Effect of N-fertilizer Application on Yield, Grain Quality and N-fertilizer Use Efficiency of the Rapeseed Cultivars with Normal and High Oil Content

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Abstract In this study, seed yield, quality and N-fertilizer use efficiency in rape (*Brassica napus* L.) were researched in normal oil content cultivar (Yangyou 6) and two high oil content cultivars (Zhongshuang 11 and Zheyou 50). Results showed that the average oil content of all treatments in Yangyou 6, Zhongshuang 11 and Zheyou 50 was 42.87%, 47.37% and 48.28%, respectively. The average protein content of all treatments in Yangyou 6, Zhongshuang 11 and Zheyou 50 was 24.15%, 22.71% and 21.84%, respectively. The increased ratio of total nitrogen accumulation amount in Yangyou 6 was higher than that in Zhongshuang 11 and Zheyou 50. Among three cultivars, the total protein accumulation amount in Yangyou 6 was highest, and the total oil accumulation amount was highest in Zheyou 50. With increasing nitrogen fertilization, the value of different parameters of N-fertilizer use efficiency decreased. The average N use efficiency in Yangyou 6 was 68.70%, which was higher than that in Zhongshuang 11 and Zheyou 50 (65.06% and 60.30%, respectively). The average N-fertilizer agronomic use efficiency in Yangyou 6 was also highest among three cultivars, which was 8.97 kg seed/kg N. On the contrary, the average N-fertilizer physiological use efficiency in Zhongshuang 11 and Zheyou 50 was 13.03 kg seed/kg N and 13.84 kg seed/kg N, respectively, which was higher than that in Yangyou 6 (12.91 kg seed/kg N). Differences in partial factor productivity of N-fertilizer were slight among three cultivars.

Key words Rapeseed, Cultivars, Quality, N-fertilizer use efficiency

1 Introduction

Nitrogen is a necessary nutrient element for plants, and plays an important role in the improvement of crop yield and quality. China is the world's largest producer of rapeseed, with the planting area of 7 million ha, and its yield accounts for one third of that of the world[1]. In recent years, the rapeseed oil consumption accounts for about 50% of the domestic edible vegetable oil consumption[2]. The cabbage type rapeseed has high plant and its grain is rich in protein, and the application of N-fertilizer is a key factor affecting yield[3-7]. However, excessive application of nitrogen will not only make the nitrogen utilization efficiency decrease steadily and agricultural production costs rise, but also reduce the oil content of grain and affect its quality[8-9]. Meanwhile, great nitrogen losses can bring about serious environmental pollution[10-11]. Presently, many researchers have studied the rational management and use efficiency of N-fertilizer for rapeseed[12-16], and the results of research have played an important role in guiding efficient rapeseed production. With the improvement of breeding technology, some rapeseed varieties with high oil content have been cultivated and promoted in production, but there is a shortage of related basic physiological researches. In this study, we used normal and high oil content rapeseed varieties for planting, and studied the influence of N-fertilizer application on rapeseed yield, quality and N-fertilizer use efficiency, so as to provide theoretical basis for high-yield, high-efficiency and high-quality rapeseed production.

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2 Materials and methods

2.1 Materials The test rapeseed cultivars were Yangyou 6, Zhongshuang 11 and Zheyou 50, bred by Lixiahe Institute of Agricultural Sciences, Oil Crop Research Institute of Chinese Academy of Agricultural Sciences and Zhejiang Academy of Agricultural Sciences, and Zhongshuang 11 and Zheyou 50 had high oil content.

2.2 Methods The experiment was carried out in the experimental farm of Yangzhou University during 2014 - 2015. The experimental soil was sandy loam soil; organic matter content was 22.4 g/kg; alkali-hydrolyzable nitrogen content was 109.5 mg/kg; available phosphorus content was 18.8 mg/kg; available potassium content was 87.2 mg/kg. The experiment had four treatments: non-application of N-fertilizer (N_0); 120 kg/ha (N_1); 240 kg/ha (N_2); 360 kg/ha (N_3). Basal fertilizer: seedling fertilizer: bolting fertilizer is 5∶2∶3. The application rate of P_2O_5 and K_2O under two treatments was all 150 kg/ha. All of phosphate fertilizer was as basal fertilizer; half of potash fertilizer was as basal fertilizer and half as bolting fertilizer. Using the seedling transplanting method, it was sown on September 24, 2014, and transplanted on October 28, with row spacing of 40 cm and plant spacing of 20 cm. The plot area was 24 m^2, and the conver-

ted planting density was 1.25×10^5 plant/ha. With N-fertilizer as main plot factor and cultivar as split-plot factor, the split plot design was used, with three replications. On May 29, 2015 (maturing period), 10 plant samples were taken consecutively from each plot, aired, threshed, dried at 80℃ and weighed. Nitrogen content was determined by Kjeldahl method, and the grain protein content was calculated by the product of nitrogen content and protein factor of 6.25. Grain oil content was determined by Soxhlet extraction method. N-fertilizer use efficiency parameters were calculated as follows[17]:

Absorption and utilization rate (%) = $100 \times (TN_{+N} - TN_{-N})/F_N$

Agronomic use efficiency = $(GY_{+N} - GY_{-N})/F_N$

Physiological use efficiency = $(GY_{+N} - GY_{-N})/(TN_{+N} - TN_{-N})$

N partial factor productivity = GY_{+N}/F_N

where TN_{+N} was the overground part N-accumulation in the fertilization area; TN_{-N} was the overground part N-accumulation in the control area; F_N was the nitrogen application rate; GY_{+N} was the grain yield in the fertilization area; GY_{-N} was the grain yield in the control area.

The test data were processed with Microsoft Excel 2007, and the analysis of variance and significance test were conducted using DPS7.05 statistical software.

3 Results and analysis

3.1 Differences in yield, protein content, oil content, total nitrogen and oil content between various cultivars under different N-fertilizer levels

Under different N-fertilizer treatments, the average yield of Yangyou 6, Zhongshuang 11 and Zheyou 50 was 2716.5, 2701.1 and 2661.1 kg/ha, respectively (Table 1). The yield increased after application of N-fertilizer. Compared with N_0, the yield of Yangyou 6 under N_1, N_2 and N_3 increased by 111.7%, 163.8% and 198.3%, respectively; the yield of Zhongshuang 11 under N_1, N_2 and N_3 increased by 105.5%, 146.6% and 175.2%, respectively; the yield of Zheyou 50 under N_1, N_2 and N_3 increased by 109.6%, 140.6% and 163.4%, respectively. Yangyou 6 was sensitive to N-fertilizer, the yield was lowest under N_0, and the yield was highest after application of N-fertilizer. Under different N-fertilizer treatments, the protein content of Yangyou 6, Zhongshuang 11 and Zheyou 50 was 24.15%, 22.71% and 21.84%, respectively; the average total nitrogen accumulation of the three cultivars was 179.4, 176.6 and 161.7 kg/ha, respectively; the average total grain protein accumulation of the three cultivars was 674.6, 627.5 and 595.7 kg/ha, respectively. Yangyou 6 had the highest protein content, total nitrogen accumulation and total grain protein content. Under different N-fertilizer treatments, the average oil content of the three cultivars was 42.87%, 47.37% and 48.28%, respectively; the average total oil accumulation was 1152.0, 1270.1 and 1273.4 kg/ha, respectively. Zheyou 50 had the highest oil content and total oil accumulation. With the increase of N-fertilizer application rate, the rapeseed yield, protein content, total nitrogen accumulation and total oil accumulation were all increased significantly, while the oil content was gradually decreased.

Table 1 Differences in yield, protein content, oil content, total nitrogen and oil content between various cultivars

Items	Cultivars	N_0	N_1	N_2	N_3
Yield//kg/ha	Yangyou 6	1243.5d	2633.0c	3280.1b	3709.5a
	Zhongshuang 11	1306.0d	2683.5c	3220.4b	3594.4a
	Zheyou 50	1308.4d	2742.4c	3147.6b	3445.8a
Protein content//%	Yangyou 6	21.01d	23.89c	25.37b	26.31a
	Zhongshuang 11	20.19d	22.42c	23.57b	24.64a
	Zheyou 50	19.11d	21.46c	22.88b	23.92a
Oil content//%	Yangyou 6	44.89a	43.17b	42.09c	41.31c
	Zhongshuang 11	49.09a	47.30b	46.93bc	46.15c
	Zheyou 50	50.37a	48.66b	47.36c	46.71c
Total nitrogen uptake//kg/ha	Yangyou 6	60.5d	154.3c	218.9b	283.7a
	Zhongshuang 11	65.7d	157.8c	215.9b	267.1a
	Zheyou 50	59.0d	145.5c	193.8b	248.6a
Total grain protein content//kg/ha	Yangyou 6	261.2d	629.0c	832.2b	976.1a
	Zhongshuang 11	263.6d	601.7c	759.1b	885.6a
	Zheyou 50	249.9d	588.5c	720.3b	824.0a
Total grain oil content//kg/ha	Yangyou 6	558.1d	1136.7c	1380.6b	1532.6a
	Zhongshuang 11	641.0d	1269.2c	1511.3b	1658.9a
	Zheyou 50	659.0d	1334.4c	1490.6b	1609.4a

Note: Different lowercase English letters after the same row data indicated significant differences by LSD method, the same in Table 3.

3.2 Analysis of variance on yield, total nitrogen accumulation and quality during the maturation period

The analysis results of variance on grain yield, total nitrogen accumulation and quality during the maturation period could be shown in Table 2. As was evident in Table 2, N-fertilizer treatments and cultivar treatments had a significant or very significant impact on traits, and the

interaction between N-fertilizer and cultivars had a very significant impact on yield, total nitrogen accumulation, grain protein content and total oil accumulation, but had no significant impact on oil and protein content.

Table 2 Analysis of variance on yield, total nitrogen accumulation and quality

Source of variation	Yield	Protein content	Oil content	Total nitrogen content	Total protein content	Total oil content
Block	NS	NS	NS	NS	NS	NS
N-fertilizer	**	**	**	**	**	**
Cultivars	*	**	**	**	**	**
N-fertilizer × cultivars	**	NS	NS	**	**	**

Note: NS indicated non-significance level, * and ** indicated 5% and 1% significance level, respectively.

3.3 N-fertilizer use efficiency difference The common quantitative indicators related to N-fertilizer use efficiency included N-fertilizer absorption use efficiency, N-fertilizer physiological use efficiency, N-fertilizer agronomic use efficiency and N-fertilizer PFP. As could be seen from Table 3, the values of indicators about N-fertilizer use efficiency decreased with the increase of N-fertilizer application rate. Under three nitrogen application levels, the N-fertilizer absorption and use efficiency of different cultivars was 52.65%—78.10%, and it was lowest for Zheyou 50 under different nitrogen treatments. With the increasing application of N-fertilizer, the N-fertilizer absorption and use efficiency of Yangyou 6 was low, and it greatly decreased for Zhongshuang 11 and Zheyou 50. Compared with N_1, the N-fertilizer absorption and use efficiency of Yangyou 6, Zhongshuang 11 and Zheyou 50 declined by 20.63%, 27.05% and 26.94% under N_3, respectively. The N-fertilizer agronomic use efficiency was 5.94—11.95 kg seed/kg N. The average N-fertilizer agronomic use efficiency of Yangyou 6, Zhongshuang 11 and Zheyou 50 was 8.97, 8.61 and 8.52 kg seed/kg N, respectively. The N-fertilizer physiological use efficiency was 11.05—16.59 kg seed /kg N. The average value (13.84 kg seed/kg N) of Zheyou 50 was highest under different treatments, and the average value (12.91 kg seed/kg N) of Yangyou 6 was lowest. The N-fertilizer PFP was 9.57—22.85 kg seed/kg N. The average N-fertilizer PFP of Zhongshuang 11, Zheyou 50 and Yangyou 6 was 15.30, 15.25 and 15.18 kg seed/kg N, respectively. With the increasing application of N-fertilizer, N-fertilizer PFP greatly decreased, and compared with N_1, the N-fertilizer PFP of three cultivars under N_3 decreased by 53.05%, 55.37% and 58.12%, respectively.

Table 3 The differences in N-fertilizer use efficiency between different rapeseed cultivars under different nitrogen application levels

Items	Cultivars	N_1	N_2	N_3
N-fertilizer absorption and use efficiency//%	Yangyou 6	78.10a	66.00b	61.99c
	Zhongshuang 11	76.68a	62.57b	55.94c
	Zheyou 50	72.06a	56.18b	52.65c
N-fertilizer agronomic use efficiency//kg seed/kg N	Yangyou 6	11.58a	8.49b	6.85c
	Zhongshuang 11	11.48a	7.98b	6.36c
	Zheyou 50	11.95a	7.66b	5.94c
N-fertilizer physiological use efficiency//kg seed/kg N	Yangyou 6	14.82a	12.86b	11.05c
	Zhongshuang 11	14.97a	12.75b	11.37c
	Zheyou 50	16.59a	13.64b	11.28c
N-fertilizer PFP//kg seed/kg N	Yangyou 6	21.94a	13.67b	10.30c
	Zhongshuang 11	22.36a	13.42b	9.98c
	Zheyou 50	22.85a	13.11b	9.57c

4 Conclusions and discussions

4.1 Effect of nitrogen application on rapeseed yield, total nitrogen accumulation and total grain protein and oil content

The application of N-fertilizer was a key factor in crop production, and after the application of N-fertilizer, the rapeseed grain protein content increased and oil content decreased, which was consistent with previous findings[3-9]. For the three cultivars, the cultivars with high oil content had low protein content, and vice versa. Zheyou 50 had the highest oil content, and the average oil content was 48.28% under four treatments; it had the lowest protein content and the average protein content was 21.84%. Yangyou 6 had the lowest oil content, and the average oil content was 42.87% under four treatments; it had the highest protein content, and the average oil content was 24.15%. Yangyou 6 had the highest total nitrogen accumulation and total grain protein content, and the average was 179.4, 674.6 kg/ha under different N-fertilizer treatments, respectively. Zheyou 50 had the highest total oil content, and the average was 1273.4 kg/ha under different N-fertilizer treatments. The total nitrogen accumulation, total grain protein and oil content were at the middle level for Zhongshuang 11. At present, improving oil content is the primary breeding objective of rapeseed, but with the decrease of glucosinolate content in rapeseed grain, the development and utilization of rapeseed grain protein have also been the focus of attention[18-19].

4.2 Effect of nitrogen application on N-fertilizer use efficiency of different rapeseed varieties N-fertilizer absorption and

use efficiency, N-fertilizer physiological use efficiency, N-fertilizer agronomic use efficiency and N-fertilizer PFP, are used to describe N-fertilizer utilization efficiency, but there is a restriction relationship between various indicators, and they often reflect different meanings in different areas of research and have different application values[17, 20]. Zou Juan *et al.*[21] also pointed out that the N-fertilizer use efficiency of rapeseed was affected by the environment. The results in this paper showed that the N-fertilizer absorption and use efficiency of two high oil content cultivars Zhongshuang 11 and Zheyou 50 was lower than that of the normal oil content rapeseed cultivar Yangyou 6; the average N-fertilizer agronomic use efficiency was also highest for Yangyou 6 under three N-fertilizer treatments; the N-fertilizer physiological use efficiency of two high oil content cultivars Zhongshuang 11 and Zheyou 50 was higher than that of Yangyou 6; there was a small difference in N-fertilizer PFP among three cultivars. With the increase of N-fertilizer application rate, the value of various indicators about N-fertilizer use efficiency of different rapeseed varieties decreased significantly, which indicated that reducing nitrogen application rate was one of the effective ways to increase the N-fertilizer use efficiency, but the low nitrogen application rate was not conducive to the yield increase of rapeseed, therefore, there was still a need to conduct in-depth study on reasonable use of optimal fertilizer application rate based on actual conditions.

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