Rape Breeding and Its Intellectual Property Protection in China

Li GAO[1], Leying WU[2]*, Yamin PENG[1], Yuanpeng SUN[1], Jin ZENG[1], Zhiguo SUN[1]

1. Centre for Cultural Studies on Southern Hubei Province, Xianning 437100, China; 2. College of Economics and Management, Hubei University of Science and Technology, Xianning 437100, China

Abstract Rape is the third largest oil crop in the world and the first one in China. The national average rapeseed yield is only 2 077.5 kg/hm^2, and the rapeseed oil yield is 894 kg/hm^2. This paper introduced the main types, germplasm resources, breeding bases and breeding progress of Chinese rape, and studied its high-quality varieties, breeding patents and new varieties of agricultural plants. We analyzed the main problems such as serious loss of germplasm resources in *Brassica campestris* L. and *Brassica juncea* (L.) Czern. et Coss and weak "agricultural chip" in rape field, and put forward strategies such as strengthening the protection of rape germplasm resources, encouraging the development of "agricultural chip" in rape industry clusters with national advantages and characteristics, and strengthening the protection of agricultural intellectual property rights.

Key words Rape; Rapeseed; Rape breeding; Intellectual property rights; Edible oil supply safety; China

Introduction

China has designated agricultural biological breeding as an "agricultural chip"[1-2], and has made important strategic arrangements to revitalize and enhance the modern seed industry. The *Action Plan for Seed Industry Revitalization*, approved by the Central Committee for Comprehensive Deepening Reform in 2021, proposes five major actions: implementing the protection and utilization of germplasm resources, innovative research, enterprise support, base improvement, and market purification. The *Construction Plan for Modern Seed Industry Improvement Project during the 14th Five Year Plan Period* jointly issued by the National Development and Reform Commission and the Ministry of Agriculture and Rural Affairs requires further improvement of the agricultural germplasm resource protection system, the establishment of a number of modern seed and breeding industry production bases, and the promotion of breeding innovation capability to advanced levels. In 2022, the Ministry of Agriculture and Rural Affairs identified five national seed industry formation enterprises for oil crops: Anhui Guohao Agricultural Technology Co., Ltd., Qingdao Huashi Seedling Co., Ltd., Henan Jinwoye Agricultural Development Co., Ltd., Zhongken Jinxiu Huanong Wuhan Technology Co., Ltd., and Shaanxi Ronghua Agriculture Technology Co., Ltd. The development of agricultural seed industry and the innovation in biological breeding require the protection of agricultural intellectual property rights[3-6].

Nearly 70% of edible vegetable oils in China rely on imports. Rapeseed oil accounts for about 50% of domestic edible oil, and as the largest oil crop in China, rape occupies a core position in ensuring the safety of China's edible oil supply. However, currently, the average yield of rapeseed per hectare in China is only 2 077.5 kg, and the oil content is about 43% and the oil production is 894 kg/hm^2. There is still a lot of room for improvement in its yield per hectare and oil production per hectare, and it is necessary to strengthen the "agricultural chip" and protect intellectual property rights.

Therefore, we should learn from the experience of Canadian rape crops[7], to strengthen the innovation of new biotechnology and the "agricultural chip" in rape field and enhance the level of the entire chain of agricultural intellectual property creation, application, protection, management, and service.

Main Types of Rape

The types of rape cultivated in China can generally be divided into three types, namely *Brassica campestris* L., *Brassica juncea* (L.) Czern. et Coss and *Brassica napus* L.[8-10].

B. campestris L., including northern *B. campestris* L. and southern *B. campestris* var. *chinensis* Mak, evolved from Chinese cabbage, and the northwest region of China is one of its origins. It has the characteristics of short growth period, early maturity, late sowing tolerance, barren tolerance, cold resistance, drought resistance, wide adaptability, and lodging resistance. However, it has low single yield and weak disease resistance. In the past, it was widely planted in the north and south of China, but now the planting area is becoming smaller and smaller, especially in main rapeseed production areas.

Brassica juncea (L.) Czern. et Coss is an oil-based variety of mustard in *Brassica* of Cruciferae. It is a composite species that evolved from natural interspecies hybrid between *Brassica* (aa, $n=10$) and *Brassica nigra* L. (bb, $n=8$) and is diploid. China is one of its origins. It has characteristics such as well-developed root system, drought tolerance, barren tolerance, and cold tolerance, but its yield per unit area is low. In the past, it was mainly planted in the southwest plateau of China and the arid areas of northwest China, but the planting area has become smaller and

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Li GAO (1983 -), male, P. R. China, lecturer, PhD, devoted to research about characteristic agriculture and rural revitalization.
* Corresponding author. E-mail: 815019007@qq.com.

smaller.

B. napus L. is native to the Mediterranean coast of Europe and is mainly grown in the Yangtze River basin. The rice and winter rape rotation model has been promoted in the south. It has characteristics such as fertilizer tolerance, high yield, and strong disease resistance, but it also has relatively long growth period, poor cold tolerance and drought resistance, and poor tolerance to barren soil.

China is the origin of *B. campestris* and *B. juncea*. Rape has been cultivated for over 8 000 years. Carbonized rapeseed remains have been found at the Dadiwan Site in Gansu (8 000 years ago) and Banpo Site in Xi'an, Shaanxi (6 800 years ago)[11]. *B. napus* has been introduced for nearly 90 years[12]. In the early 1930s, Professor Yu of Zhejiang University introduced Japanese *B. napus* from North Korea for the first time. In 1941, Professor Sun of the university directly introduced European *B. napus* from the British Botanical Garden. At present, the main type of rape planted in China is *B. napus*, which basically replaces the locally sourced *B. campestris* and *B. juncea* in main rapeseed production areas.

Germplasm Resources and Breeding Bases

China has abundant rape germplasm resources[10-11], including numerous local varieties of *B. campestris* and *B. juncea*. There are 8 498 rape germplasm resources in the National Crop Germplasm Resources Platform. Among them, there are 3 640 types of *B. napus*, 2 809 types of *B. campestris*, 1 871 types of *B. juncea* var. *foliosa*, 159 types of *B. carinata* A. Braun, and 19 types of *B. nigra*.

In the *Catalogue of Available Crop Germplasm Resources* (*First Batch*) released by the Ministry of Agriculture and Rural Affairs in March 2023, there are 500 types of rape germplasm resources, including 399 selected varieties, 51 strains, 49 local varieties, and 1 other variety (*B. carinata* A. Braun). It involves 457 varieties of *B. napus*, 24 varieties of *B. campestris*, 14 varieties of *B. juncea*, 4 varieties of *B. juncea* var. *foliosa*, and 1 variety of *B. carinata*. These 500 rape germplasm resources are preserved in the National Mid-term Genebank for Oil Crops (Wuhan).

There are 7 state-level regional breeding bases for rape varieties, including Xishui County and Gucheng County of Hubei Province, Changshun County of Guizhou Province, Hanzhong City of Shaanxi Province, Shandan County and Minle County of Gansu Province, and Huzhu County of Qinghai Province, as well as 8 state-level rape seed production counties, including Hengyang County in Hunan Province, Hengfeng County in Jiangxi Province, Santai County in Sichuan Province, Luojiang District in Deyang City, Jingyang District in Deyang City, Tongnan District in Chongqing, Mianxian County in Shaanxi Province, and Nanzheng District in Hanzhong City.

Breeding Progress

In the 8 000 year history of rape cultivation, in order to adapt to the traditional cultivation mode in China and rotate with crops such as rice, *B. campestris* and *B. juncea* were mainly domesticated and cultivated in the direction of early maturity and high yield.

After the establishment of the People's Republic of China, the focus was on improving *B. napus*[8]. In the late 1950s to 1970s, early maturity was the main goal of *B. napus* breeding. Through systematic selection, radiation mutagenesis, and especially interspecific hybridization with early-maturing *B. campestris*, a group of early- and medium-maturing Chinese unique "semi-winter" types of *B. napus* was successfully cultivated.

In the 1970s and 1980s, a series of key and excellent variety resources were selected and effectively utilized to further enhance and coordinate high yield, stable yield, disease resistance, and adaptability of *B. napus*.

In the late 1970s, China launched the rape quality breeding project. Later, mainly using the high-quality variety resources with low erucic acid and low glucosinolate contents introduced from Canada, Australia, Germany, France, Sweden and other countries, combined with the genetic resources and heterosis of *B. campestris* and *B. juncea*, we successfully broke through the contradiction between quality and yield, and between quality and resistance, and cultivated a batch of high-yield, multi-resistance and double-low (low erucic acid and low glucosinolate) *B. napus* varieties.

Nowadays, the focus is on exploring and utilizing various germplasm resources with high yield, disease resistance, and high quality, in order to improve the yield, quality, and resistance level of rape in China. A large number of "semi-winter" *B. napus* varieties with various excellent traits and unique Chinese characteristics, suitable for cultivation conditions in different regions of China, have been selected.

The breeding of *B. napus* has gone through two stages: environmental adaptation and high-yield and high-quality selection breeding. In the first stage, genes controlling developmental rhythm, plant type, chlorophyll content and stress resistance were mainly strongly selected, leading to improved adaptability. In the second stage, genes controlling thousand-seed weight, number of seeds per pod, effective pod number per plant, plant height, glucosinolate and erucic acid were strongly selected, leading to continuous improvement in yield and quality.

High-quality Varieties

The goal of rape quality breeding is to select varieties with high oil content, high oleic acid and linoleic acid, high protein and low erucic acid, low linolenic acid, low glucosinolate, low fiber, and yellow seeds. Its breeding methods mainly include mutation breeding, cell engineering technology, molecular marker technology, and transgenic breeding.

China has cultivated rape varieties with high oil content, such as Huayouza 50, Zhongshuang 11, Zheyou 33, Zhongyouza 39, Qinyou 2, Xiangzayou 763, Chuanyou 46, and Huayou 98 (Table 1).

High-yield rape varieties such as Zhongyouza 501, Qinyou 797, Qinyou 10, Fengyou 737, Dazouyou 888, Huayouza 50, Huayouza 9, Huayouza 6, Yangguang 2009, Yangguang 198 and Zhongshuang 12 have been cultivated (Table 2).

Table 1 Rape varieties with high oil content in China

Type	Variety	Oil content//%	Suitable area
B. napus	Huayouza 50	49.56	Winter rape areas in Sichuan, Chongqing, Yunnan, Guizhou, Hubei and Hunan
	Zhongshuang 11	49.04	Winter rape areas south of the Huaihe River in Jiangsu Province, south of the Huaihe River in Anhui Province, and those in Zhejiang Province and Shanghai City
	Zheyou 33	48.35	Winter rape areas in Shanghai, Zhejiang and Jiangsu and those south of the Huaihe River in Anhui Province
	Zhongyouza 39	48.35	Winter rape areas in the Yangtze River Basin
	Qinyou 2	48.00	Winter rape areas in the southwest area and Huang – Huai River Basin and its southern areas
	Xiangzayou 763	45.71	Winter rape areas in Hunan and other areas
	Chuanyou 46	45.05	Winter rape areas in Sichuan, Chongqing, Shaanxi, Hubei and Jiangxi
B. juncea	Huayou 98	45.54	Winter rape areas in Henan, northern Hubei, northeastern Anhui and northwestern Jiangsu, as well as spring rape areas in northwestern Gansu, northeastern Inner Mongolia and northwestern Liaoning

Table 2 High-yield rape varieties in China

Variety	Suitable area	Characteristics	Rapeseed yield per unit area//kg/hm^2
Zhongyouza 501	Winter rape areas in Sichuan, Yunnan, Guizhou, Chongqing, Hubei, Zhejiang and Jiangxi	*B. napus*, a high-yield, high-oil and double-low hybrid rape variety, resistant to sclerotinia and lodging, suitable for machine harvesting, with a total growth period of 220 d and an oil content of 50.38%	3 196.7 averagely, up to 6 299.2
Qinyou 797	Winter rape areas in Shaanxi and the middle and lower reaches of the Yangtze River	*B. napus*, a high-yield, high-oil and high-quality rape variety, with wide adaptability, strong lodging resistance and disease resistance, suitable for mechanized harvesting, having a total growth period of 218 d and an oil content of 46.63%	5 782.5 averagely
Qinyou 10	Winter rape areas in the lower reaches of the Yangtze River and other areas	*B. napus*, a semi-winter sterile three-line hybrid variety, with low resistance to sclerotinia, medium resistance to viral diseases, strong lodging resistance, a total growth period of 236 d and an oil content of 42.76%	2 640 averagely
Fengyou 737	Winter rape areas in Shanghai, Zhejiang, Anhui and south of the Huaihe River in Jiangsu	*B. napus*, a semi-winter sterile three-line hybrid, moderately susceptible to sclerotinia, with strong lodging resistance, a total growth period of 232 d and an oil content of 44.86%	2 707.5 averagely
Dazouyou 888	Winter rape areas in Hubei, Hunan, Jiangxi, Anhui, Jiangsu, Zhejiang, Shanghai, Sichuan, Chongqing, Guizhou, Yunnan, and Hanzhong and Ankang in Shaanxi	*B. napus*, a semi-winter cytoplasmic male sterile three-line hybrid variety, moderately resistant to sclerotinia and viral diseases, with a total growth period of 219 d and an oil content of 46.87%	3 026 averagely
Huayouza 50	Winter rape areas in Hubei, Hunan, Jiangxi, Shanghai and Zhejiang, and those south of the Huaihe River in Anhui and Jiangsu	*B. napus*, a semi-winter nuclear male sterile three-line hybrid variety, with low susceptibility to sclerotinia, low resistance to viral diseases, strong cold resistance, strong lodging resistance, and a total growth period of 216 d	3 178.5 in the first growth cycle; 2 770.5 in the second growth cycle
Huayouza 9	Winter rape areas south of the Huaihe River in Anhui and Jiangsu, and those in Zhejiang, Shanghai, Hubei, Hunan, Chongqing and Guizhou	*B. napus*, a semi-winter cytoplasmic male sterile three-line hybrid variety, with moderate cold resistance, low susceptibility to sclerotinia and viral diseases, strong lodging resistance, an oil content of 41.09%, and a total growth period of 233 d	2 252.4 in the first growth cycle; 2 872.8 in the second growth cycle
Huayouza 6	Winter rape areas in southern and central northern Henan	*B. napus*, a semi-winter hybrid variety, with moderate tolerance to cold and sclerotinia, good resistance to viral diseases, good fertilizer tolerance, good resistance to lodging resistance, an oil content of 41.50%, and a total growth period of 224 d	2 169 averagely
Yangguang 2009	Winter rape areas in Hubei, Hunan and Jiangxi	*B. napus*, a semi-winter conventional variety, with low resistance to sclerotinia, strong lodging resistance, an oil content of 43.98%, and a total growth period of 217 d	2 470.5 averagely
Yangguang 198	Winter rape areas in Sichuan, Chongqing, Guizhou, Yunnan, and Hanzhong and Ankang of Shaanxi	*B. napus*, a semi-winter conventional variety, with low resistance to sclerotinia, strong lodging resistance, black seeds with an oil content of 44.35%, and a total growth period of 225 d	2 643 averagely
Zhongshuang 12	Winter rape areas in Hubei and other areas	*B. napus*, a semi-winter conventional variety, with a compact plant type, strong lodging and cold resistance, an oil content of 39.94%, and a total growth period of 219.5 d	3 096.2 in the first growth cycle; 3 210.5 in the second growth cycle

The *National Catalogue for Promotion of Excellent Crop Varieties* (*2023*) includes 26 rape varieties. Among them, ① there are 9 backbone varieties: Fengyou 737, Fengyou 730, Huayouza 62, Zhongshuang 11, Huayouza 9, Yangguang 2009, Qinyou 10, Zheyou 50, and Qingza 5, ② 6 growth type varieties, Qingyou 3, Zhongyouza 19, Dadi 199, Huayouza 50, Ganyouza 8, and Qingza 12, ③ 6 seedling type varieties: Zhongyouza 501, Fangyou 777, Chuanyou 81, Qinyou 1618, Ningza 182, Baoyou 150, and ④ 5 specialized varieties: Yangguang 131 (short-growth-period rapeseed), Fengyou 320 (short-growth-period rapeseed), Huayouza 62R (root swelling-resistant rapeseed), Huayou 2129 (high oleic acid rapeseed), and Kangyou 3 (yellow-seed high-oleic-acid rapeseed). Among these varieties, Qingza 5 and Qingza 12 are specialized varieties for spring rapeseeds; Fengyou 737, Huayouza 62, Huayou 50, Qinyou 1618, and Huayouza 62R are varieties that can be used for both spring and winter rapeseeds; and other 19 are specialized varieties for winter rapeseeds.

Breeding Patents

Thirty four provincial-level administrative regions in China have obtained 19 101 national invention patents and 3 308 national utility model patents in the field of rapeseed cultivation (IPC International Patent Classification A01); and in the field of rape breeding (IPC international patent classification A01H), we have obtained 3 010 national invention patents and 37 national utility model patents (Table 1). The top ten provinces in the field of rape breeding that have obtained national patents are Beijing City, Hubei Province, Jiangsu Province, Shandong Province, Zhejiang Province, Shanghai City, Chongqing City, Guangdong Province, Hunan Province, and Shaanxi Province (Table 3).

Table 3 Statistical table of national patents obtained by provincial administrative regions in the field of rapeseed planting and breeding in China (unit: patents)

Province	Breeding field (IPC A01H)		Planting industry (IPC A01)		Province	Breeding field (IPC A01H)		Planting industry (IPC A01)	
	Invention patent	Utility model patent	Invention patent	Utility model patent		Invention patent	Utility model patent	Invention patent	Utility model patent
Beijing	660	1	1 522	61	Jilin	43	0	151	48
Hubei	357	1	1 202	293	Hainan	37	0	143	9
Jiangsu	282	3	3 005	422	Jiangxi	34	2	313	90
Shandong	276	3	1 622	189	Heilongjiang	32	0	156	112
Zhejiang	196	1	1 249	165	Tianjin	29	0	460	43
Shanghai	189	0	536	41	Fujian	26	0	222	57
Chongqing	158	2	448	75	Shanxi	24	1	126	55
Guangdong	126	1	1 215	133	Xinjiang	21	2	124	40
Hunan	116	3	1 222	240	Hebei	19	2	263	103
Shaanxi	103	4	825	100	Liaoning	14	0	408	45
Sichuan	101	1	865	253	Qinghai	10	1	99	47
Anhui	94	1	2 044	272	Hong Kong	6	0	14	0
Henan	91	2	500	154	Inner Mongolia	2	1	69	42
Guizhou	61	2	706	46	Ningxia	2	0	33	25
Yunnan	50	1	405	87	Taiwan	1	0	5	2
Gansu	48	1	397	161	Tibet	0	0	32	11
Guangxi	44	2	950	42	Macao	0	0	0	0

The top ten patentees in the field of rape breeding (international classification A01H) with the highest number of patents in China are: Huazhong Agricultural University, Pioneer Hi-Bred International, Inc, BASF Plant Science, Southwest University, Oil Crops Research Institute of Chinese Academy of Agricultural Sciences, Dow Agrosciences China Ltd., Nanjing Agricultural University, Institute of Genetics and Developmental Biology, Chinese Academy of Sciences, Monsanto Company, and E. I. du-Pont de Nemours and Company (Table 4). Among them, the second, sixth, ninth, and tenth are American companies, and the third is a German company.

As applicants (patentees), five national seed industry formation enterprises for oil crops have received relatively few national patents in the fields of rape breeding and agricultural breeding (IPC A01) (Table 5).

Table 4 Top ten patentees in the field of rape breeding with the highest number of patents in China (unit: patents)

Patentee	Number of patents
Huazhong Agricultural University	180
Pioneer Hi-Bred International, Inc	170
BASF Plant Science	163
Southwest University	132
Oil Crops Research Institute, Chinese Academy of Agricultural Sciences	115
Dow Agrosciences China Ltd.	108
Nanjing Agricultural University	107
Institute of Genetics and Developmental Biology, Chinese Academy of Sciences	104
Monsanto Company	102
E. I. duPont de Nemours and Company	98

Table 5 National patents obtained by national seed industry formation enterprises of the oil seed category in the field of rape breeding and agricultural breeding (unit: patents)

Enterprise	Rape breeding		Agricultural breeding	
	Invention patent	Utility model patent	Invention patent	Utility model patent
Anhui Guohao Agricultural Technology Co., Ltd.	3	9	25	14
Qingdao Huashi Seedling Co., Ltd.	0	0	0	0
Henan Jinwoye Agricultural Development Co., Ltd.	0	0	0	0
Zhongken Jinxiu Huanong Wuhan Technology Co., Ltd.	0	0	1	5
Shaanxi Ronghua Agriculture Technology Co., Ltd.	0	0	0	0

New Varieties of Agricultural Plants

B. napus, *B. juncea* and *B. campestris* were included in the second, sixth and tenth batches of the *List of New Plant Varieties under National Protection of the People's Republic of China* on March 7, 2000, May 20, 2005, and April 16, 2016, respectively. However, so far, China has only authorized the right to new agricultural plant varieties of *B. napus*. The application announcement only involves 15 varieties of *B. campestris* and 1 variety of *B. juncea*, but the right to new agricultural plant varieties of *B. campestris* and *B. juncea* that originated locally has not yet been authorized.

China has authorized 304 new agricultural plant varieties of *B. napus*, involving 16 provinces including Sichuan, Guizhou, Hubei, Jiangsu, Anhui, Hunan, Shaanxi, Zhejiang, Henan, Yunnan, Shanghai, Guangdong, Jiangxi, Qinghai, Chongqing, Gansu, and a total of 82 owners of plant variety rights including 39 from research institutions, 33 from enterprises, 7 from universities, and 3 individuals. Among them, the main owners of plant variety rights are Guizhou Rape Research Institute, Oil Crop Research Institute of the Chinese Academy of Agricultural Sciences, Mianyang Academy of Agricultural Sciences, Guizhou Institute of Oil Crops, Jiangsu Academy of Agricultural Sciences, Crop Research Institute of Sichuan Academy of Agricultural Sciences, Crop Research Institute of Hunan Province, Nanchong Academy of Agricultural Sciences, Hybrid Rapeseed Research Center of Shaanxi Province, and Zhejiang Academy of Agricultural Sciences.

There are 77 new agricultural plant varieties of *B. napus* in Sichuan Province, involving 22 owners of plant variety rights. In specific, there are 16 varieties owned by Mianyang Academy of Agricultural Sciences: Mianyou 14, Mianyou 15, Mianyou 16, Mianyou 17, Mianyou 63, Mianyou 9AB-2, Mianhui 6, Mianhui 95-269, Mianhui 99-206, Mianyou 19, Mianyou 20, Mianyou 33, Mianyou 88, Mianyou 309, Mianyou 322, Mianyou 328. Crop Research Institute of Sichuan Academy of Agricultural Sciences has 13: JA0421, JA0555, JA1, JA20, JA5110, JA9, Chuanyou 23, Chuanyou 39, Dezhongyou 168, Tianfuyou 1, Tianfuyou 668, Zuoyou 1431, and Zuoyou 1701. Nanchong Academy of Agricultural Sciences has 6: Nanyou 9, Nanyou 10, Nanyou 12, Nanyou 461, Dehengyou 900, and Changjiang Zaoyou 3. Chengdu Academy of Agriculture and Forestry Sciences owns 5: Rongyou 12, Rongyou 13, Rongyou 14, Rongyou 15, and Rongyou 16. Mianyang Xinyu Seed Industry Co., Ltd. has 5: Mianxinyou 38, Mianxinyou 58, Mianxinyou 68, Xinyuyou 7, and Xinyuyou 8. Shifang Xiaonan Agricultural Technology Co., Ltd. has 5: Dielianhua, Shifanghong, Shifanghongyou 3, Xiaochunfeng, and Youhong. Sichuan Fangpai Seed Industry Co., Ltd. has 4: Fang11AB, Fang11R, Fangpaiyou 555, and Fangyou 11. Sichuan Shuyu Technology Agriculture Development Co., Ltd. has 4: Deyou 99, Deyouza 10, Longting 1, and Shuyou 168. There are 3 owned by Chengdu Second Research Institute of Agricultural Science: Rong A0464, Rong A950424, and Rong C0982. Chengdu Crop Research Institute has 2: Rongyou 17 and Rongyou 18. Luo Sanpei owns 2: Mianxin 11 and Mianxinyou 12. Sichuan Huafeng Seed Industry Co., Ltd. has 2: 8702A and Shufeng 6608. Denong Zhengcheng Seed Co., Ltd. has one: Deyou 8. Sanxingdui Rapeseed Research Institute in Guanghan City has one: Deyouzao 1. Leshan academy of Agricultural Sciences owns one: Leyou 101A. Mianyang Youbang Agriculture Development Co., Ltd. has one: Mianbangyou 1. Sichuan Guohao Seed Industry Co., Ltd. has one: Guohaoyou 5. Sichuan Keyuan Agricultural High tech Co., Ltd. has one: Chuanyou 22. Sichuan Longping High-tech Seed Co., Ltd. has one: Chuanyou 21. Sichuan Mianbang Agricultural Technology Co., Ltd. has one: Mianbangyou 221. Sichuan Xihe Rape Seed Industry Co., Ltd. has one: Xiheyou 3. Yibin Academy of Agricultural Sciences has one: Yiyou 15.

There are 63 new agricultural plant varieties of *B. napus* in Guizhou Province, involving 3 owners of plant variety rights. Specifically, Guizhou Rape Research Institute owns 48 varieties: ADMB1, AMB1, CT1358, DH0815, DJMR1, DJMR4, DJR1, DJTMR1, DJYMA1, DJYMR1, DJYMR2, DJYMR3, DTMR1, DW871, DYR1, MB1, MB2, MR1, MR2, MR2, MR3, MR4, MR5, Baoyou 517, Baoyouzao 12, Dexinyou 18, Dingyou 17, Jinnongyou 1, Mianxinyou 19, Nonghuayou 101, Sanbei 98, Shengyou 15, Tianyou 97, Xianyouza 2, Xiangyou 1, Yiyou 1, Youke 1, Youyan 11, Youyan 1220, Youyan 157, Youyan 1707, Youyan 50, Youyan 599, Youyan 817, Youyanmi 714, Youyanmi 764, Youyanzao 18, Yuyou 6, and Zhongnongyou 9. There are 15 varieties owned by Guizhou Institute of Oil Crops: Qianhuangyou21, Qianyou15, Qianyou 16, Qianyou 17, Qianyou 18, Qianyou 19, Qianyou 20, Qianyou 22, Qianyou 28, Qianyou 29, Qianyou 30, Qianyou 31, Qianyou 32, Qianyouzao 1, and Youyan 10. Guizhou Hemufu Seed Co., Ltd. has one: Youyan 818.

There are 39 new agricultural plant varieties of *B. napus* in Hubei Province, involving 11 owners of plant variety rights. In specific, Oil Crops Research Institute, Chinese Academy of Agricultural Sciences owns 22 varieties: 6019A, OR88, ZYP77, Dadi 195, Xiwang 122, Xiwang 699, Yangguang 1601, Yangguang 1602, Yangguang 2009, Zhongshuang 10, Zhongshuang 11,

Zhongshuang 3370, Zhongyou 589, Zhongyou Baihua 1, Zhongyou Weitai 1, Zhongyou Xitai 1, Zhongyou Xitai 2, Zhongyou Xitai 3, Zhongyou Xitai 4, Zhongyouza 13, Zhongyouza 39, Zhongyouza 7. Hubei Lizhong Seed Technology Co., Ltd. has 5 varieties: Liyou 618, Liyou 718, Liyouza 108, Liyouza 168, and Liyouza 178. Huazhong Agricultural University has 4: Bing 409, Huashuang 4, Huashuang 5, and Huayouza 62. Hubei Fuyue Agriculture Development Co., Ltd. has one: Fuyou 2. Hubei Ceres Technology Co., Ltd. has one: Gushenyou 5. Jingzhou Jinghua Seed Technology Co., Ltd. owns one: You 201. Wuhan CMP Super Seeds Co., Ltd. has one: T2159. Wuhan Liannong Breed Industry Technology Co., Ltd. owns one: 616A. Wuhan Zhongyou Technology New Industry Co., Ltd. has one: 1019A. Wuhan Zhongyou Sunshine Times Breed Industry Technology Co., Ltd. has one: 12X26. Wuhan Zhongyou Yangguang Seed Technology Co., Ltd. owns one: Zhongshuang 6.

There are 36 new agricultural plant varieties of *B. napus* in Jiangsu Province, involving 11 owners of plant variety rights. Specifically, Jiangsu Academy of Agricultural Sciences owns 14 varieties: APL01, Ning'ai 1, Ningyou 18, Ningyou 20, Ningyou DS3, Ningyou M342, Ningyou M9, Ningza 11, Ningza 1818, Ningza 1838, Ningza 27, Ningza 29, Ningza 9, and Tuhuanghua N301. There are 4 varieties owned by Lixiahe Agricultural Science Institute of Jiangsu Province: Yangyou 8, Yangyou 5, Yangyou 6, and Yangza 11. Zhenjiang Institute of Agricultural Sciences in Hilly Area of Jiangsu Province has 4: Dongyou 1, Jinhuang 2, Zhenyou 7, and Zhenyou 8. There are 4 varieties owned by Jiangsu Coastal Agricultural Research Institute: Yanyou 2, Yanyou 4, Yanyouza 5, and Yanyouza 7. Taihu Lake Region Agricultural Research Institute of Jiangsu Province has 2: Suyou 4 and Suyou 8. Huaiyin Agricultural Science Research Institute of Xuhuai Region, Jiangsu Province owns 2: Huaizayou 3 and Huaizayou 5. Yu Jingzhong owns 2: Shilichao and Shilijia. Ji Weijuan owns one: A28. Jiangsu Kingearth Seed Co., Ltd. has one: Yangyou 10. Nanjing Agricultural University has one: Nannongyou 3. Yangzhou University has one: Suyou 211.

There are 21 new agricultural plant varieties of *B. napus* in Anhui Province, involving 9 owners of plant variety rights. There are 5 varieties owned by Crop Research Institute of Anhui Academy of Agricultural Sciences: 5AB, Wanyou 15, Wanyou 16, Wanyou 20, and You AB. Anhui Agricultural University has 4 varieties: Huiyou 808, Huiyouza 511, Huiyouza 521, and Zayou 15. Anhui Guohao Agricultural Technology Co., Ltd. has 3 varieties: Haoyou 58, Huihaoyou 10, and Huihaoyou 12. Anhui GOSUN Agricultural Tech Co., Ltd. owns 2 varieties: Fengyou 827 and Guoshengyou 6. Anhui Tianhe Agricultural Technology Group Co., Ltd. has 2: Tianyouzao 1 and Tianyouzao 2. Hefei Fengle Seed Co., Ltd. has 2: Guohuayou 1208 and Huayou 2. Anhui Huishang Tongchuang High Tech Seed Industry Co., Ltd.: Tongyouza 2. Anhui Jinpeiin Technology Co., Ltd. owns one: Dehuiyou 88. Anhui Green Rain Seed Industry Co., Ltd. has one: Lvyou 218.

There are 15 new agricultural plant varieties of *B. napus* in Hunan Province, involving 5 owners of plant variety rights. In specific, there are 11 varieties owned by Crop Research Institute of Hunan Province: 167A, H20A, Fengyou 701, Fengyou 306, Fengyou 5103, Fengyou 520, Fengyou 679, Fengyou 737, Fengyou 958, Xiangzayou 5, and Youfei 1. Changde Agricultural and Forestry Science Academy has one: Youtai 927. Hunan Agricultural University owns one: Gaoyousuan 1. Hunan Yahua Seed Industry Scientific Research Institute has one: Huaxiangyou 12. Linli Rural Practical Technology Research Institute has one: Shenxuan 1.

There are 9 new agricultural plant varieties of *B. napus* in Shaanxi Province, involving 9 owners of plant variety rights. Among them, 6 varieties are owned by Hybrid Rapeseed Research Center of Shaanxi Province: Qinyou 33, Qinyou 1618, Qinyou 1699, Qinyou 558, Qinzayou 1, and Rongmi 1. Xianyang Agricultural Science Research Institute owns 3: Qinyou 8, Qinyou 9, and Qinyou 10.

There are 8 new agricultural plant varieties of *B. napus* in Zhejiang Province, involving 3 owners of plant variety rights. Among them, 6 varieties are owned by Zhejiang Academy of Agricultural Sciences: Zheshuang 3, Zheshuang 6, Zheyou 18, Zheyou 50, Zheyou 51, and Zheyou 601. Wenzhou Jiayou Seed Industry Co., Ltd. has 3: Jiayou 3. Jiaxing Institute of Agricultural Sciences in Zhejiang Province owns one: Jiayou 1427.

There are 7 new agricultural plant varieties of *B. napus* in Henan Province, involving 5 owners of plant variety rights. In specific, Henan Institutes of Cash Crops has 2 varieties: Shuangyou 10 and Shuangyou 195. Henan Academy of Agricultural Sciences owns 2: Shuangyou 8 and Za 98033. Henan Institute of Cotton and Oil Crops has one: Zashuang 2. Xinyang City Academy of Agricultural Sciences owns one: Xinyouza 2906. Zhoukou Normal University owns one: Zhouyou 589.

There are 6 new agricultural plant varieties of *B. napus* in Yunnan Province, involving 2 owners of plant variety rights. Among them, 3 varieties are owned by Yunnan Institute of Cash Crops: Yunyoushuang 2, Yunyouza 5 and Yunyouza 6. Yunnan Academy of Agricultural Sciences owns 3: Yunyouza 10, Yunyouza 18, and Yunyouza 22.

There are 5 new agricultural plant varieties of *B. napus* in Shanghai, involving 1 owner of plant variety rights, *i. e.*, Shanghai Academy of Agricultural Sciences. The 5 varieties are HF08, Heza 19, Huyou 039, Huyou 18, and Huyou 21.

There are 5 new agricultural plant varieties of *B. napus* in Guangdong Province, involving 2 owners of plant variety rights. Among them, 3 varieties are owned by Guangshiji Zhuanjiyin Technology Co., Ltd.: Chuanyou 36, Chuangzayou 5, and Chuangzayou 9. Chuangshiji Seed Industry Co., Ltd. has 2: Chuangzayou 7 and Hanyou 8.

There are 4 new agricultural plant varieties of *B. napus* in Jiangxi Province, involving 1 owner of plant variety rights. There are owned by Crop Research Institute of Jiangxi Academy of Agricultural Sciences: 283B, G5034AB, R210, and Ganyouza 5.

There are 4 new agricultural plant varieties of *B. napus* in Qinghai Province, involving 2 owners of plant variety rights. Qinghai Academy of Agriculture and Forestry Sciences has 3: Qingza 12, Qingza 17, and Qingza 5. Qinghai University has one: Qingza 15.

There are 3 new agricultural plant varieties of *B. napus* in

Chongqing City, involving 2 owners of plant variety rights. Among them, there are 2 owned by Chongqing Academy of Agricultural Sciences: Qingyou 1 and Qingyou 2. Chongqing Three Gorges Academy of Agricultural Sciences has one: Wanyou 25.

There is one agricultural plant variety of *B. napus* in Gansu Province, involving one owner of plant variety rights, *i. e.*, Crop Research Institute of Gansu Academy of Agricultural Sciences. The variety is named Longyouza 1.

Main Issues of Rape Breeding and Its Intellectual Property Protection

Severe loss of germplasm resources in *B. juncea* and *B. campestris*

With the introduction of *B. napus*, the weakness of low yield per unit area of *B. juncea* and *B. campestris* has been exposed. It has become a trend for *B. napus* to replace locally sourced *B. juncea* and *B. campestris* in main production areas of rapeseeds. The loss of germplasm resources in *B. juncea* and *B. campestris* is severe, especially in the Yangtze River Basin.

The role of National Crop Germplasm Resource Bank needs to be fully realized

Rape is the third largest oilseed crop in the world and the largest in China, with a wide distribution, especially for the *B. juncea* and *B. campestris* types. National Mid-term Genebank for Oil Crops (Wuhan), National Crop Germplasm Resources Bank, National Central Plains Characteristic Horticultural Crop Germplasm Resources Genebank (Hefei), National Fujian and Taiwan Characteristic Crop Germplasm Resources Genebank (Zhangzhou), National Southeast Mountain Crop Germplasm Resources Genebank (Yichun), National Southwest Characteristic Horticultural Crop Germplasm Resources Genebank (Chengdu), National Yunnan – Guizhou Plateau Characteristic Crop Germplasm Resources Genebank (Guiyang), National Crop Germplasm Resources Backup Genebank (Xining) and National Central Asian Characteristic Crop Germplasm Resources Mid-term Genebank (Urumqi) are all responsible for protecting germplasm resources. However, in the *Catalogue of Available Crop Germplasm Resources* (*First Batch*), 500 rape germplasm resources are all preserved in the National Mid-term Genebank for Oil Crops (Wuhan), while other comprehensive national crop germplasm resources genebanks seem to have little protection effect on rape germplasm resources.

The intellectual property creation ability and protection awareness of national seed industry formation enterprises for oil crops are quite weak

As applicants (patentee), five national seed industry formation enterprises for oil crops have only been authorized for 45 national patents accumulatively in the field of agricultural breeding (IPC A01), and only 12 national patents have been obtained in the field of rape breeding. Among them, three enterprises have not obtained national patents in the field of agricultural breeding, and four enterprises have not obtained national patents in the field of rape breeding.

As applicants (owners of variety rights), five national seed industry formation enterprises have accumulated only three new agricultural plant varieties in the field of rape (IPC A01). Except for Anhui Guohao Agricultural Technology Co., Ltd., 4 enterprises have not obtained new agricultural plant varieties of rape.

Most major producing provinces have weak patent creativity in the field of rape breeding

Most of the main producing provinces have weak patent creativity and awareness of intellectual property protection in the field of rape breeding, and have not been authorized for many Chinese patents, not as many as foreign companies such as Pioneer Hi-Bred International, Inc, BASF Plant Science Co., Ltd., Dow Agrosciences Company, Monsanto Company, and E. I. duPont de Nemours and Company.

There are not many new agricultural plant varieties of rape in most major producing provinces

Only 304 new agricultural plant varieties of *B. napus* have been authorized nationwide, involving only 16 provinces, but no new varieties of *B. juncea* and *B. campestris* have been authorized. Except for Sichuan, Guizhou, Hubei, Jiangsu, and Anhui, there are not many new agricultural plant varieties of rape in other provinces, especially in spring rape areas.

The 'agricultural chip' in the field of rape is weak

China has the world's largest rape planting area and the world's second largest rapeseed yield. Currently, the average rapeseed yield per hectare in China is only 2 077.5 kg, and the oil content is about 43% and the oil production is 894 kg/hm^2. Its yield per hectare and oil production per hectare are both not high, making it difficult to compare with strong rapeseed countries such as Canada. The key issue is that China as a large rapeseed country is weak in "agricultural chip" in the field of rape, and universities are weak in new agricultural plant varieties of rape, with only 13 new varieties authorized, only involving 7 universities such as Huazhong Agricultural University and Anhui Agricultural University.

Rape Breeding and Its Intellectual Property Protection Strategies

Strengthening the protection of rape germplasm resources

We should investigate national rape germplasm resources, and protect rape germplasm resources, especially local varieties of wild rape, *B. juncea* and *B. campestris*, depending on global biodiversity observation stations, national nature reserves, national forest parks, national natural heritage sites, and important agricultural cultural heritage sites in China and globally, so as to maintain rape biodiversity.

Giving play to the role of national and provincial crop germplasm resources banks

It is necessary to expand the conservation scale of rape crop germplasm resources available for use in the National Mid-term Genebank for Oil Crops (Wuhan), and to launch the preservation function of rape germplasm resources in comprehensive national crop germplasm resource genebanks, including National Central Plains Characteristic Horticultural Crop Germplasm Resources Genebank (Hefei), National Southeast Mountain Crop Germplasm Resources Genebank (Yichun), National Southwest Characteristic Horticultural Crop Germplasm Resources Genebank (Chengdu),

National Yunnan – Guizhou Plateau Characteristic Crop Germplasm Resources Genebank (Guiyang), National Crop Germplasm Resources Backup Genebank (Xining) and National Central Asian Characteristic Crop Germplasm Resources Mid-term Genebank (Urumqi). We should create provincial-level rape crop germplasm resources genebanks, and give full play to the protection role of national and provincial-level crop germplasm resources genebanks for rape germplasm resources.

Encouraging the development of "agricultural chip" in national advantageous characteristic industrial clusters of rape

Building seed industries with national advantages and characteristics, such as the Jianghan Plain rape industry cluster in Hubei Province, the early-maturing rape industry cluster in Hunan Province, the rape industry cluster in Sichuan Province, the mountainous winter idle rape industry cluster in Guizhou Province, and the rape industry cluster in Qinghai Province, can promote the protection and utilization of germplasm resources in the field of rape breeding, and enhance the creativity and awareness of intellectual property rights such as patents and new agricultural plant varieties.

Building state-level regional breeding bases and seed production counties for rape varieties

Seven state-level regional breeding bases for rape varieties, including Xishui County Gucheng County of Hubei Province, Changshun County of Guizhou Province, Hanzhong City of Shaanxi Province, Shandan County and Minle County of Gansu Province, and Huzhu County of Qinghai Province, as well as eight state-level seed production counties for rape varieties, including Hengyang County in Hunan Province, Hengfeng County in Jiangxi Province, Santai County in Sichuan Province, Luojiang District in Deyang City, Jingyang District in Deyang City, Tongnan District in Chongqing, Mianxian County in Shaanxi Province, and Nanzheng District in Hanzhong City, can be built and supported to promote the high-quality development of rape seed industry.

Supporting rape seed industry formation enterprises

It is necessary to establish provincial-level and national rape seed industry formation enterprises, and to encourage and support national seed industry formation enterprises for oil crops, including Anhui Guohao Agricultural Technology Co., Ltd., Qingdao Huashi Seedling Co., Ltd., Henan Jinwoye Agricultural Development Co., Ltd., Zhongken Jinxiu Huanong Wuhan Technology Co., Ltd., and Shaanxi Ronghua Agriculture Technology Co., Ltd. We should create national invention patents and new practical patents in the field of rape breeding, and cultivate excellent new varieties.

Establishing a politics, industry, academia, research and application innovation platform for rape breeding

With the main rapeseed producing provinces and cities as units, we will strengthen the government's guiding role, and implement the rape seed industry revitalization action and improvement project from aspects such as germplasm resource protection, innovative research, enterprise support, base improvement, and market purification. We will collaborate with the rapeseed industry, universities, research institutions, and new agricultural business entities to establish a politics, industry, academia, research and application innovation platform for rape breeding, so as to enhance the rape breeding of national advantageous characteristic industrial clusters, state-level regional improved seed breeding bases, state-level seed production counties, and seed industry formation enterprises and promote deep integration of politics, industry, academia, research, and application.

Strengthening the protection of agricultural intellectual property rights

We should strengthen the promotion of the strategy of strengthening the country through intellectual property rights, enhance social education on agricultural intellectual property rights, cultivate awareness of intellectual property protection among breeders, maintain the diversity of rape genetic resources, and improve the level of the entire chain of intellectual property creation, application, protection, management, and service in rape breeding.

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