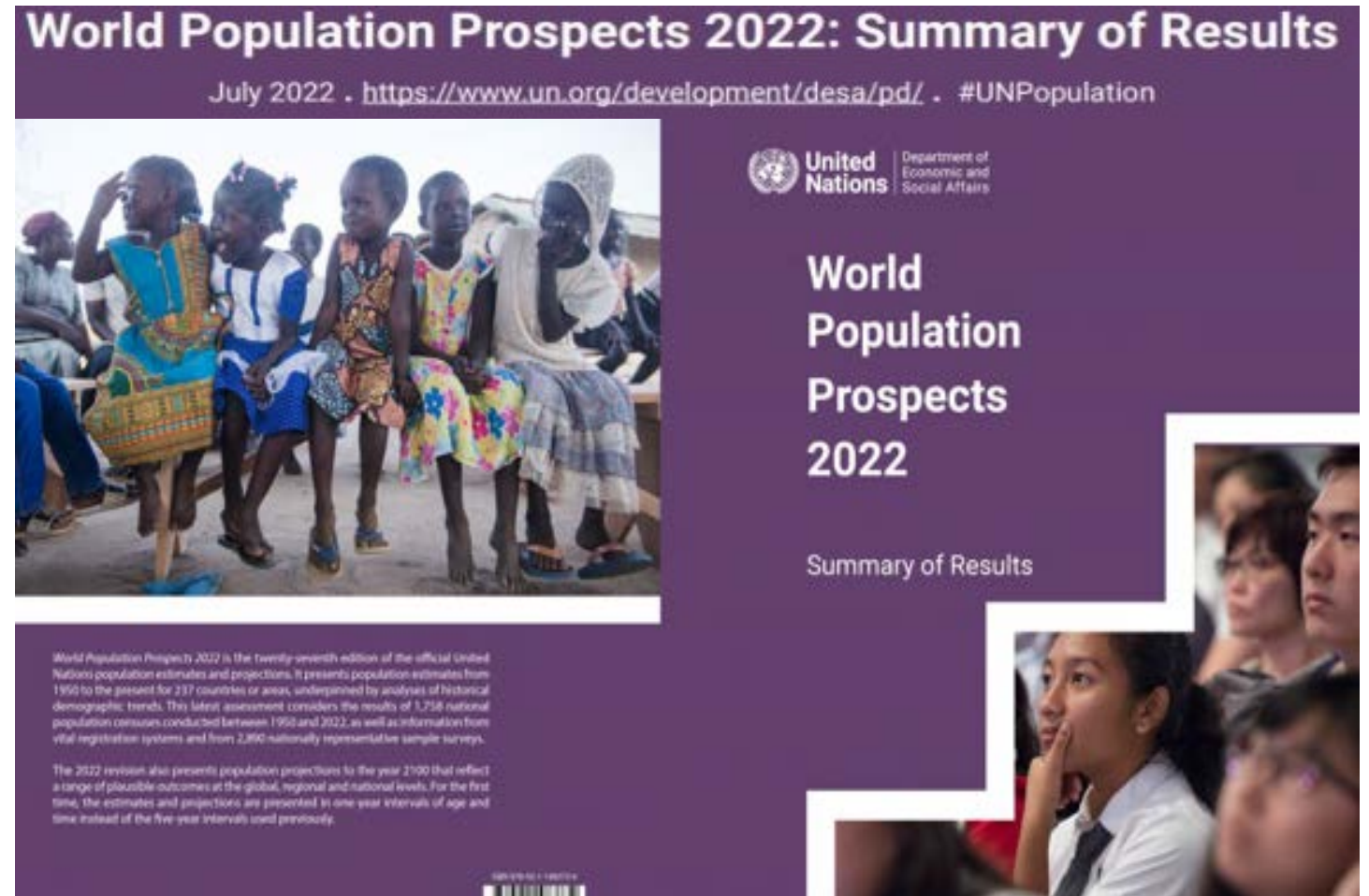
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1. Background and objectives

The world population is growing rapidly, and there is a sharp contradiction between population growth and the growth of food crops, oilseed crops and total production.



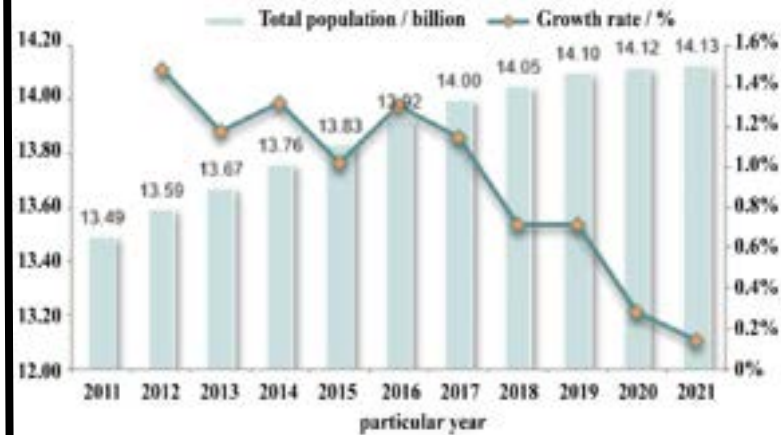
The projections by the United Nations suggest that the world's population could grow to around 8.5 billion in 2030 and 9.7 billion in 2050.

1. Background and objectives

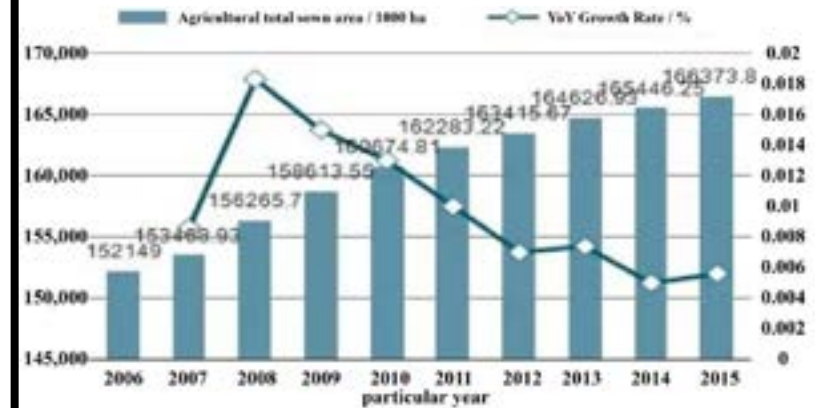
P.R.China

In China, as in the world, there is a sharp contradiction between the increasing population and the need of increasing crop production as well

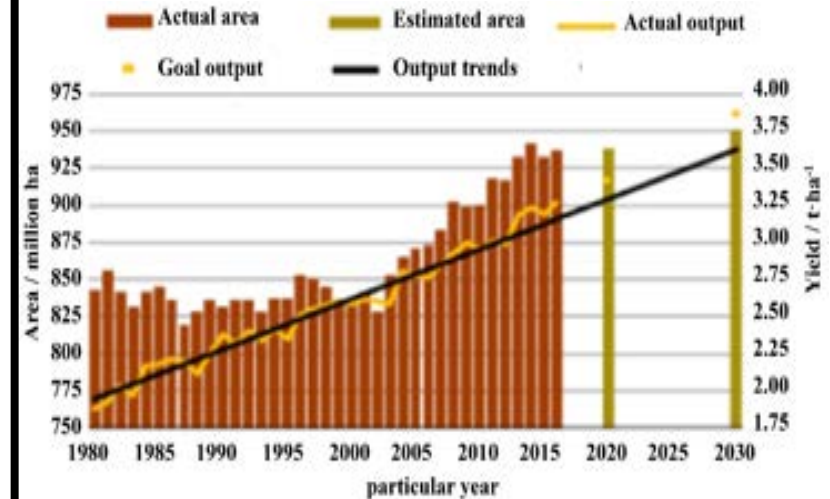
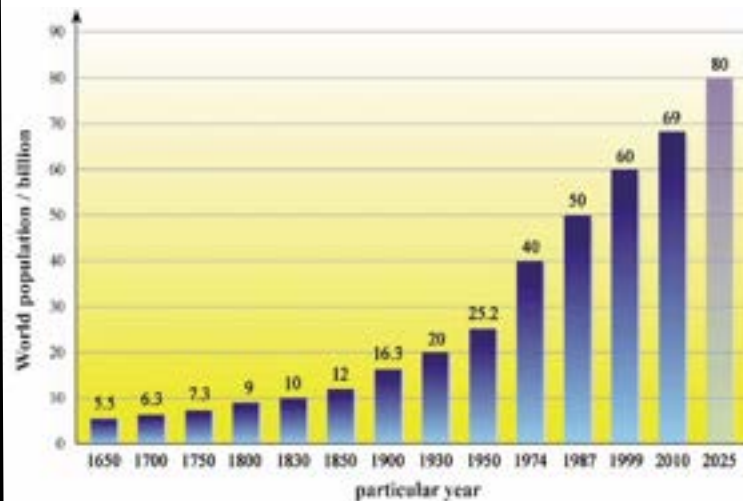
Change of population size



Change of agricultural planting area

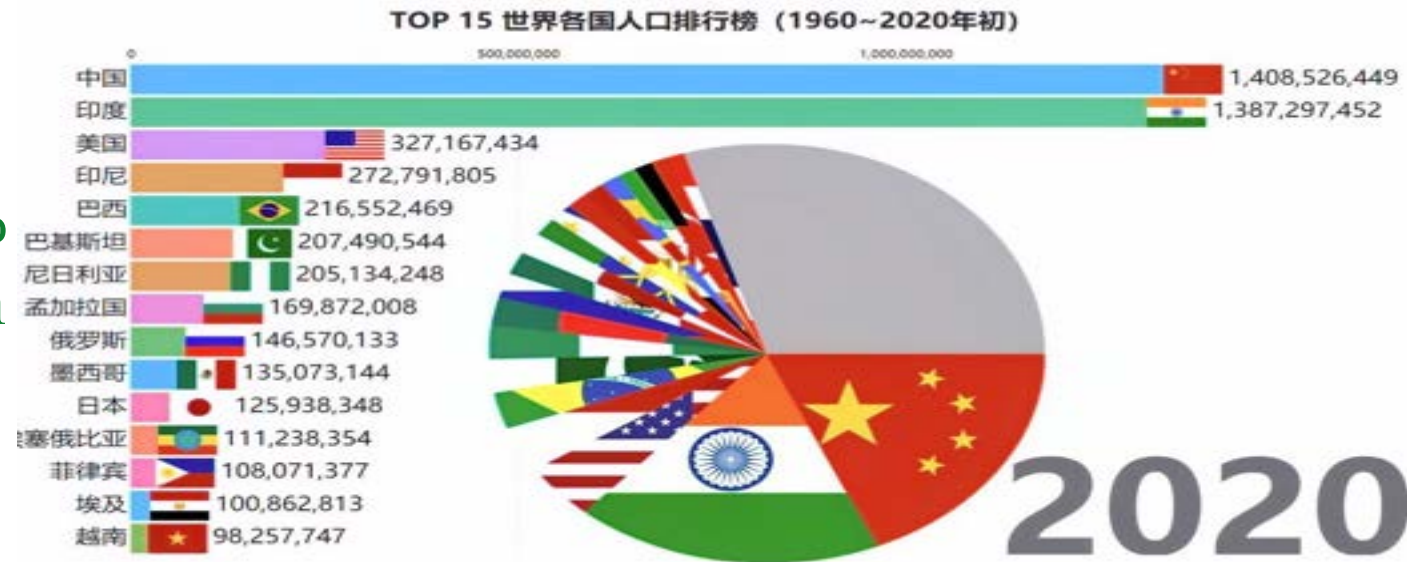


Global



1. Background and objectives

China has a large population. We feed 20% of the world's population with 7% of the world's land.

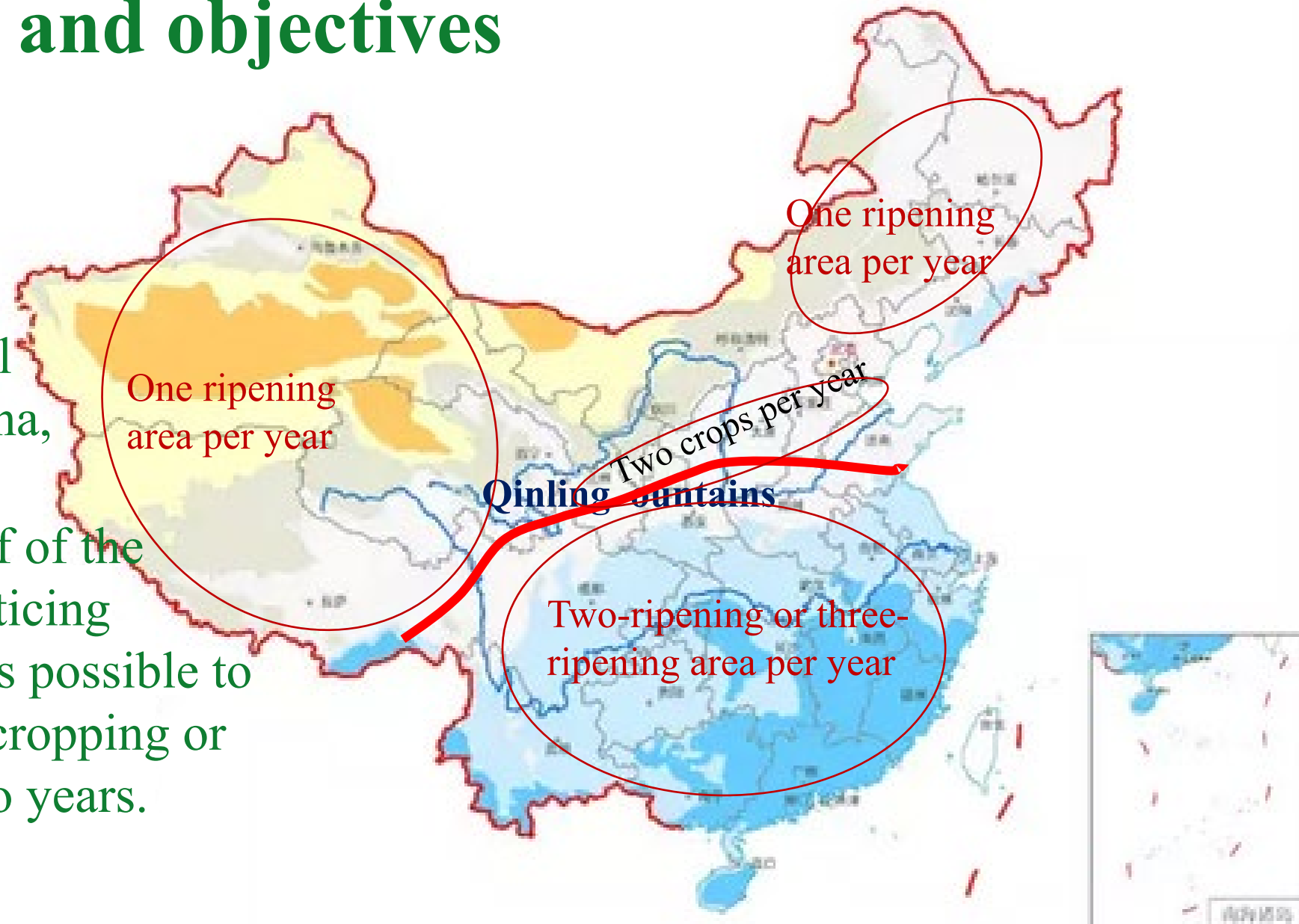


How to support food production in the future is a major challenge for Chinese agricultural scientists.

1. Background and objectives

The reformation of planting system is the way to increase total output of grain and oil crops in northern China,

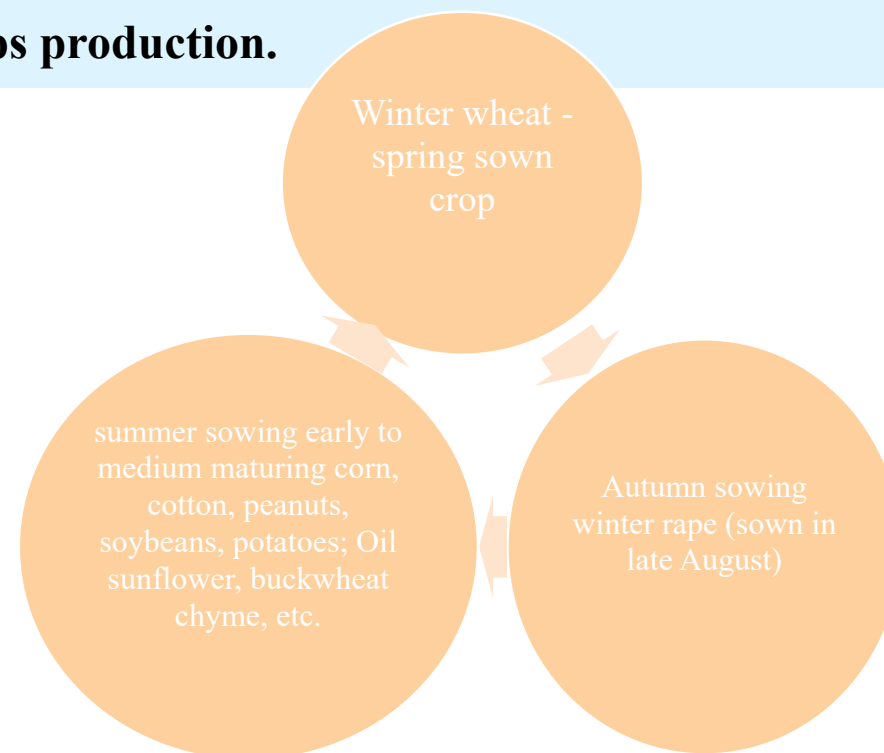
It is estimated that half of the cultivated land is practicing monocropping and it is possible to change it into double cropping or tripple cropping in two years.



1. Background and objectives

Winter rapeseed ripens early and is the best crop in northern China to change monocropping to double cropping or tripple cropping per two years.

In northern China, winter rapeseed matures at the end of May and early June, and the remaining $\geq 0^{\circ}\text{C}$ accumulated temperature above 2000°C , to meet the requirements of summer sown corn, miscellaneous grains and other $\geq 10^{\circ}\text{C}$ accumulated temperature of 18°C - 26°C , it is feasible to apply the "winter crop+" planting mode to increase the total grain and oil crops production.



1. Background and objectives

There're two problems in the growth of winter rapeseed:

No.1, Low temperature and drought in winter restrict the growth and over-wintering of winter rape in north China.

	Tian shui	Wu wei	Zha ng Ye	Jiuquan	Gan nan	Tachen g	Altai	Shache	Gongzhu ling	Rao River
Average coldest monthly temperature (° C)	-2.4	-8.7	-10.2	-9.7	-9.3	-9.70	-15.3	-5.80	-13.0	-18.0
The coldest month average minimum temperature (° C)	-7	-13.8	-17.1	-15.6	-18.0	-24.70	-23.5	-10.7	-17.9	-27.1
Extreme minimum temperature ° C	-18.2	29.5	-30	-31.6	-28.5	-40.00	-41.7	-24.5	-33.7	-35.9
Average annual temperature ° C	10.9	7.6	7.1	7.3	3.0	7.65	4.75	12.01	5.6	4.02
Number of frost-free days (d)	186	172	156	162	56-60	150	120	177.0	144	130
Rainfall(mm)	507.6	154	136.8	92.0	532.6	290.8	212.6	61.30	577.1	516.5
Annual evaporation (mm)	1462	1904	2082	2063	1270	1744.9	1597.8	2235.6	1579.4	1312.1
Latitude °N	34°5'	43°	39°46'	38°56'	35°	46°74'	47°86'	38°45'	44°09'	47°34'
Elevation(m)	1100	1500	1477	1482	3160	1000	1000	1230	594	545.0

1. Background and objectives

Due to the influence of low temperature, the planting area of winter rape in China is basically limited to the area of around 35° north latitude.

Northern boundary of winter wheat wintering:
40° 46° N;

Extreme low temperature -24~-20.9° C;
The coldest month minimum temperature is -9~-10° C;
Negative accumulated temperature in winter -700~-800° C.

Northern boundary of winter rape: about 35°N; Lu, Hebei, and southern Jin, south of Yan'an, Shaanxi, south of southeastern Long.

Average annual temperature 7-8°C?

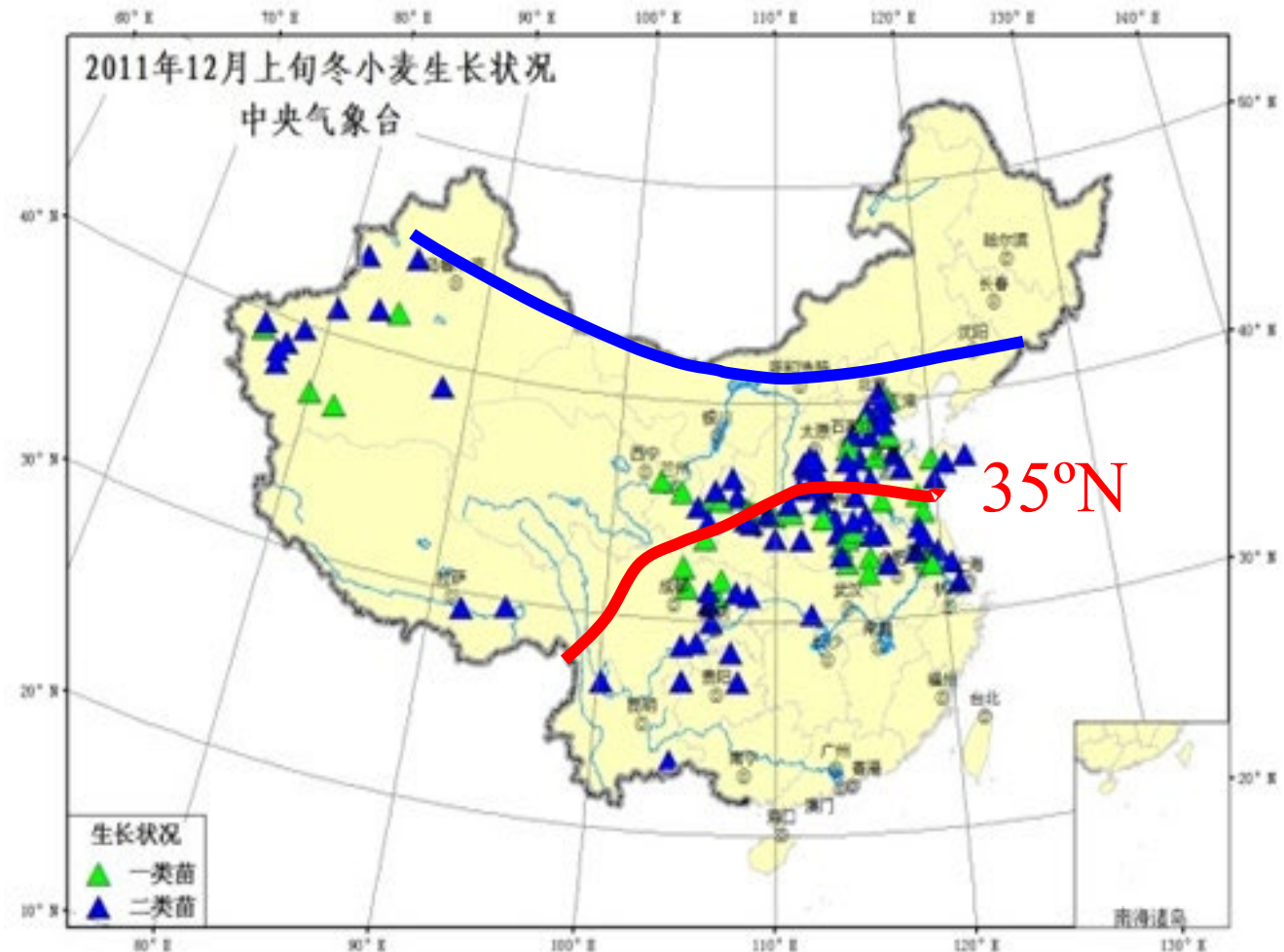
The average temperature in January is -5.05°C;

The coldest month minimum temperature is -9~-10°C;

Extreme low temperature -23.6°C;

Negative accumulated temperature in winter -423°C.

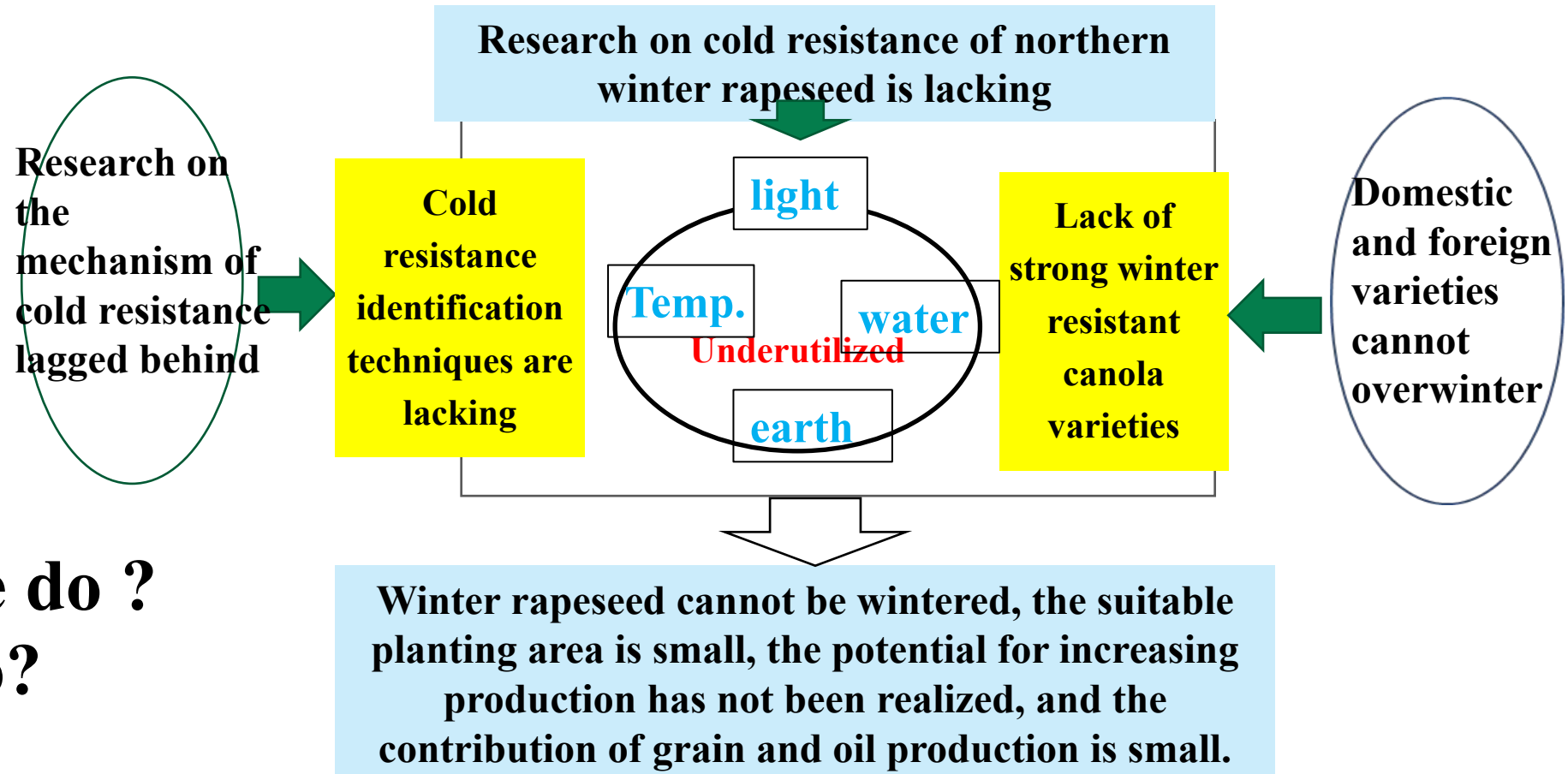
Winter-spring wheat and rapeseed dividing line



1. Background and objectives

Problems for winter rapeseed growing:

No.2, there are neither cold resistant germplasms and varieties nor technical support.



What should we do ?
What we can do?

Objective and Methods

Our goal is to breed varieties with strong cold resistance, and reform the traditional planting system to double cropping or tripping cropping per two years via the aid of winter rapeseed varieties.



2. The main results and progress

2.1 The characteristics related to cold tolerance of winter rapeseed

First, we found that creeping growth habit and growth cone depression are the basic characteristics of cold resistance in winter rapeseed.



Cold-resistant varieties have creeping growth habits



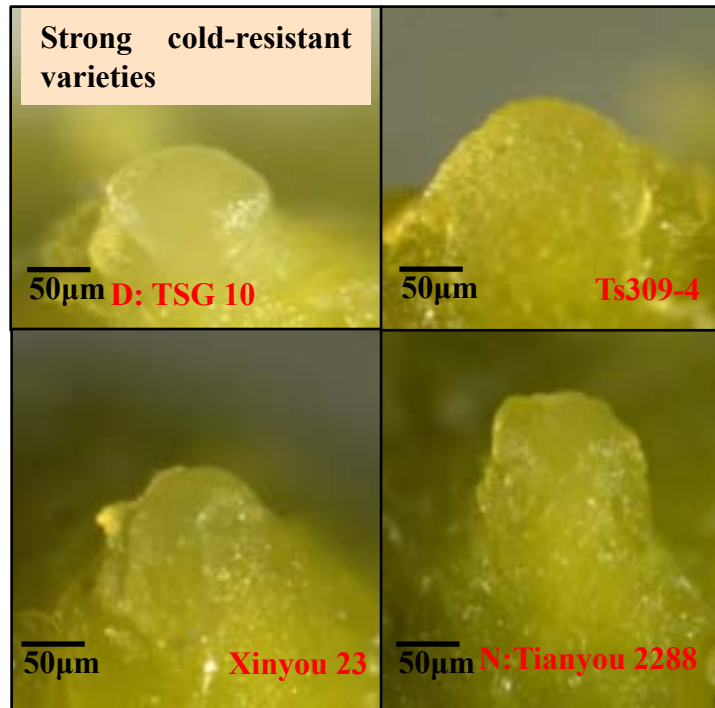
Strong cold-resistant varieties

Cold-resistant varieties grow cone depressions

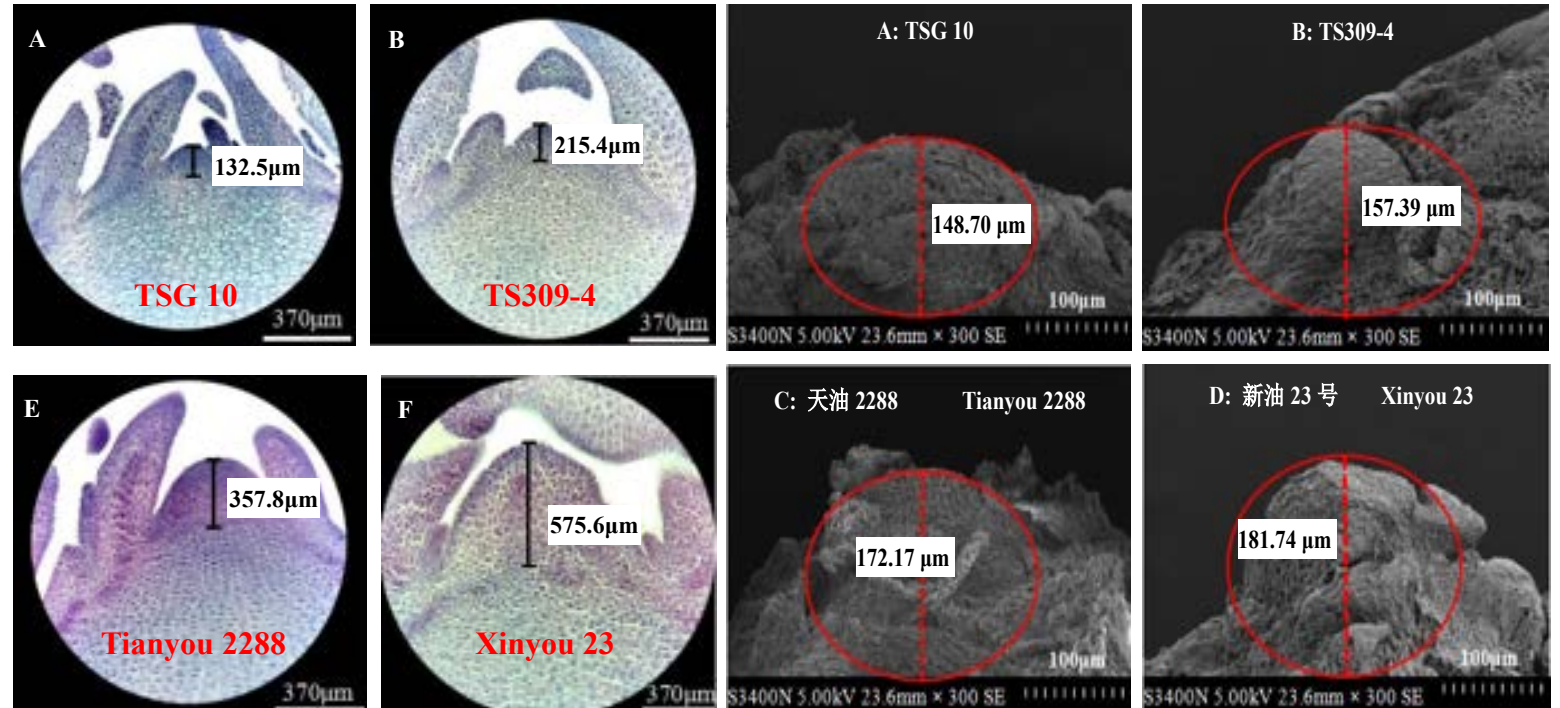


2.1 Characteristics of winter rapeseed with strong cold resistance

The growth cones of cold-resistant varieties such as *tsg10* are significantly lower than those of weak cold-resistant varieties such as Tianyu 2288 and Xinyou 23.



Results of Stereomicroscope

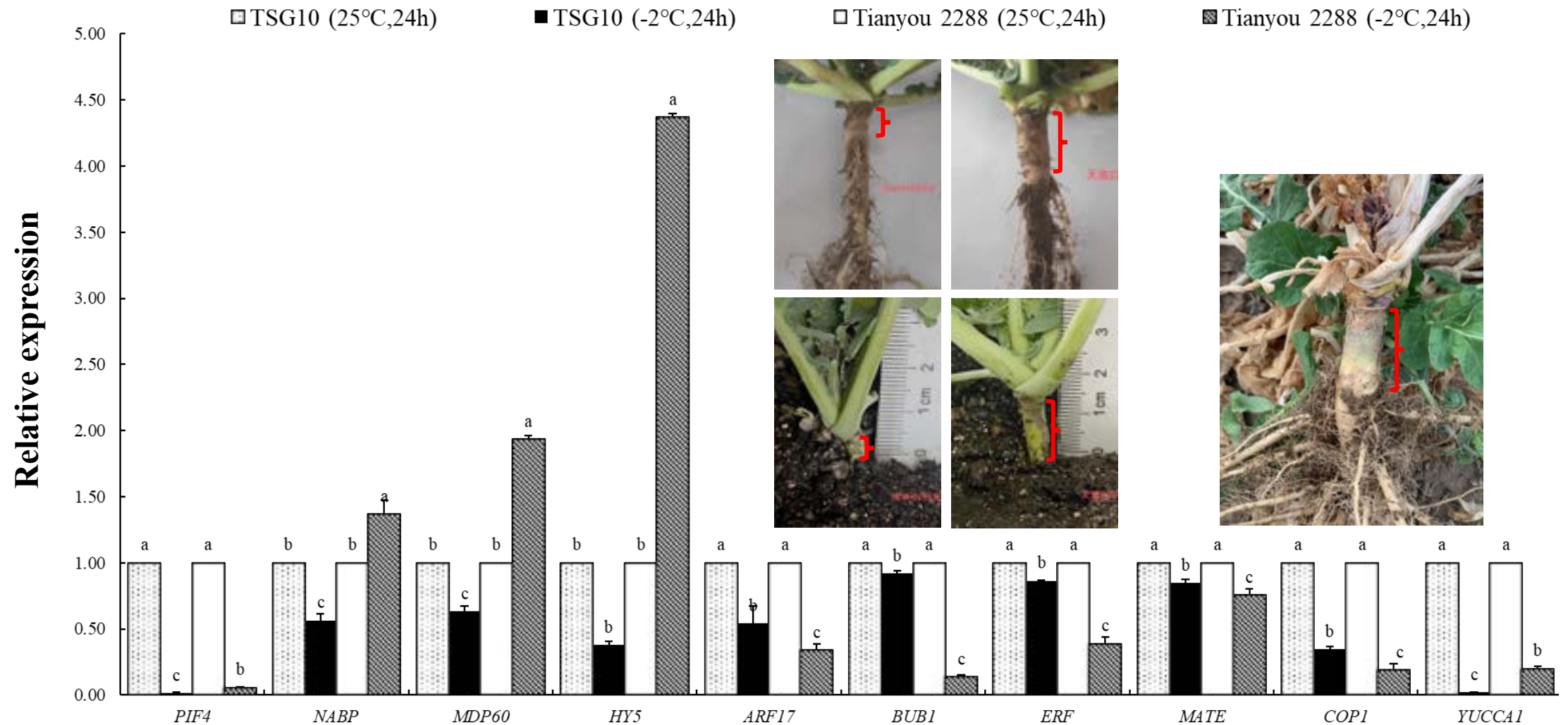


Results of Paraffin Sections

Results of Scanning Electron Microscope

2.1 Characteristics of winter rapeseed with strong cold resistance

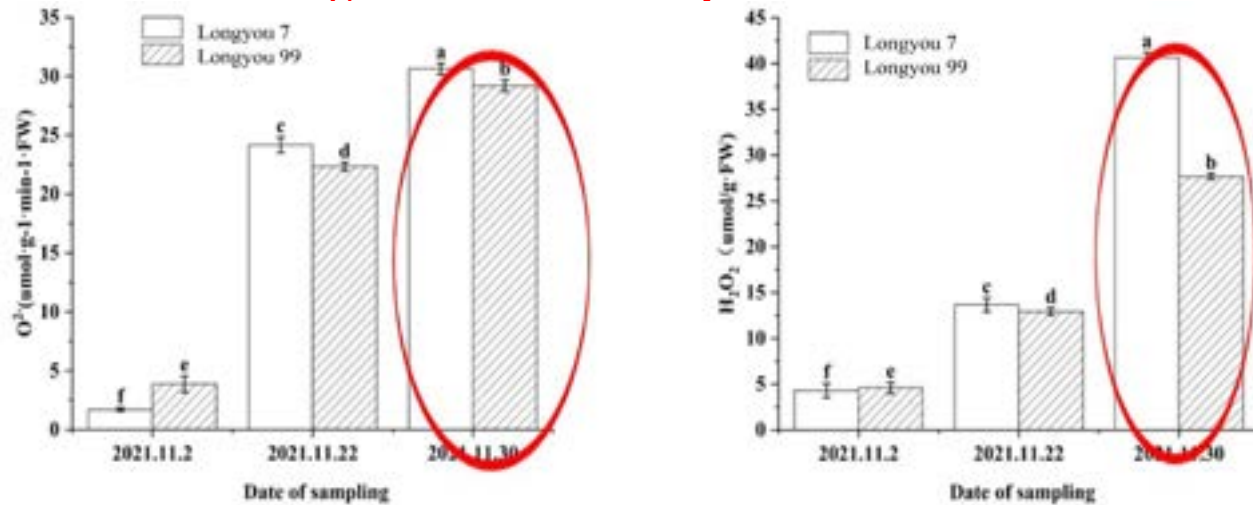
- Our study found that hypocotyl is another important organ affecting winter rapeseed overwintering.
- The hypocotyl of strong cold-resistant varieties is significantly shorter than that of weak cold-resistant varieties.
- Hypocotyl regulation-related genes have obvious expression differences in different cold-resistant materials.



2.1 Characteristics of winter rapeseed with strong cold resistance

- The cold resistance of winter rapeseed is closely related to the dry leaf period and other related traits.

- The cold-resistant variety, Longyou 7, undergoes the dry leaf stage earlier in anticipation of winter.



- The contents of O_2^- and H_2O_2 in leaves of different cold-resistant varieties before withering stage were determined.
 - The contents of O_2^- and H_2O_2 in Longyou 7 were significantly higher than those in Longyou 99.



Longyou 99

Longyou 7



Longyou 99

Longyou 7

2.1 Characteristics of winter rapeseed with strong cold resistance

- We confirmed the correlation between cold resistance and vernalization by spring sowing and autumn sowing.
 - Spring-sowing strong cold-resistant varieties cannot pass vernalization.
 - Weak cold-resistant varieties can undergo segregation through vernalization or novernalization.



2.1 Characteristics of winter rapeseed with strong cold resistance

The segregation of the F2 generation derived from the crosses between winter and spring varieties

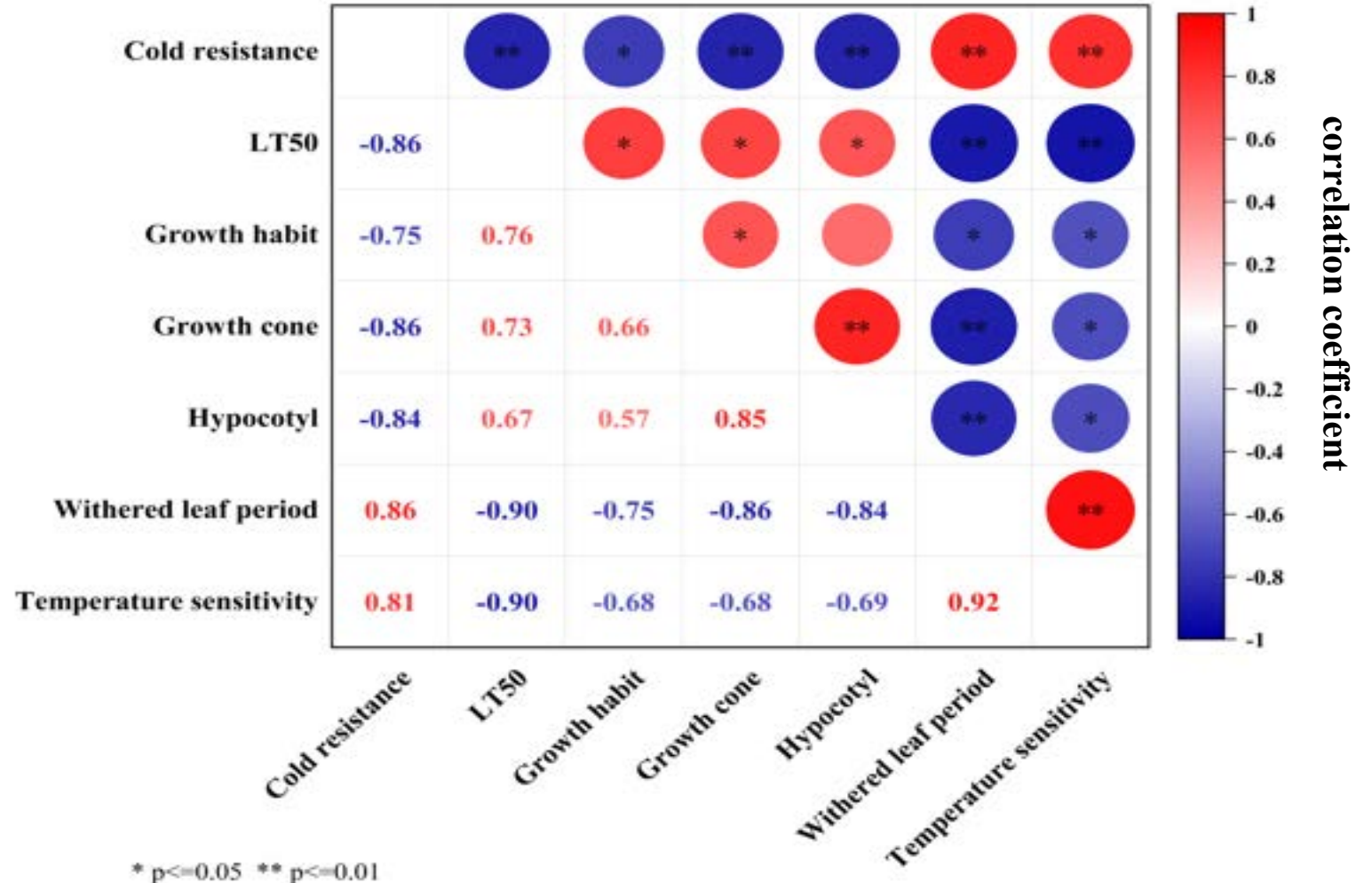


- The plants through vernalization could not overwinter, and the strong winter plants that did not pass vernalization successfully overwinter.

2.1 Characteristics of winter rapeseed with strong cold resistance

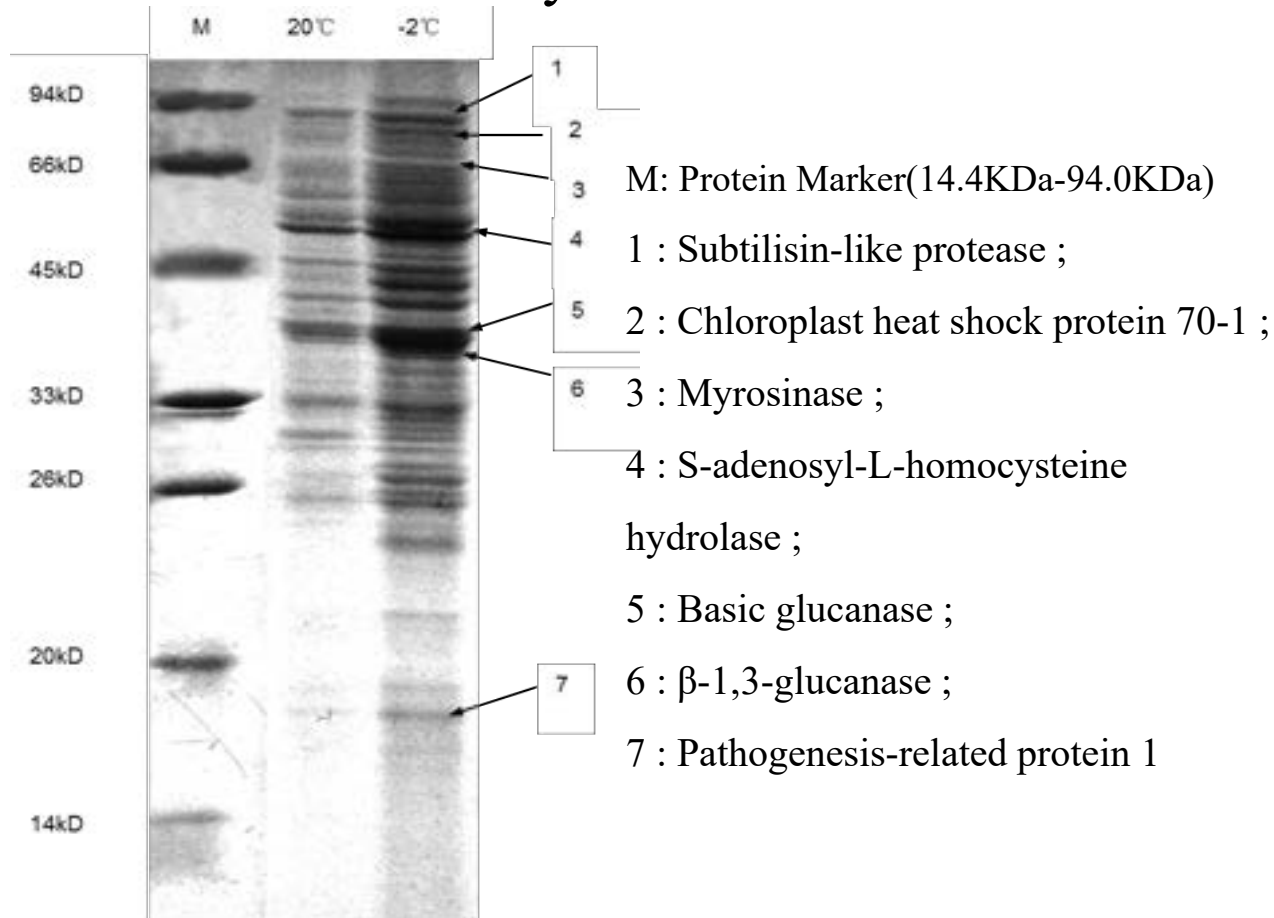
Based on the results of the correlation analysis, we found that cold resistance is mainly related to the following characteristics.

- Winter rapeseed varieties with strong cold resistance
 - Creeping growth
 - Growth cone low
 - Hypocotyl short
 - The time to enter the overwintering period is early
 - The vernalization time is long and the temperature is lower.



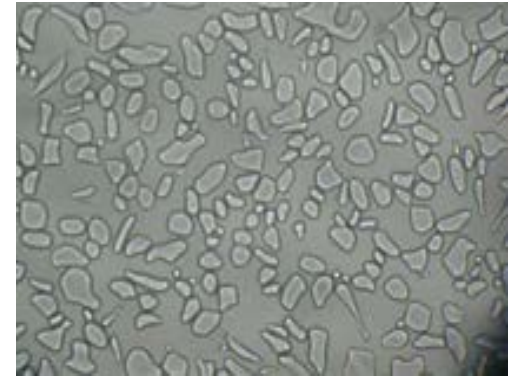
2.1 Characteristics of winter rapeseed with strong cold resistance

we found that the antifreeze activity of extracellular protein of the cold –tolerant varieties increased after low temperature stress treatment, which also inhibited the growth of intercellular ice crystal.



Leaf apoplast protein of Longyou 6

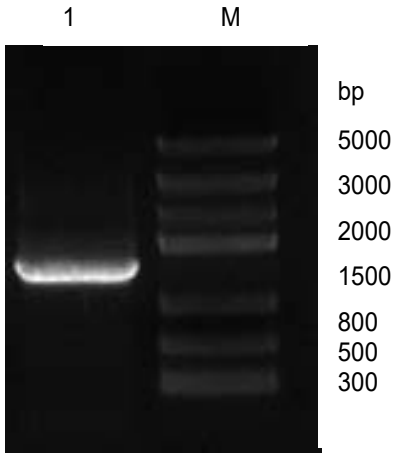
The growth state of ice crystals in apoplast extract of Longyou 6 leaves at normal temperature.



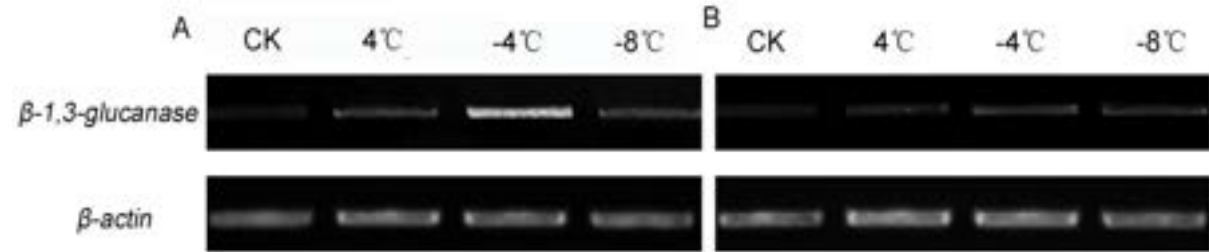
Recrystallization inhibition effect of apoplast protein crude extract from Longyou 6 leaves induced at low temperature.

2.1 Characteristics of winter rapeseed with strong cold resistance

we also found that β -1, 3-glucanase gene was related to cold resistance.



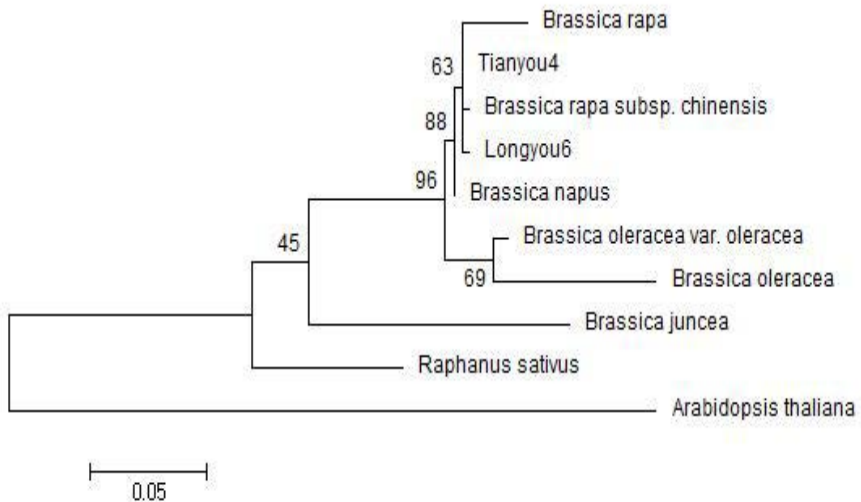
Cloning of β -1,3-glucanase gene



Semi-quantitative RT-PCR analysis of β -1,3-glucanase gene in winter oilseed rapeseed under low temperature stress.

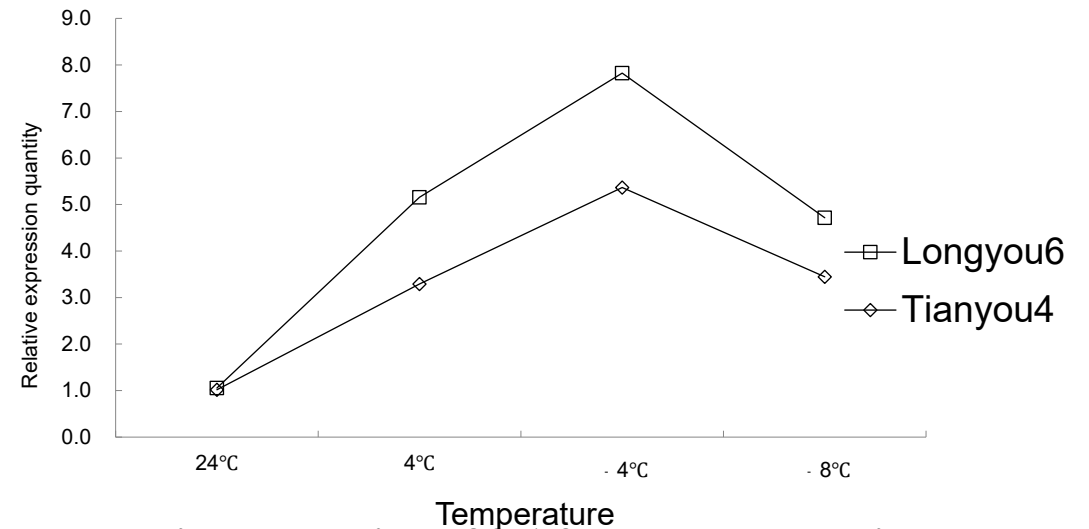
(A) Semi-quantitative RT-PCR analysis of β -1,3-glucanase in Longyou 6

(B) Semi-quantitative RT-PCR analysis of β -1,3-glucanase in Tianyou 4



Phylogenetic tree analysis of β -1,3-glucanase protein sequence of Longyou 6

Cloning and expression of β -1,3-glucanase gene from winter rapeseed (*Brassica rapa* L.)



Relative expression of β -1,3-glucanase gene in leaves of winter rapeseed under low temperature stress

2.2 'Double short 'cold resistance breeding technology system

Based on this study, we have established the winter rapeseed 'double short 'cold resistance breeding technology system in our lab., including short Growth cone, Short hypocotyl, Creeping growth, early dried leaf period, ect



Creeping growth



Growth cone low



Cold resistance identification technical indicators



The time to enter the overwintering period is early



Short hypocotyl



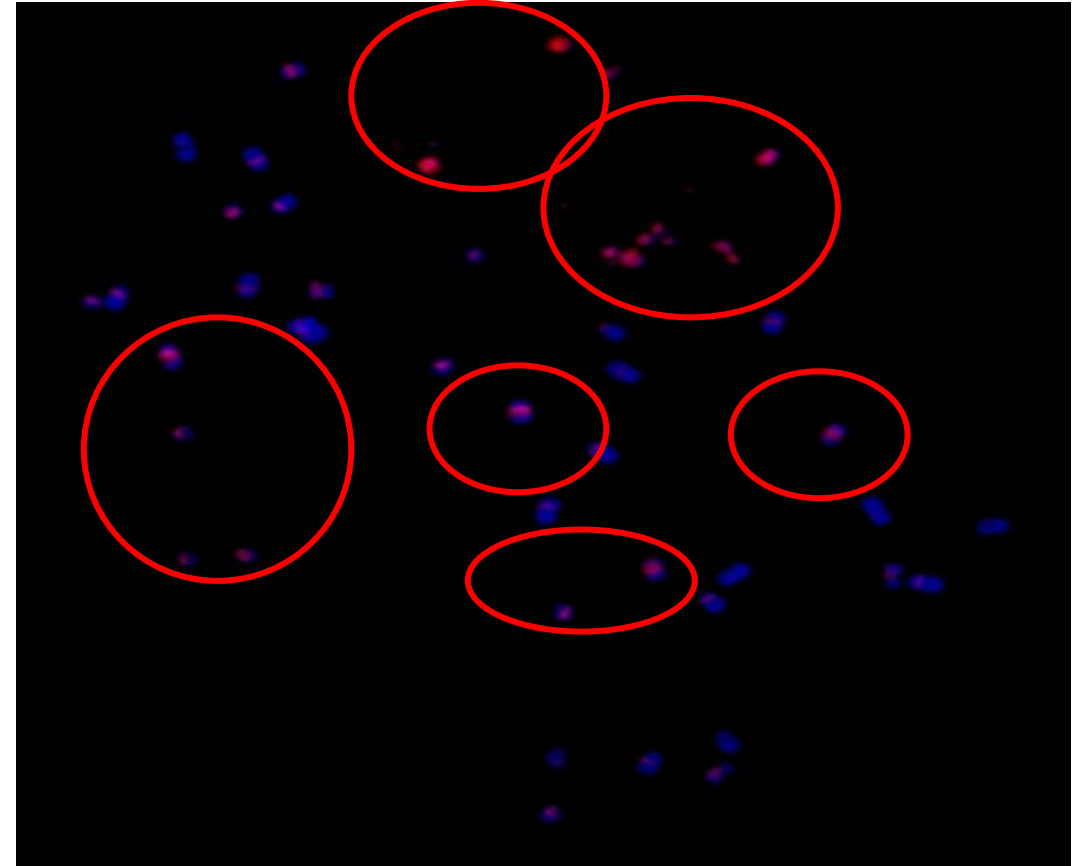
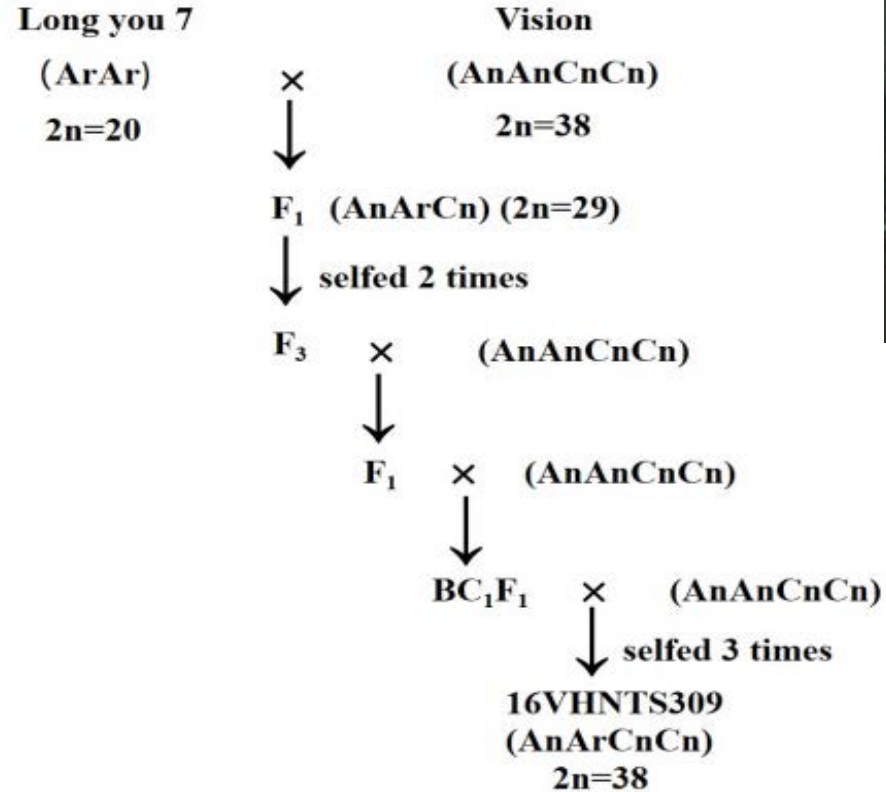
Plants that have not passed vernalization



Field cold resistance record specification

2.3 The breeding of winter rapeseed with excellent cold-resistant

A group of varieties of winter rapeseed with excellent cold-resistant have been developed by vernalization identification, directional selection and distant hybridization, such as longyou 6, longyou 7.



High-quality cold-resistant winter rapeseed germplasms and varieties were created by distant hybridization.

Under the extreme low temperature of -30 ° C in winter, the overwintering rate was more than 85 %.

The genome of Longyou 7 (Ar) was used as a probe, and the signal was mostly located in the intermediate centromere and satellite. The cold resistance of 16VHNTS309 was related to the gene introduction of winter rapeseed Longyou 7.

Longyou No. 6 and Longyou No7. etc, the survival rate of these varieties was higher than 85% in Hexi Corridor of Gansu Province, Altay of Xinjiang, and GongZhuLing of Jilin at the extreme low temperature -30°C during the winter time , showing excellent cold resistance. with a growth period of 280 to 290 days.



The overwintering situation of super cold-resistant varieties such as Longyou 6 and Longyou 7 were in Jiuquan City (-30°C extreme low temperature)

The performance in the field of Longyou No. 6 , Longyou No7. etc

Longyou No. 6 and Longyou No7. **have** a yield of more than 3000 Kg per hectare.



The performance in flowering



Final flowering



The plant of
Maturation period

The performance of cold tolerance winter rapeseed in different regions in northern china



Longyou 7, ,regreening period, Huanxian, latitude 37 ° N, altitude 1880 m.



Longyou 7, flowering stage, Zhuoni, latitude 35 ° N, altitude 3160 m.



Longyou 7, mature period, Zhuoni, latitude 35 ° N, altitude 3160 m.



Longyou 8, flowering period, Huining, latitude 35 ° N, altitude 2100 m.



Longyou 27, Imature period, Jingning, latitude 35 ° N, altitude 2000 m.



Longyou 7, flowering period, Hezuo, Gannan, latitude 35 ° N, altitude 2800 m.

The performance in the field of Longyou No. 6 , Longyou No7. etc, in different regions



Longyou 88, Jingchuan,
Pingliang ,latitude 35 ° N, altitude 1225



Longyou 88,
Shijiazhuang, Hebei, latitude 38 ° N,
altitude 1000, final florescence



Longyou 88, Tianshui, Gansu, latitude
35 ° N, altitude 1800, final florescence



Longyou 88, Lixian, gansu ,latitude 35 °
N, altitude 1800,



Longyou 88, Kuntong, Pinliang, latitude
35 ° N, altitude 1225, final florescence

The performance in the field of Longyou No. 6 , Longyou No7. etc, in different regions



Shache County, Xinjiang, latitude 38 ° N



Tacheng City, Xinjiang, 47°N



Wulumuqi City, Xinjiang 44°N



Longyou 24, Pingan District, Qinghai,
latitude 36° N, altitude 2200 m



Aletai City, Xinjiang, 48°N



Lasa City, Xizang, 3600

The performance in the field of Longyou No. 6 , Longyou No7. etc, in different regions



Beijing City, 41°N



Beijing City, 41°N



Dalian, Liaoning, 41°N



Linhe District, Inner Mongolia, 41°N



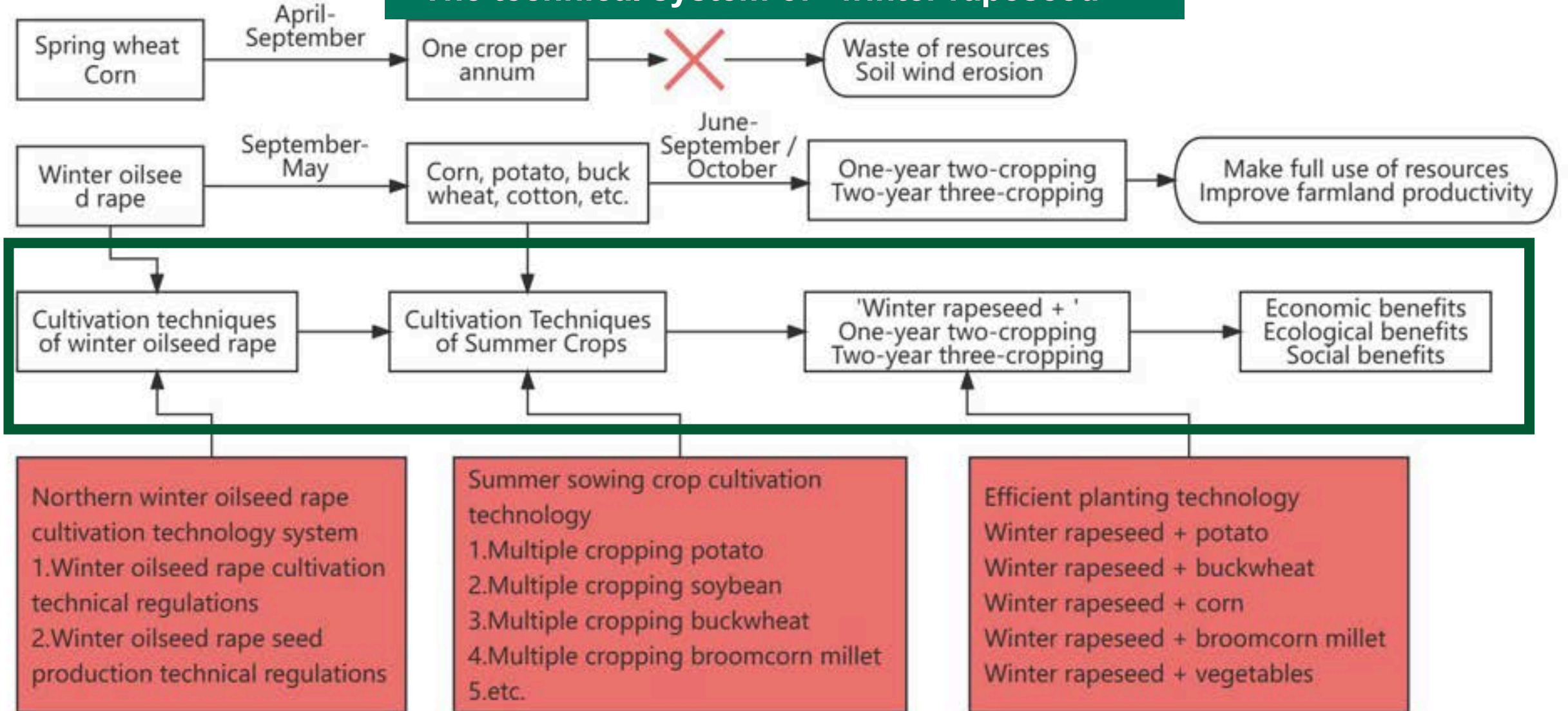
Gongzhuling City, Jilin, 44°N



Raohe county, Heilongjiang, 48°N

2.4 High-efficiency planting technology model has been established by the application of cold-tolerant winter rapeseed

The technical system of ' winter rapeseed + '



2.5 The regionalization and development potential of winter rapeseed in northern China

Our study shows that the main factors affecting overwintering are as follows:

meteorological factor	Contribution rate (%)
Negative accumulated temperature in winter	0.18
Extreme winter low temperature	0.17
The lowest temperature of the coldest month	0.17
mean annual temperature	0.11
The average temperature of the coldest month	0.10

Contribution rate of main climatic factors affecting winter oilseed rapeseed overwintering in cold regions of northern China

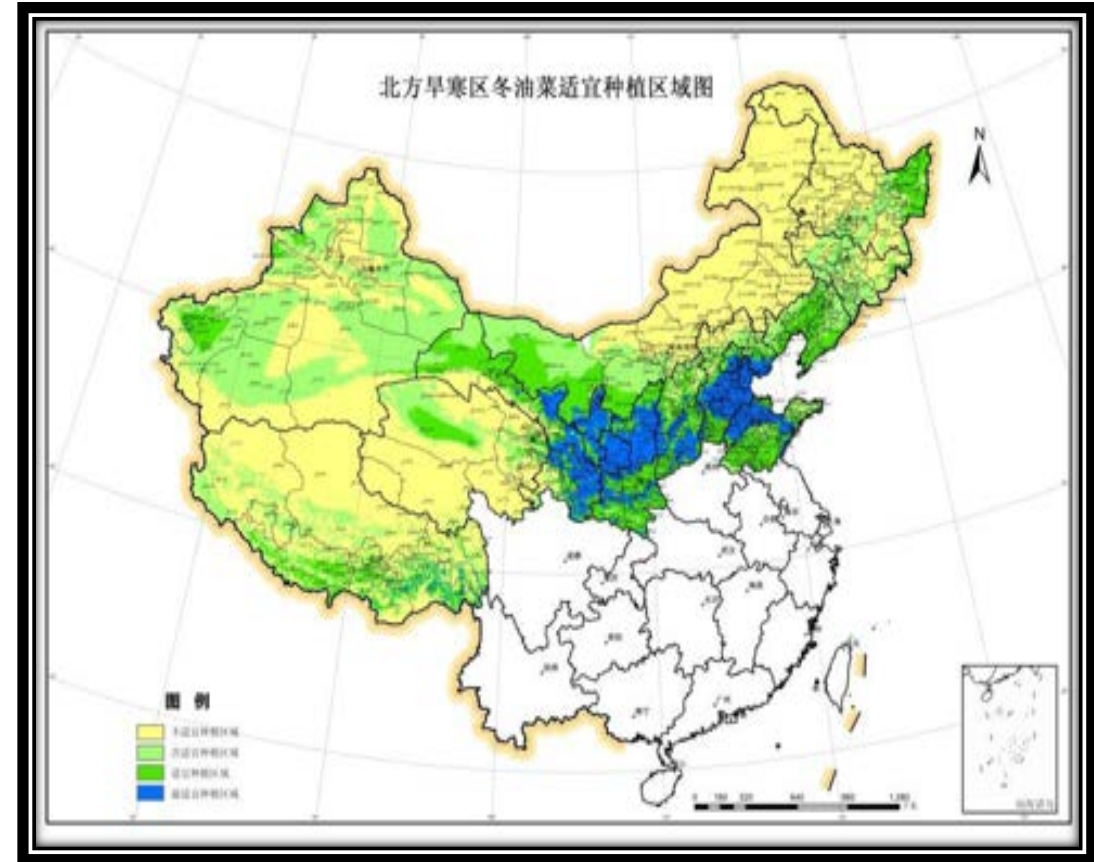
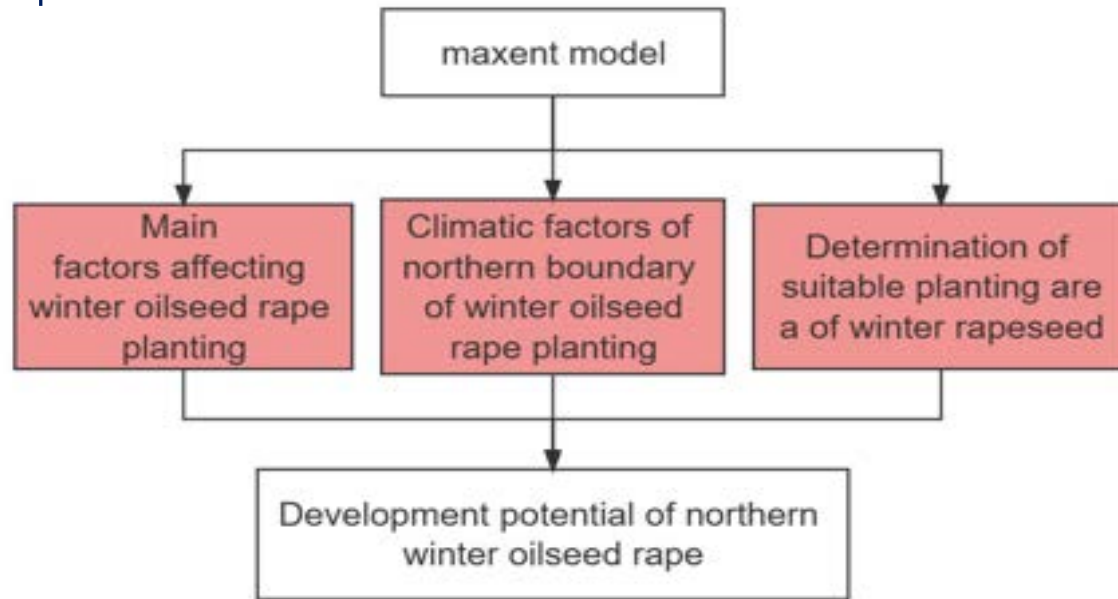


Winter oilseed rape planting regionalization in northern China

- I. Northeast winter rapeseed subregion ;
- II. North China winter oilseed rape subregion ;
- III. Ordos Plateau winter rapeseed area ;
- IV. Winter oilseed rape subregion of Loess Plateau ;
- V. Ganxinlvzhou winter rapeseed sub-region ;
- VI. winter rapeseed sub-region of the Tibetan Plateau.

Development potential of winter rapeseed in northern China

Based on the Maxent simulation results, north China for the winter rapeseed production was divided into four areas depend on the adaptability of winter rapeseed.



Winter oilseed rape planting area in northern China:

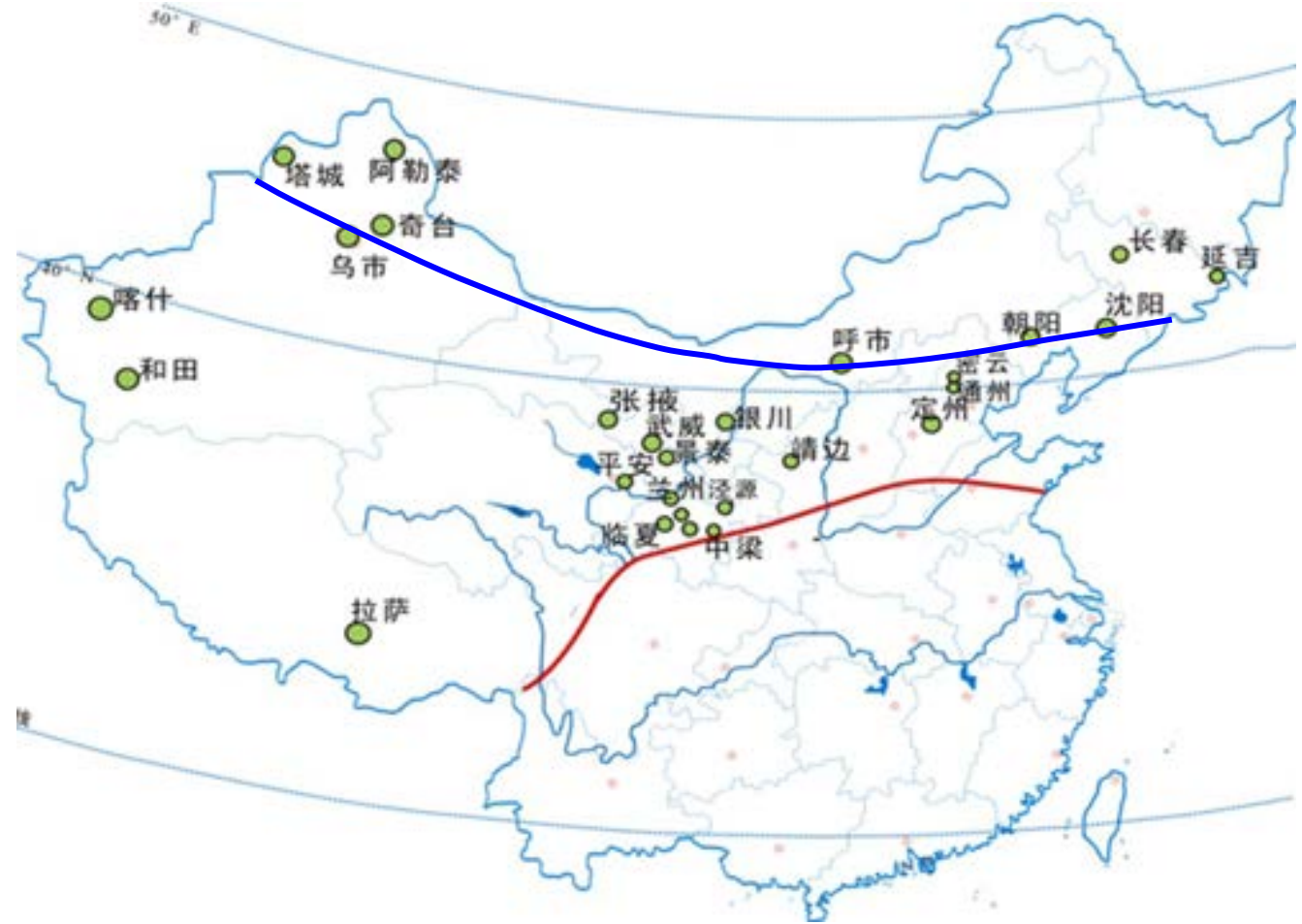
- 4. Unsuitable area
- 3. Sub-suitable region
- 2. Suitable region
- 1. The most suitable area

The Maxent model was employed for simulating the prospective spatial distribution of winter rapeseed in the arid and frigid regions of northern China. The assessment outcomes revealed a potential cultivation area of 50 million mu for winter rapeseed development.

3. Application and its effect

3.1 The planting area of winter rapeseed in China moved to the north by 13 latitudes, from 35°N Tianshui in Gansu to 48°N Altay in Xinjiang and Raohe in Heilongjiang.

- Winter rapeseed, a new winter crop, has been added to northern China.
- China has added a new winter rapeseed producing area of about 3 million hectares.



3.2 The winter rapeseed promoted the reformation of planting systems in the monocropping areas in northern China, to double cropping or tripple cropping per two years.



Winter rapeseed-potato, two crops three year



Winter rapeseed-soybean, 2-year triple cropping



Winter rapeseed-rice, 2-year triple cropping



Winter rapeseed-maize, 2-year triple cropping



Winter rRape - Sunflowe, 2-year triple cropping r



Winter rapeseed-cotton, 2-year triple cropping



Winter rapeseed-seed melon, 2-year triple cropping



Winter rapeseed-buckwheat, 2-year triple cropping



Winter oilseed rape-tartary buckwheat, 2-year triple cropping



Winter rapeseed-millet, 2-year triple cropping



Winter rapeseed-broomcorn millet, 2-year triple cropping



Winter rapeseed-vegetables, two crops a year



Winter rapeseed-pear cover



Almond-winter oilseed rape cover interplanting

3.3 Promote the integrated development of agricultural industry in northern China

Based on the application of cold-resistant winter rapeseed, **rapeseed flower viewing Festivals** have been held, and **the beekeeping industry** has been developed, which also promoted the integrated development of agricultural industry in northern China.



3.4 This study also provided important scientific and technological support to improve agricultural ecological benefits, economic benefits and social benefits



The application of winter rapeseed promoted the growth of grain and oil crops production, as a new winter cover crop in northern China, which has achieved remarkable ecological benefits by reducing soil erosion and protecting the environment with over 95% field coverage in winter and spring.

4. Conclusion and Foresight

- We have successfully developed several cold tolerant winter rapeseed varieties. The new varieties can withstand low temperatures as low as -30°C in northern China during winter.**
- With the utilization of cold-resistant winter rapeseed varieties, the planting area of winter rapeseed in northern China has successfully moved north by 13 degrees latitudes(from 35°N to 48°N), and it is estimated that the potential cultivation area for winter rapeseed will increase to over 3 million hectares in northern China.**
- The application of cold-resistant winter rapeseed has led to the formation of an efficient planting model of 'winter rapeseed + summer crops,' which will help improve the oilseed and grain crops' production in China.**

Team Members:

- Professor Wu Junyan
- Associate Researcher Li Xuecai
- Associate Researcher Ma Li
- Associate Professor Wang Wangtian
- Dr. Liu Lijun
- Dr. Yang Gang
- Dr. Pu Yuanyuan
- Dr. Fahim
- Fan Junqiang
- Lu Xiaoming
- And others

Thank you for your Time!