

Studies on rapeseed production and cultivation science & technology in China

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Abstract

China is one of the earliest countries that started to cultivate rapeseed in the world. Its ancient rapeseed cultivation could be traced to pre-historic times, with a history of 6000-7000 years. And the earliest record of rapeseed cultivation was about 2500 years ago. Since 1987, both China's rapeseed planting area and total yield have been the largest all over the world. It shows that direct relationships exist between the fast development of rapeseed production and innovation and application of cultivation science and technology. China is divided into two oilseed rape production regions, winter region and spring region. The former takes up above 90% of the total rapeseed planting area, which is further divided into 7 subregions, loess plateau subregion, Huanghuai plain subregion, Yunnan-Guizhou Plateau subregion, Sichuan basin subregion, middle reaches of Yangtze River subregion, lower reaches of Yangtze River subregion and coast of South China subregion. Three main species of oilseed rape, *Brassica napus*, *B.rapa* and *B.juncea*, were planted. Of them, *B.rapa* and *B.juncea* were mainly cultivated before the PRC was built. After middle 1950s, *B.napus* began to **popularize**. At present, it has reached about 95% of the total oilseed rape area, and *B.rapa* just makes about 4%, *B.juncea* makes about 1%. Based on the sensitivity to temperature and photoperiod, cultivating rapeseed in China could be divided into four types, which is, winter hardiness and weak response to photoperiod type(winter rape), distributed into centre and north of China, including loess plateau subregion and Huanghuai plain subregion, with a mean day-length of about ten and a half hours before anthesis; half winter hardiness and weak response to photoperiod type(winter rape), mainly concentrated in the southwest of China and the reaches of the Yangtze River, including Yunnan-Guizhou Plateau subregion, Sichuan basin subregion, middle reaches of the Yangtze River subregion and lower reaches of the Yangtze River subregion, with a mean day-length of about eleven hours before anthesis; Spring hardiness and weak response to photoperiod type(winter rape), distributed into the coast of south China and parts of southwest of China, with a mean day-length of about eleven hours; spring hardiness and high response to photoperiod type(spring rape), with a mean day-length of above fourteen hours. To adapt to different farm regions with different farming resources and complex ecological conditions, varieties of cultivation modes and technologies has been built. Their significant characters are high yielding and multi-crop systems, for example, in the reaches of the Yangtze River, rape-rice double crops system mainly, concurrent with rape-cotton double crops system and in triple crops system regions, existing rape-rice-drought (e.g. soybean, sweet potato, corn) system and rape-drought crop-drought crop system, such as corn-potato-rape, corn-corn-rape etc. Spring rape usually adopts one crop system. Since late 1980s, it has been developing double-low rapeseed and advancing cultivation technology of improving seed quality and yield, raising work efficiency and saving labor hours in the rapeseed production. As to the prospect of China's rapeseed industry, on the one hand people's living standard has greatly improved, their dietary pattern is changing fundamentally, which will enlarge the requirement of edible rapeseed oil inevitably; on the other, as an optional source of bio-diesel, rapeseed has been predicted to enter into a new stage of high-speed development. In the reaches of the Yangtze River, there are about 20 million hectare winter fallow field for rapeseed production each year. Therefore, combined with the prospect that oil content raise from 42% to 50%, yield level increase from 1800kg/ha to 3000kg/ha through variety improving and cultivation technology innovation, there is strong potential for the development of rapeseed production.

Key words: Rapeseed; Cultivation; Production; Science and Technology Development

Introduction

China is the earliest country for rapeseed growing. Chinese archaeologists have unearthed vegetable seeds stored in a gallipot at Banpo, a New Stone Age Site in Xi'an, Shanxi province. The Institute Botany, Chinese Academic Sciences (1963) using C-14 testing demonstrated that they are probably rape seeds, *B.juncea* or *B.rapa* and were 6000-7000 years old. The earliest reference in China which recorded rapeseed, "Shi jing", was published in Xizhou dynasty (1066BC – 771BC), 2500 years ago. In 2004, China's rapeseed planting area was 7.27 million hectares, mean yield 1813kg/ha and total production reached 1.318 million tons, which increase about 3 times, 3 times and 12 times respectively compared with those figures of 1950–1960. Now she occupies nearly one third of the world's rapeseed planting area and total production, being the largest country for rapeseed production. For there are direct relationships between the development of rapeseed production and innovation and application of cultivation science and technology, most Chinese researchers of rapeseed cultivation science are focusing on climate division, genetic improving, demonstrating and extending new varieties, characterizing physiology and ecology of different varieties, developing practice of cultivation systems and planting pattern and theory of high yield and quality physiology. From late 1980s, it began to develop double-low varieties of rapeseed, and establishing corresponding cultivation technology of high quality, high yield, saving labors and high efficiency. As to the prospect of China's rapeseed

industry, enlarging requirement of edible rapeseed oil and the executing bio-diesel plan will necessarily bring the old crops into a new stage of high-speed development.

Rape Regional Planning in China

China is situated in the eastern part of Asia, on the west coast of the Pacific Ocean. As a country with vast territory, diverse climates exist. From the south to the north, the country is divided into tropical, subtropical, warm-temperature, temperate and frigid-temperate zones. Heat and water resources are rich and suitable for crop growing in each area.

China is divided into two oilseed rape production regions, winter region and spring region. The boundary starts from Shanghai Guan, moving eastward along Hetao, Liupan Mountain, upper reaches of the Bailong River, west boundary of Sichuan basin, to the lower reaches of Yarlung Zangbo River, north and west of which is spring rape region and south of which is winter rape regions (fig.1). The winter rape makes up above 90% of the total rapeseed planting area, while spring rape accounts below 10%.

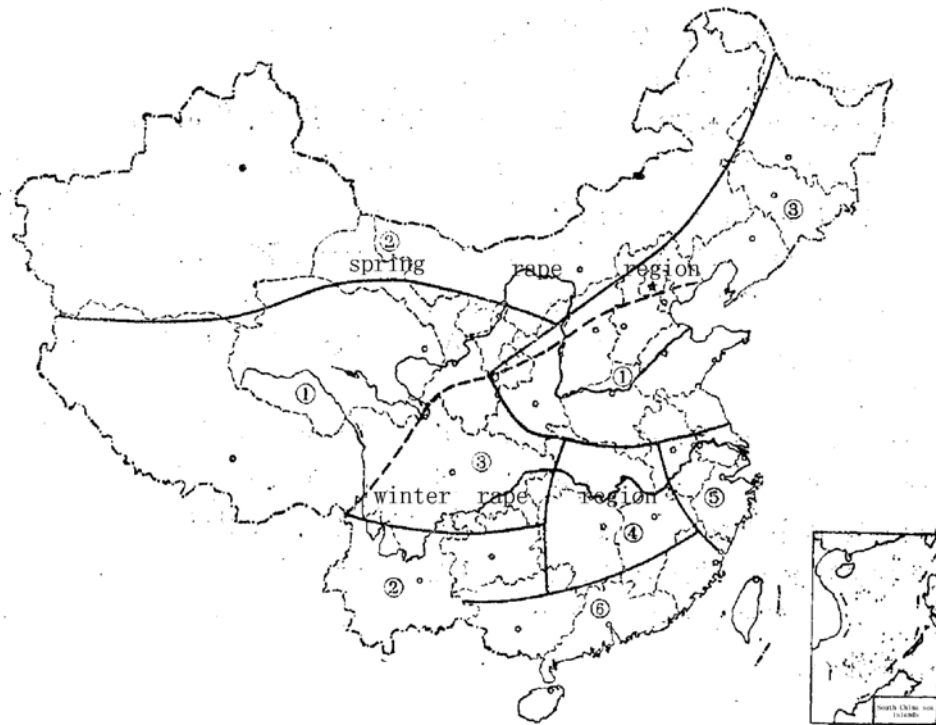


Fig.1 Rapeseed production sub-area in China

Winter rape region: Taking Wuhan, a Central China city for example, the air temperature and precipitation is as below (Table 2). It adopts double- or triple-crop system. And rapeseed usually rotated with rice, cotton, corn and so on. Almost all the rapeseed species are *B.napus*, sowed in September, transplanted in middle or last 10 days of October, harvested in first or middle 10 days of May next year, with a whole growing stage of about 220 days.

Table 2 Climate data in Wuhan city

Month	Monthly mean air temperature(°C)		Monthly mean precipitation(mm)	Monthly numbers of precipitation days(d)	Rapeseed growing month
	Minimum	Maximum			
1	-0.5	8.1	34	8	√
2	1.4	9.6	57	10	√
3	6.1	14.6	92	13	√
4	12.2	21.0	134	14	√
5	17.7	26.2	151	13	√
6	21.8	29.8	212	12	
7	25.2	32.9	151	11	
8	24.6	32.7	132	9	
9	19.4	27.8	84	9	√
10	13.4	22.7	89	10	√
11	7.2	16.4	59	9	√
12	1.5	10.5	28	7	√

Note: The climate data come from World Meteorological Organization (WMO). The climate data are the mean value of 30 years from 1961 to 1990 in Wuhan. Total precipitation is 1223mm per year.

The winter rape region is further divided into 7 subregions, loess plateau subregion, Huanghuai plain subregion, Yunnan-Guizhou Plateau subregion, Sichuan basin subregion, middle reaches of Yangtze River subregion, lower reaches of the Yangtze River subregion and coast of South China subregion. Of them, Sichuan basin subregion, middle reaches of Yangtze River subregion, lower reaches of Yangtze River subregion are the largest rapeseed production belts in the world. The yield, planting area of these three subregions takes 80% and 85% of the total in China, respectively.

Spring rape region: Taking the northwest city Xi'ning for example, the air temperature and precipitation is as below (Table 3). It adopts one or time and a half cropping systems(The half season is used to grow forage or vegetable). Except for planting some species such as *B.rapa*, *B.juncea*, *Eruca sativa* etc., *B.napus* is the mainly planted rapeseed specie, which was usually sowed in May, harvested in September, with a whole growing stage of about 120 days.

Table 3 Climate data in Xi'ning city

Month	Mean Monthly Temperature(°C)		Mean precipitation(mm)	Monthly numbers of precipitation days(d)	Rapeseed growing month
	minimum	maximum			
1	-14.1	1.1	1	2	
2	-10.7	3.6	2	3	
3	-4.0	9.5	6	4	
4	1.7	15.8	20	6	
5	6.3	19.8	46	11	√
6	9.2	22.6	54	13	√
7	11.5	24.4	81	15	√
8	11.0	23.9	76	14	√
9	7.5	18.5	54	14	√
10	1.7	13.9	23	8	
11	-5.8	7.1	4	3	
12	-12.2	2.2	1	2	

Note: The climate data come from World Meteorological Organization (WMO). The climate data are the mean value of 30 years in Xi'ning. Total precipitation is 368mm per year.

Types and ecological distribution of rapeseed in China

There are three rapeseed species, *B.napus*, *B.rapa* and *B.juncea*, mainly cultivated in China. And the latter two were the dominant rapeseed species in the Chinese long history until *B.napus* was introduced to China in the 1950s. Nowadays, *B.napus* predominates 95%, however *B.rapa*, accounts for 4% approximately and *B.juncea* 1% of China's rape planting area. Since double-low rapeseed and hybrid rapeseed were successfully bred in 1980s and possess many distinguished characters, they are now popularized and have taken more than 70% and 50% of the total rape planting area, respectively.

Table 4 Photoperiod sensitivity and temperature sensitivity of rapeseed in China

Variety	temperature sensitivity	Photoperiod sensitivity	Representative varieties
Winter rape	Winter(0-5°C, 20-30d)	Weak (>12h)	Yuejing, Shengli
	Semi-winter(5-15°C, 15-20d)	Weak (>12h)	Ganyou No.5, Xiangyou No.15
Spring rape	Spring(15-20°C, 15-20d)	Weak(>12h)	Yunyou No.31,Luzhou No.5
	Spring (15-20°C, 15-20d)	Strong(>14h)	Tower, Wistar

Photoperiod and temperature sensitivity of rapeseed in China

Ecological Distribution of *B.napus* in China

Based on their response to photoperiod and temperature, varieties planted in China can be divided into 4 types.

Winter hardiness and weak response to photoperiod type (winter rape): They are distributed in centre and north of China, including loess plateau sub-belt and Huanghuai plain sub-belt, whose latitude is between 33° and 40° North, longitude is between 105° and 125° East. It belongs to humid temperate continental climate. The hottest month is July whose mean temperature is 20~28°C. And the coldest month is January which has a average temperature of -8~-2°C. Before rapeseed anthesis, it requires an average day-length of about ten and a half hours.

Half winter hardiness and weak response to photoperiod type(winter rape): They are mainly concentrated in the southwest of China and the reaches of the Yangtze River, latitude 25-33°North, longitude 100-125°East, including Yunnan-Guizhou Plateau sub-belt, Sichuan basin sub-belt, middle reaches of the Yangtze River sub-belt and lower reaches of

the Yangtze River sub-belt. It belongs to humid temperate continental climate. The hottest month is July whose mean temperature is 20–28°C. The coldest month is January which has a average temperature of 1–10°C. Before rapeseed anthesis, it requires an average day-length of eleven hours approximately.

Spring hardiness and weak response to photoperiod type (winter rape): They are spread in the coast of south China and part of southwest of China, latitude 18–35°North, longitude 98–125° East. It belongs to humid subtropical climate. The hottest month is July whose mean temperature is 20–28°C. And the coldest month is January which has a average temperature of 10–20°C. Before rapeseed anthesis, it requires an average day-length of eleven hours approximately.

Spring hardiness and high response to photoperiod type (spring rape): They are distributed in the northwest and northeast of China, whose north altitude is 35–50°, east longitude is 73–135°. There are more than 100 days that the temperature is above 10°C annually. Before rapeseed anthesis, the average day-length reaches about 14 hours.

Sensitive period for light and temperature of rapeseed

(1) temperature sensitive period

Rapeseed is a Green Vernalization type, that is, low temperature is most effective to promote development during seedling growth. Our research on seedlings treated by low temperature below 6°C for 30 days showed that vernalization is independent on type and seedling age and bud differentiation of all the treatments are advanced. 7-8 or 9-10 leaf age seedlings of winter or semi-winter rape varieties is the most sensitive stage to low temperature, while 7-8 leaf age of spring rapeseed varieties seedlings is the most sensitive stage. After low temperature induced, the seedling main-stem extended slightly, stolon branches became upright or semi-upright, leaf color turned thin green, and the content of gibberellin reached maximum of their whole growth stage.

(2) Light sensitive period

To definite the sensitive period of different rapeseed varieties for light, different types of varieties of rape seeds were sowed on October 5th, treated by a long day condition of 14.5 hours light per day, ending at 2, 4, 6, 8, 10, 12 leaf age respectively, and then growing under natural light, controlled with those growing under natural light. Results showed that, winter and semi-winter types at 11~12 leaf age and spring-hardness winter rape and spring rape types at 9~10 leaf age are most sensitive to long day light condition. It obviously suggests that the period of rapeseed sensitive to light is behind that to temperature.

(3) Relationship between ecotypes of rape cultivars and introduction

Under the autumn seeding conditions of suitable temperature and light in Changsha city, winter rape grows well. However, spring rape could not develop well because of short day-length of 11.5h and its maturation date delayed (Table 5). While under the summer sowing conditions in Kunming city, a day-length of 14.5 hours promote the development of spring rape, making it matured earlier. But for winter rape, the lowest temperature above 5°C could not meet its need of temperature sensitivity and bud and flower could not emerge.

Table 5 Growth stage change of rapeseed cultivars in different regions and sowing date

Types	Varieties	Autumn sowing in Changsha(day/month)			Summer sowing in Kunming(day/month)		
		Sowing date	Bud emergence date	Maturing date	Sowing date	Bud emerging date	Maturing date
Spring oilseed(Spring)	Qifei	10/10	12/2	latest	1/6	5/7	Earliest
Winter oilseed(Spring)	Luzhou No.5	10/10	4/1	Early	1/6	3/7	Early
Winter oilseed (Semi-winter)	Aijiazao	10/10	1/2	middle	1/6	18/7	middle
Winter oilseed (Winter)	Shengli oilseed	10/10	14/2	Late	1/6	Not	Not matured

4. Plant system and cultivation modes for rapeseed in China

Several cultivation modes and technologies have been built to adapt to different farm region with different farming resources and complex ecological conditions. Their significant characters are high yielding and multi-crop system per year, such as in the reaches of the Yangtze River, rape-rice double crops system mainly, concurrent with rape-cotton double crops system. In triple crops system region there are rape-rice-drought crop (e.g. soybean, sweet potato, corn) system and rape-drought crop-drought crop system, such as corn-potato-rape, corn-corn-rape etc. Spring rape usually adopts one crop system.

For example, the sub-region of middle reaches of the Yangtze River, which is the concentrated production area of rice and rapeseed in China, using rice as the previous crop or/and subsequent crop of rapeseed, takes the upland- paddy crop rotation systems of double crops system and triple crops system. Meanwhile, to some extent, there are also double crops system and triple crops system of rape rotated with cotton or grain.

Rape-rice-rice triple crops system: Characterized by the main crop of double cropping rice rotated with winter crops such as rape, green manure, barley or wheat, rape-rice-rice triple crops system accounts for 40% of the total rapeseed planting area in the reaches of the Yangtze River. In that the crop-dovetail time of this system is short, ample water and heat resource, favorable conditions such as fertilizer and labor and high cultivation technology are necessary for realizing high yield of the three crops. Meanwhile, for the field soil is damp and hardening and lacks effective nutrition after the previous crop late rice is harvested, rape seeds can not be sowed and seedlings can not be transplanted timely, resulting in that the plants grows

slowly. Hence, to produce high yield of the three crops, it is key to ditching and field drying and harrowing field thoroughly before and after the harvest of late rice respectively, applying sufficient base fertilizer and breeding strong seedlings etc.

Rape-rice-drought crop triple crops system: It is multi-crop system that farmers grow drought crop such as soybean, sweet potato, corn or Short-term green manure etc. after early rice is harvested, and then plant rape seeds.

Rape-drought crop-rice triple crops system: Rape-early soybean-rice triple crops system is the typical of this system, with rape exchanging with barley or wheat, summer crops exchanging with double cropping rice.

Triple crops system in dry land: Such as rape-corn-potato, rape-corn-corn, rape-sweet potato-corn, etc.

Rape-rice double crops system: In this system, winter rape exchanged with barley, wheat, horsebean and green manure. Of them, rape rotated with middle rice is the typical cropping system. And the planting area of rape-rice crops system is equal to that of rape-rice-rice triple crops system.

Rape-cotton double crops system: This system is distributed extensively in the cotton production regions, in which rape exchanges with wheat or horsebean. In this system, wide/narrow row alternation transplanting technique (rape and cotton interplant with each other) is adopted. At the beginning of spring, base fertilizers are applied to the rows reserved, ditches are dug to sow cotton seeds or transplant cotton seedlings after rapeseed is harvested. And in late October before cotton is to be harvested, rapeseed seedlings are transplanted into the ditches of the cotton field.

There are two winter rape cultivation modes, seedling raising and transplanting mode and direct seeding mode. At present, these two cultivation modes accounts for 50% of the total planting area respectively in the reaches of the Yangtze River. Through seedling raising and transplanting, ①contradictions of planting season can be solved, bringing on the yield increase of grain, cotton and rape. In the main winter rape production provinces distributed in the reaches of the Yangtze River, many regions adopted early rice-late rice-winter rape triple crops system and rape was usually planted in the rice field. However, rape seeds need to be sowed in September while late rice was usually harvested between the last 10 days of October and the first 10 days of November, which produced the contradiction. And this kind of contradiction also existed in the rape-cotton crops system, for there is considerable overlap between rape seeds sowing date and late rice harvesting date. However, they all can be solved by seedling raising and transplanting technique. ②it is helpful to breed strong seedlings and enhance rapeseed yield per unit area. On the one hand, the seedling bed is able to make sowing date not to be affected in the multi-crop system, and can breed strong seedling through elaborate management. On the other, the seedlings could be sorted by their size and growing situation, and weak seedlings could be culled before transplanting, producing consistent seedlings in the same field. ③the seed dosage decreased. Usually the seedling bed can breed 100 to 160 thousand plants/ha when sowing 0.5-0.75kg seeds, which can meet a need of 8 hectares in the field for transplanting.

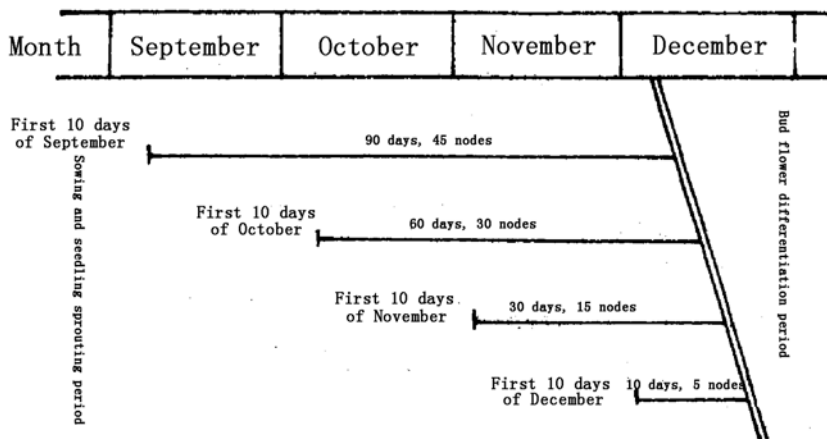


Fig.2 Node number of the main stem of semi-winter rape cultivars in different sowing date in Hunan Province

Winter rape must be sowed in its season as early as possible to increase the node number of the main stem, which makes it possible to develop more branches and siliques (fig.2). Thinning out seedlings and final singling should be timely after seeds sprout, leaving plant spacing 8-10cm. They were transplanted at the seedling age of 30-35 days, with a density of 10,000 seedlings/ha.

Before winter, cultivation and management should be strengthened. For the target of high yield, the seedling growing situation in January should be: leaves are thick green but not to turn red; leaf margin is lightly purple; plants grow thick but not to bolt; they have 15 leaves per plant (including 8-12 green leaves and 3-7 cicatricles) and a well-developed root system and the diameter of root neck is about 1-1.5cm. During winter, frost prevention and heat preservation work, such as to fertilize and earthen up rapeseed plants should be done to make sure rapeseed over winter safely. After spring, it is important to prevent rapeseed stem rot and to do artificial supplementary pollination work. At this time, the plant growing situation should be: height of bolt is proper; plants are strong, have uniform diameter distribution; the leaf area index reaches 4-5 at flowering stage; they are not premature and there are not diseases during maturing stage.

(2) Direct seeding with zero tillage (DSZT) in rice field of winter rape

The prominent advantages of this cultivation technique are: it is not necessary to till the field for rape seeds sowing,

which protect the soil structure and decrease soil and water loss. Since soil nutrition concentrate on the layer of 0-5cm, and microorganism are also activity in up-layers of soil, zero tillage is good for rapeseed growth. And high density, deeply distributed root system of the DSZT increased lodging resistance of rapeseed plants. Obviously, zero tillage also saved labor hours and improved efficiency.

Rice field with low water table, loose soil and ample nutrition should be selected for DSZT. Dry soil 10 days before rice harvested. Do chemical weeding work as soon as possible after rice harvested. Then dig ditches (30cm wide and 25cm deep) and divide fields into districts for 2m wide. Usually rape seeds were sowed between late September and early October, producing about 20 thousand plants/ha at a seed dosage of 0.20-0.25kg/ha. Notably, sowing dose should be increased by 0.30kg/ha when sowing date is delayed.

Sowing patterns such as sowing in rows, broadcast sowing etc. could be selected. Usually the sowing ditches dug 2-3 days after rice was harvested and herbicide was sprayed. Rape seeds were mixed with fine soil 20kg and borax 1kg per ha, and then sowed in rows or broadcasted sowed.

In recent years in China, many regions adopted sowing machine, such as the 2BF-6 model united sowing machine, designed by Hunan Agricultural University, can finish sowing, fertilizing, ditching and Covering Soil continuously. They use control-release fertilizer that released in different rape growth stage to reduce the labor hours and production cost. And the harvest work is also done by machines.

(3) Cultivation of spring rape

Spring rape is mainly distributed in the north and northwest of China, including Qinghai, Xinjiang, Gansu, Neimeng, Heilongjiang etc. Except for Qinghai mainly planting *B.rapa* and Xinjiang mainly growing *B.juncea*, other provinces are mainly planted *B.napus*.

Spring rape finished its growing stage usually needs 100-120 days, but the shortest may be 60 days. Its buds differentiate at 2-4 leaf age and appear at 6-8 leaf age. There are just 40 days from flowering to maturing. As it adopts one crop system, direct sowing and planted by machine should be more efficient for its cultivation.

High yield and early matured varieties of spring rape should be selected. Fertilizing, watering and preventing diseases, pests and weeds must be adapted to their characters. Experiments showed, it is helpful to preventing diseases, pests and weeds for rape to rotate with other crops in each 3 years.

Development of rapeseed production and prospect for the future

The reaches of the Yangtze River is the largest rapeseed belt in the world. Exceeding 300,000,000 farmers engaged in rapeseed cultivation directly and rape is their first cash crop in early spring. Along the Yangtze River, both transportation and trade for rapeseed is convenient. Moreover, though as the main production region of rape, its planting area have not reached saturation in the reaches of the Yangtze River, leaving large area of winter-fallow field. The main production regions, including 10 provinces, have a cultivable land of 30855.8 thousand hectares, but the planting area of rape, wheat, barley, potato and other vegetables are 5722, 6640.1, 438.5, 1776.8 and 493.2 thousand hectares, respectively, leaving 15787.2 thousand hectares winter-fallow field. And in addition to the river-beach Land 1934 thousand hectares and large area of winter-fallow field in the reaches of Huanghuai and spring rape regions, the total rape planting area could reach 26000 thousand hectares from the present 7500 thousand hectares. In 2005, the planting area of double low rapeseed has reached 74.3%, and mean yield reached 1770.00kg/ha. Furthermore, the effect was notable to popularize hybrid rape varieties and extend disease resistant varieties. Many high-quality varieties have been bred, such as Zhongyouza No.11 and recently bred variety Zhongyou No.0361, with a high oil content of 45%, 54.72% respectively.

Combined with variety improvement, cultivation technique innovation, and by the mechanism production and information technology population, it is possible that oil content of rape seeds raise from the present 42% to 50%, yield level increase from 1800kg/ha to 3000kg/ha. The total rape yield in China will rise to 40% of the world in near future. Therefore, as to the prospect of China's rapeseed industry, on the one hand people's living standard has greatly improved, and their dietary pattern is changing fundamentally, which will enlarge the requirement of edible rapeseed oil inevitably; on the other, as an optional source of bio-diesel, rapeseed has been predicted to enter into a new stage of high-speed development. There is strong potential for the development of rapeseed production.