Studies on feasibility of expanding winter rapeseed northwards into dry, cold regions in Northwest China

SUN Wancang[1], MA Weiguo[2], LEI Jianmin[3], WANG Heling[4], LIU Qin[5], FAN Huiling[1], YANG Renyi[6], WANG Xuefang[1], YE Jian[1], ZENG Jun[1], ZHANG Yahong[1], KANG Yanli[1], GUO Xiujuan[1], WEI Wenhui[1], YANG Jie[1], LU Xiuxia[1]

[1]Department of Genetics and Crops Breeding, College of Agronomy, Gansu Agricultural University, Lanzhou 730070, China; Email: wangcangsun@yahoo.com.cn
[2]Gansu Vocational College of Animal Husbandry Engineering, Wuwei, Gansu 733006, China;
[3]Tianshui Institute of Agriculture, Tianshui, Gansu 741000, China;
[4]Lanzhou Institute of Dry Land Meteorology, Chinese Bureau of Meteorology, Lanzhou 730070, China;
[5]Zhangye Institute of Agriculture, Zhangye, Gansu 734000, China;
[6]Jiuquan Institute of Agriculture, Jiuquan, Gansu 735000, China

Abstract

Field experiments were carried out in 2001-2006 at 10 locations in Gansu Province, the Northwest China, where the latitude ranged from 35°30' to 39°46'N, the elevation ranged from 1477 to 2300m, the precipitation ranged 92.0-630mm, and the annual average temperature ranged 5.9-8.7 °C. Forty The 40 cultivars/lines of *Brassica napus* tested could not survive the local winter. All 15 *B. rapa* materials tested, all of which were native of Northwest China, had the overwintering rates >70% at most locations. At Jiuquan, the northernmost location, only the ultra winter-hardy lines MXW-1 and DQW-1 survived the winter. The *B. rapa* winter rapeseed had desirable agronomic characteristics and outyielded spring rapeseed and flax. Its early maturity maximized the multiple crop index and increased unit land cash return. As a winter cover crop, it might eliminate a dust source that furnished the damaging sand storms in northern China. It is not only possible but also beneficial economically, environmentally and ecologically to grow winter rapeseed in the dried and cold regions in Northwest China.

Key words: Winter rapeseed; crop adaptation; cover crop; winter hardiness; Northwest China; sand storm.

Introduction

Global warming is one of the greatest challenges facing the world. Chinese scientists showed that the average temperature in China increased by 0.4-0.5 °C in the past century, and that the warming-up in the Northwest of China was greater than the average of the country (Zhang, 2000; Zhai et al, 1997; Qin, 2002). A warm climate may make it possible to expand winter rapeseeds northwards (Zhang, 2000; Zou et al, 2001). Generally, winter rapeseed yields higher than spring rapeseed. There are investigations reporting on expanding the winter wheat and winter rapeseed northwards in recent years (Wang et al., 1994; Wang, 1999; Zou et al, 2001). Located in Northwestern China, Gansu province belongs mostly the spring rapeseed region (Liu, 1987). This study was to find out the feasibility of expanding winter rapeseed northwards into dry, cold regions in Gansu.

Material and methods

Field experiments were carried out from 2001 to 2006 at 10 locations in Gansu, China. The major climatic parameters of those locations were: Latitude 36°30´-39°46´, elevation 1477-2300m, January temperature -7.2-10.2°C, annual average temperature 5.9-8.7°C, frost-free days 140-180, annual precipitation 92-630mm. The following four types of experiments were conducted:

1. Overwintering test of *Brassica napus* and *B. rapa* varieties (2001-2003): Forty *B. napus* and 12 *B. rapa* winter rapeseed varieties/lines were tested for overwintering at Jingyuan, Lanzhou, Wuwei and Zhangye.

2. Evaluation of winter *B. rapa* (2003-2006): The experiments were carried out at Liuchuan, Beitan, Lanzhou, Yongdeng, Wuwei, Zhangye, Jiuquan. All varieties used in these experiments were *B. rapa*, because only *B. rapa* varieties could survive the local cold winter.

3. Comparison of winter rapeseed with spring rapeseed and/or flax (2002-2006): Winter rapeseed was grown side by side with flax and/or spring rapeseed, the primary oilseed crops, in the demonstration fields of 0.03 to 0.20 ha at Liuchuan, Beitan, Linxia, Lintao, Yuzhong, Yongdeng and Wuwei.

4. Evaluation of the cash return (2003-2005): Field experiments were conducted at Liuchuan to evaluate the unit land cash return from growing winter rapeseed.

In the experiment 1, 2 and 4, a randomized complete block design with three replicates was used. The plots were 11.2m^2 each. In the experiment 1, 40 *B. napus* cultivars used were: SW-0756, Modena, Orkan, SLM-046, Consul, Chcyenne, Fornax, Calibra, Hopper, Hecald, Synergy, Embleme, Ryder, Pastell, Talent, Pronto, Jocker, Alove, Ebolite Olara, Parade-2, Gazzala, RPC202, Actas, Okapi, Roby, OR2-8/99, ASCN, Broomerary, GWC-1, Ebolite-1, SLM046-1, Olson, Korola, Akar, ISN1770,

Kolvert, Orient, Aladsne. These varieties were mostly introduced from Europe. In the Experiment 1 and/or 2, 15 *B. rapa* varieties used were: 964, 813, 8728, Tianyou 1, Tianyou 2, Yanyou 2, 876, 986, Hejiawan, MXW-1, WYW-1, DQW-1, 02C-Za9, 9852 and 9889. All the *B. rapa* materials were either landraces or cultivars bred locally in Northwest China.

Results

1. Overwintering rates of B. napus and B. rapa varieties

The *B. rapa* varieties showed much stronger winter-hardiness than the *B. napus* ones. On average, the overwintering rates for the 12 *B. rapa* varieties at different locations were from 84% to 96%, and those for the 40 *B. napus* cultivars were only 0 – 8.8% (Table 1).

Table 1. Average overwintering rates of 40 *B. napus* cultivars and 12 *B. rapa* varieties

	Jingyuan	Lanzhou	Yongdeng	Zhanye
Overwintering rate of *B. napus* (%)	4.5	8.8	0.0	0.0
Overwintering rate of *B. rapa* (%)	95.0	96.0	90.0	84.0

2. Evaluation of winter B. rapa

Twelve varieties were tested at Jingyuan, Lanzhou, Yongdeng and Zhangye in 2003-2005, and eight varieties were tested at Wuwei, Zhangye and Jiuquan in 2005-2006. A total of 15 different varieties were tested. All varieties could survive the winter locations, the South of Wushaoling Mountains, i.e. Liuchuan, Beitan, Lanzhou, Yongdeng. When grown further north in the Hexi corridor, only MXW-1, DQW-1 and WYW-1 had high overwintering rates with 100, 100 and 93%, respectively, at Wuwei and Zhangye (Figure 1). At the northernmost location Jiuquan, only the ultra winter-hardy MXW-1and DQW-1 survived the local winter.

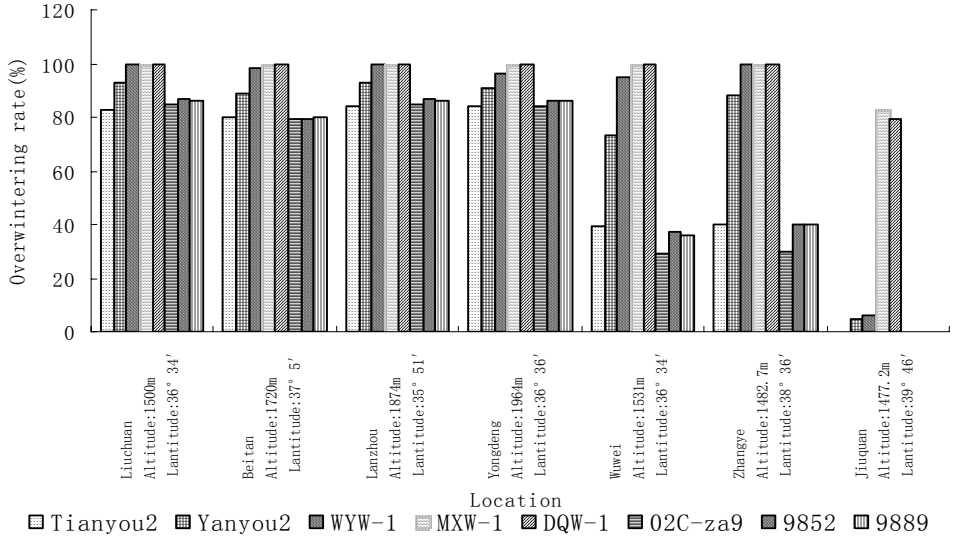

Figure 1. Overwintering rates of 8 *B. rapa* varieties (lines) at 7 locations in 2005-2006 field experiment.

The winter *B. rapa* grew normal and healthy with relatively high pods per plant, seeds per pod, 1000-seed weight, and oil content. The growth periods from emergence to maturity were 275-295 days. The seed yield generally ranged from 2579.82 to 3353.42kg/ha, with the highest yield of 4400 kg/ha from the variety WYW-1 at Zhangye in 2005-2006 (Table 2).

Table 2. Characteristics of the winter *B. rapa* varieties tested in 2005-2006 *

Cultivar	Plant height (cm)	Pods/ plant	Seeds /pod	1000-seed weight(g)	Growth period (days)	Oil content (%)	Seed yield (kg/hm^2)
Tianyou 2	107.8	212.6	21.5	3.6	283~290	42.35	2691.52
Yanyou 2	101.2	163.4	21.3	3.2	281~283	43.03	3097.50
WYW-1	100.2	232.0	19.6	3.7	275~283	44.15	3353.42
MXW-1	113.5	295.6	20.6	3.6	288~295	43.50	3273.37
DQW-1	107.2	240.6	21.1	3.0	288~295	42.89	2978.36
02C-Za9	109.9	264.0	22.0	2.8	283~290	42.07	2715.12
9852	105.9	145.8	20.1	3.3	283~290	4179	2587.92
9889	101.5	216.6	19.8	3.3	283~290	40.84	2579.82

*The values were either the average or the range at the seven locations.

3. Comparison of yield between winter rapeseed and spring rapeseed and/or flax

Spring rapeseed and/or flax were the major oilseed crops in these regions. In order to show the local farmers the possibility of planting winter rapeseed as an oilseed crop, *B. rapa* winter rapeseed with the spring rapeseed and/or flax –depending on which was the dominating oilseed crop locally– were grown at 7 locations in 2002-2005. Winter rapeseed outyielded the control in all years and locations, with the yield increase over the control ranging from 2 to 37% (Table 3).

Table 3. Comparison of seed yields between the winter rapeseed and the spring rapeseed and/or flax.

Location	Year	Winter rapeseed (kg/ hm^2)	Control (spring rapeseed or flax) (kg/hm^2)	Increase over the control (%)
Liuchuan	2002/2003	2753	2325	18
	2003/2004	2885	2402	20
	2004/2005	3122	2480	26
Beitan	2003/2004	2946	2417	22
	2004/2005	2865	2340	22
Linxia	2002/2003	2552	2412	6
	2003/2004	2531	2400	5
	2004/2005	3122	2775	12
Lintao	2002/2003	2474	2250	10
	2003/2004	2522	2112	19
	2004/2005	2984	2331	28
Yuzhong	2002/2003	2670	2175	23
	2003/2004	2475	2267	21
	2004/2005	2775	2025	37
Yongdeng	2004/2005	2838	2282	24
Wuwei	2004/2005	3152	2394	32

4. Economical value of winter rapeseed

Farmers can plant winter rapeseed only if they get more cash return from the same land. In order to calculate the cash value of the winter rapeseed, we incorporated the winter rapeseed into new cropping systems and compared them with the popular cropping systems used by the local farmers. Of the eight cropping systems compared (Table 4), three had winter rapeseed as a component crop. The other five were the popular cropping systems. Only the systems with winter rapeseed allowed growing a following crop, because the winter rapeseed harvested earlier than other summer-harvesting crops, such as flax, spring rapeseed, peas, wheat, etc. Winter rapeseed-potato multiple cropping had the highest cash value, and winter rapeseed-turnip multiple cropping also had very high cash return (Table 4).

Table 4. Average yield and cash values of 8 cropping systems in 2003-2005 at Liuchuan of Jingyuan County.

Cropping system	Crop component	Yield (kg/hm^2)	Cash value* (¥/hm^2)	Combined cash value* (¥/hm^2)	Significance of differences 5%	1%
Winter rapeseed-potato multiple cropping	Winter rapeseed	4120	12360	28492.5	a	A
	Potato	40331	16132.5			
Winter rapeseed-turnip multiple cropping	Winter rapeseed	3913	11739	25246.5	abc	ABC
	Turnip	67538	13507.5			
Winter rapeseed-corn Intercropping	Winter rapeseed	3235	9705	17308.5	bcd	ABC
	Corn	6913	7603.5			
Wheat-corn intercropping	Wheat	5253	8404.5	15408	d	C
	Corn	6336	7003.5			
Flax-corn intercropping	Flax	2546	8655	16059	d	BC
	Corn	6371	7404			
Potato-corn intercropping	Potato	47000	18799.5	25803	ab	AB
	Corn	6767	7003.5			
Pea-corn intercropping	Pea	5003	8004	18408	abcd	ABC
	Corn	9458	10404			
Wheat-soybean intercropping	Wheat	5280	8448	16365	cd	BC
	Soybean	3959	7917			

*The prices in the local markets were used. The prices used to calculate the cash values were the prices in the local market in late 2004. They were: wheat 1.6, corn 1.1, potato 1.4, rapeseed 3.0, soybean 2.0, pea 1.6, flax 3.4, turnip 0.2 ¥/kg.

Discussion

Liu (1987) pointed out that Northwest China was a genetic center with abundant diversity for *B. rapa* (*B. campestris*). Sun *et al.* (2004) reported that Gansu had very rich genetic resources of *B. rapa*. Pan (1987) reported that Dongmanjing, a *B. rapa* winter rapeseed landrace in Gansu, could be the most winter-hardy rapeseed in the world. The present study showed that *B. rapa* varieties from Northwest China had much stronger winter-hardiness than *B. napus* cultivars. This conclusion was

consistent with these bypast investigations about the *B. rapa* resources in Northwest China.

Based on our results, it was feasible to expand winter rapeseed northwards in Gansu. In the areas lower than 2000m and south of Wushouling Mountain (<36°40′N), most winter-hardy *B. rapa* varieties could overwinter safely. It was also possible to grow winter rapeseed in the Hexi Corridor north of the Wushaoling Mountain if the very winter-hardy was used. Using the ultra winter-hardy *B. rapa* varieties, such as MXW-1and DQW-1, the winter rapeseed could be grown as north as Jiuquan at 39°46′N. This meant that the winter rapeseed could be expanded 1,000km north from the border of the winter rapeseed zone defined by Liu (1987).

Conclusions

The frost-free days in these experimental places are usually sufficient for one crop but not for two crops. Our data suggests that the winter rapeseed not only have desirable agronomic characteristics, oil content and seed yield, but also make it possible to grow two crops in the one year. As a result, growing winter rapeseed may increase unit-land cash returns for the local farmers. In addition, winter rapeseed is an excellent crop that can cover completely the ground since November, while the surrounding farmland is naked and exposed to wind erosion. Therefore, growing winter rapeseed may be helpful to decrease the dust source providing devastating sand storm, which frequently occur in Northwest China (Ye, 2001).

References

Zhang Hou-xuan(2000). The problems concerning the response of China's cropping systems to global climatic changes. *Chinese Journal of Agrometeorology,* **21(1)**: 9-13.

Zhai Pan-mao, Ren Fu-min (1997). On Changes of China's maximum and minimum temperatures in the recent 40 years. *Acta Meteologica Sinica*, **55(4)**: 418-429.

Qin Da-he, Ding Yi-hui, Wang Shao-wu, Wang Su-min, et al. (2002). A Study of environment change and its impacts in western China. *Earth Science Frontiers*, 9**(2)**: 321-328.

Wang Ya-jun (1999). Analysis of rationalities and cultivation techniques of growing winter wheat northwards in Gansu. *Gansu Agricultural Science and Technology,* 1999**(7)**: 15-16.

Zou Li-kong, Zhang Jian-ping, Jiang Qing-zhen and Wang Gui-yan (2001). Research and development of winter wheat Growing in northern region. *Chinese Journal of Agrometeorology,* **22(2)**: 53-57.

Wang Shuan-quan,Liu Dong-mei (1994). The practice and acknowledgement of northward movement of rapeseed (*Brassica napus*) on Weibei Highland. *Agricultural Research in the Dried Areas*, **12(3)**: 74-78.

Liu Hou-li (1987). Cultivation of Rapeseed, Shanghai: Shanghai Press of Science and Technology, 32-36.

Liu Hou-li(1987).Genetics and Breeding of Rapeseed.Shanghai: Shanghai Press of Science and Technology,1-63.

Sun Wancang, Pan Qiyuan, Liu Zigang, Meng Yaxiong and Zeng Xiucong (2004). Genetic resources of oilseed Brassica and related species in Gansu Province, China. Plant Genetic Resources, **2(3)**:167-173.

Pan Qi-yuan(1987). "Dongmanjing" in Gansu and its values. *Oil Crops of China,* 1987**(1)**: 79-81.

Ye Du-zheng, Chou Ji-fan, Liu Ji-yuan, Zhang Zeng-xiang, etc. (2000). Causes of sand-stormy weather in Northern China and control measures. *Acta Geographic Sinica*, **55(5)**: 513-521.