Growth and Development Characteristics of Winter Rapeseed Northern-Extended from the Cold and Arid Regions in China

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Abstract

Nine cultivars of winter rapa with different cold-resistance were studied in the original growing regions and north extending regions. The results showed that the over-wintering rate of winter rapeseed reduced from 93.0%–100.0% to 40.0%–95.0%; The vegetative growth period before wilt leaf stage and the regreen stage to maturity was shortened greatly, while the duration from wilt leaf stage to regreen stage was longer than winter rapa planted in the original regions. The plant height and branch length were shortened, the 1000-grain weight and the seeds in each lique were higher at Zhangye than at Tianshui. The ultra winter-hardy cultivars and the reasonable growing date and density should be adopted in order to increase the over-winter rate of winter rapeseed in winter rapeseed extending northern regions.

Since 1980s, the global climate warms up, such change provides favorable conditions for the winter crops to expand toward the high latitude area[1-2].Research work about relocating winter rape to the north has attracted wide attention at home and abroad [3-4]. The vicinity of Tianshui in Gansu Province is the transitional zone of China winter rapeseed and spring rapeseed. With the successful breeding of cold-resistant *Brassica rapa* in China, *Brassica rapa* has been successfully introduced into the Hexi Corridor in Gansu, Altay and Urumqi in Xinjiang, Ningxia, Beijing and other areas, which makes the planting area of winter rapeseed in China moves northward about 13 latitude. This study was planned to compare and analyze the changes in main climatic factor, winter survival rate and economic traits between the original growing area and northern-extending growing area (Zhangye) of northern-extending *B. rapa*, and provide technical support to the cultivation and breeding of rape in the northern cold-arid area.

1 Materials and methods

1.1 Experimental materials and sources

Select 9 representative types of *Brassica rape* with different level of cold resistance as the experimental materials for this study, which respectively are Longyou 6, Longyou 7, Longyou 8, and Longyou 9; Tianyou 2, Tianyou 6, Tianyou 7, and Tianyou 8 ; Yanyou 2.

1.2 Basic conditions and experimental design of pilot areas

The experiments were taken place in 2006-2008 in 9 pilot areas (Tianshui, Liuchuan, Beitan, Lintao, Yuzhong, Yongdeng, Wuwei, Zhangye and Jiuquan). Tianshui is the northern-extending winter rapeseed marginal zone, Zhangye is the northern spring rapeseed area in China rapeseed planting area (Table 1). The experiments took Tianshui as the original growing area of winter rapeseed, and Zhangye as the representative pilot area for the northern growing area of winter rapeseed.

The first crop of the experimental field was spring wheat. Irrigation was needed before sowing, and manures 6000 kg/ha was applied, taking diammonium phosphate 225 kg/ha as base fertilizer. Experimental plots were randomly arranged with the area of 20m^2; each variety was sowed in three lines repeatedly with 20cm row spacing, the distance between the individual plants was 7-10cm (600,00 plants/ha). The experimental material was sowed manually on August 22, and then the seedlings were thinned out on September 15 and irrigated in the mid-November.

1.3 Trait investigation during the process of growth

The number of seedlings before the winter and after reviving was counted, and the cold resistance of the varieties was judged based on the winter survival rate. Recording of the sowing period, withered leaf period, returning green stage, budding period, start flowering period and maturing stage was made. The leaf age was checked every 10 days since five-leaf period.

1.4 Accumulation mensuration and economic traits survey of dry matter

5 plants were randomly selected three times in each plot before the winter, and the accumulation amount of dry matter of winter rapeseed was measured. Measurement method: dividing the plant into aboveground and underground parts, 65℃ baking dry, weighing, and calculating the accumulated amount of dry matter. Randomly select 10 plants for each process during maturing stage, measuring

plant height, branch height, number of primary branches, number of secondary branches, total number of branches, the number of effective silique of the main inflorescence, the number of effective silique of the whole plant, number of siliques, silique density, number of seeds of the silique, thousand seed weight, yield per plant and yield per plot. Microsoft Excel and SPSS16.0 were applied to calculate and analyze the data.

Table 1 Major meteorological factors of experiment site

	Tianshui	Lintao	Yuzhong	Yongdeng	Wuwei	Zhangye	Jiuquan
Latitude	34°33′	35°51′	35°51	36°36′	37°55	38°36′	39°46
he deepest ice soil (cm)	37	118	118	145	141	123.0	108
The average temperature in the coldest month (℃)	-2.4	-7.8	-7.8	-8.1	-8.7	-10.2	-9.7
The extreme lowest temperature (℃)	-18.2	-27.2	-27.2	-28.1	-29.5	-30.0	-31.6
Annual aerage temperature (℃)	10.9	6.6	6.6	5.9	7.6	7.1	7.3
Free frost days(d)	186	154	154	162	172	156	162
Precipitation (mm)	507.6	391	391	287	154	136.8	92.0
The average evaporation in Dec.~Feb. (mm)	119.7	123.9	109.4	157.9	136.5	130.3	127.5

2 Results and analysis

2.1 Analysis of ecological condition difference between original growing region and northern-extending regions for winter rapeseed

Comparing to the original growing region (Tianshui), the maximum depth of frozen soil increased by 70～108 cm in the northern-extending region (Zhangye); the average temperature of the coldest month decreased by 5.8～8.6℃; the lowest temperature decreased by 9.0～13.4 ℃; the frost-free days reduced 24～32 days than that in the original planting area; the rainfall reduced 116.6～415.6mm than that in the original planting area; and annual average evaporation increased -156～-728.6mm than that in the original planting area (Figure 1).

According to figure 1, after planting winter rapeseed in northern area, due to the reduction of accumulated temperature before-winter, the temperature was low during wintering period. Low temperature posed relatively greater threat on winter rapeseed in northern-extending region. The low temperature after the wintering period postpones the returning green stage of winter rapeseed, which could easily lead to spring cold damage. In the late growth stage of northern-extending winter rapeseed, the daily average temperature was lower than that in the original growing area. The period was also the pod-filling maturity period of northern-extending winter rapeseed, which was conducive to the accumulation of seed dry matter and the high yield of northern-extending winter rapeseed.

2.2 Changes in winter survival rate of different cold-resistance varieties of **northern-extending** winter rapeseed

All the tested varieties could live through the winter in the original cultivation area (Tianshui); however, in northern-extending region, due to high altitude and latitude, coupled with the maximum low temperature decreases, the winter survival rate of varieties decreased gradually (Figure 2). According to the level of winter survival rate of the rapeseed in 4 pilot areas, i.e. Zhangye, Jiuquan, Wuwei and Tianshui, the tested varieties were divided into 4 types: super-strong cold-resistance variety; strong cold-resistance variety; cold-resistance variety; and cold-tolerance variety. In the west and north of Lanzhou and Hexi district, only super-strong cold-resistance variety and strong cold-resistance variety were capable of adapting to the natural environment and ecological conditions, and live through the winter safely.

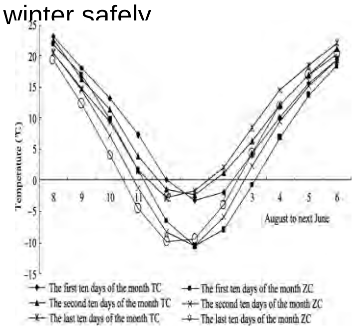

Fig. 1 Temperature changes of Zhangye and Tianshui between the first, the second and the last ten-days

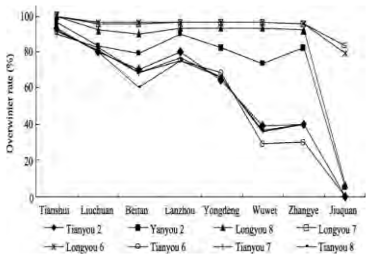

Fig.2 Overwintering rate of *B. rapa* cultivars in the original and the

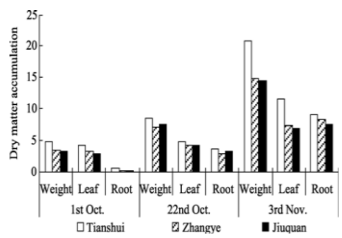

Fig. 3Dry matter accumulation characteristics of winter rapeseed in the original and northern-extending regions

Table 2 The Growing stage of winter rapeseed planted in original and northern region

Variety	Place	Sowing date	Emergency date	Dead leaves date	Regreening	Start flowering	End flowering	Maturing stage	Growing stage
Tianyou 2	Zhangye	8/22	8/31	11/13	3/23	4/18	5/13	6/12	287
	Tianshui	8/22	9/2	12/7	2/16	4/9	5/9	6/7	280
Longyou 6	Zhangye	8/22	8/31	11/11	3/22	4/26	5/21	6/16	289
	Tianshui	8/22	9/2	12/5	2/20	4/15	5/15	6/11	284

Table 3 Economic traits of northward winter rapeseed

Variety	Place	Plant height (cm)	Branch height (cm)	Number of first branch	Total of silique	Seeds/silique	1000-seed weight(g)	Yield
Tianyou 2	Zhangye	90.1	2.3	8.6	149.4	21.6	3.1	164.9
	Tianshui	137.4	35.9	8.2	170.7	21.3	3.00	163.5
	Discrepancy	47.3	33.6	-0.4	21.3	0.3	0.1	1.45
	Tianshui	101.0	30.7	6.7	163.3	19.2	2.48	49.4
	Discrepancy	9.4	28.0	-1.5	-45.6	-1.8	-0.62	172.8

2.3 Growth process analysis of **northern-extending** winter rapeseed

According to table 3, after winter rapeseed was extended to northern area, the withered leaf period comes early, and the returning green stage, budding period, start flowering period and maturing stage postpone. Taking Tianyou 2 as an example, the withered leaf period was advanced 24 days earlier, returning green stage, budding period, start flowering period, maturing stage and other growing period delay 35, 15, 11 and 4 days respectively. The growth period was extended for 6 days. The growth of winter rapeseed could be basically divided into 3 stages including before-winter period, wintering period and after-winter period. The wintering period of northern-extending winter rapeseed was extended comparing with that in the original growth area, while the before-winter growth period and after-winter growth period become short, showing the trait of "two shorts one long".

2.4 Analysis of **northern-extending** winter rapeseed yield and yield component factor variance

The data of winter rapeseeds economic traits in the original planting area and northward extended region(Zhangye) indicated that the plant height, branch position, length of rape stem, and seed number per plant reduced, while the number of silique and the thousand seed weight increased (Table 3). The main reason for increasing thousand seed weight was that the daily average temperature in northern-extending region was relatively low during the pod-filling period, with long sun lighting, prolonged pod-filling period. Meanwhile, the large temperature difference between day and night during the pod-filling period reduced the respiration consumption and improved the pod-filling intensity, which eventually maked the economic coefficient of northern-extending winter rapeseed significantly higher than that in the original growing areas. After winter rapeseed extended in northern area, the yield had greater change, and the yield of late-maturing varieties with strong cold resistance increase significantly, mainly due to different winter survival rates of different cold-resistant varieties, the actual harvests groups were therefore different.

2.5 Comparison of the before-winter nutrition, growth and dry matter accumulation between different winter rapeseed growing areas

The number of before-winter leaf emergence of Longyou 6 extended in northern-extended region was less than that in the original growing areas. Northern-extended winter rapeseed generally stopped growing after mid-October, which means the before-winter growth was mainly completed in about 50 days after the emergence of the seedling with normally 10 leaves; the dry matter accumulation in original growing area still continued in November. Northern-extended winter rapeseed stopped growing 30 days earlier than that in the original planting area. The dry matter accumulation in the same period of the original planting area was higher than that in the northern-extended area (Figure 3).

3 Discussion

3.1 Comparing to the original planting area, the average monthly temperature of northern-extending region was 1.60～7.84℃ lower, the extreme low temperature of January and February was 9～12℃ lower and up to about -30℃, while the frozen soil is 70～108 cm deeper. There was no snow cover in winter in northern relocation area. Therefore, the distinctive features of winter rapeseed northern-extending area were arid with low temperature and lower extreme temperature of long duration.

3.2 The winter survival rates of the tested winter rapeseed showed stepwise distribution with significant difference. Based on the winter survival rates, the main winter rapeseeds in northern cold-arid area were divided into four types, including super-strong cold-resistance variety, strong cold-resistance variety; cold-resistance variety and cold-tolerance variety, only super-strong cold-resistance variety and strong cold-resistance variety could adapt to the ecological conditions of the northern cold-arid area[2].

3.3 The growth period of northern-extended winter rapa was 280-290 days, the before-winter and after-winter growth period were short with long-lasting wintering period. The change trend of the economic traits was that the plant height and silique number per plant reduce, while the number of seed per silique and the thousand-seed weight increased. The thousand-seed weight increased mainly because of the longer sunshine duration and prolonged pod-filling period, and large temperature difference between day and night during the pod-filling period reduced the respiration consumption in northern-extending region. Therefore, as for the cultivation of northern-extended winter rapeseed, early-sowing in optimum time, appropriate close planting and scientific fertilization are needed so as to ensure adequate before-winter growth time and growth space, to obtain sufficient growth, and achieve the required dry matter accumulation for living through winter.

Reference

[1] Ramakrishna R. Nemani, Charles D. Keeling, Hirofumi Hashimoto *et al*., Climate-Driven Increases in Global Terrestrial Net Primary Production from 1982 to 1999, Science 2003, 300, 1560

[2] Sun W-c, Ma W-g, Lei J-m *et al*., Study on Adaptation and Introduction Possibility of Winter Rapeseed in Dried and Cold Areas in Northwest China, Scientia Agricultura Sinica,2007, 40(12): 2716-2726

[3] Rife C. L, Cold Tolerance in Oilseed Rape over Varying Acclimation Durations, Crop Science, 2003, 43: 96 – 100

[4] Beaulieu G. C, Adaptation of winter Rapeseed in Ontario, Canadian Journal of Plant Science, 1987, 67: 675-684