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Optimum Application Time and Application Rate of Nitrogen Fertilizer in *Brassica napus* L.

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Abstract To find proper nitrogen fertilizer application mode of rapeseed (*Brassica napus* L.), promote the high and stable yield of rapeseed, field experiment was carried out to study the effect of nitrogen fertilizer application modes on the yield and economic traits of Fengyou 10 rapeseed planted in two different fertility soils, and characteristics and differences of responses of different fertility soils to nitrogen fertilizer application modes were compared and analyzed. The results showed that the yield and related economic traits of rapeseed treated by nitrogen fertilizer were higher than the control group; in the nitrogen fertilizer treatment group, when the nitrogen fertilizer was applied as the base fertilizer and wintering fertilizer at the ratio of 7∶3, the rapeseed yield was higher than the control group and reached the highest; when the nitrogen fertilizer was applied as the base fertilizer, wintering fertilizer, and bud fertilizer at the ratio of 5∶3∶2, the rapeseed yield was significantly higher than the control group but was the lowest. These indicate that sufficient nitrogen supply is the basis for normal growth and development of rape seedlings. When the pure nitrogen fertilizer was at 192 kg/ha and the ratio of base fertilizer and wintering fertilizer was 7∶3, it can better coordinate the high yield of rapeseed and overall use of nitrogen fertilizer, and obtain higher rapeseed yield.

Key words *Brassica napus* L., Nitrogen fertilizer application, Yield, Economic traits, Soil fertility

1 Introduction

The rapeseed (*Brassica napus* L.) is the largest oil crop in China and the largest source of domestic edible vegetable oil. According to statistics, rapeseed oil accounted for more than 57% of domestic edible vegetable oil, which can alleviate the contradiction between supply and demand of domestic edible oil and protect China's consumption of edible oil. The oil supply security has a great strategic significance[1-2]. Therefore, it is of utmost importance to guarantee the high and stable yield of rapeseed. Studies have shown that the increase in the per unit area yield of rapeseed is not only closely connected with the improvement of rapeseed varieties, but also closely connected with proper nitrogen fertilizer application in the production management[3]. Nitrogen is a macronutrient necessary for plant growth and development, and it plays a key role in the formation of crop yield and quality[4]. Proper application of nitrogen fertilizer can effectively promote the growth and yield formation of rapeseed, and significantly increase its yield; conversely, too much, too little or improper application time will have adverse effects on the growth and grain yield of rapeseed[5-6]. At present, with the widespread application of light and simple rapeseed cultivation in production, the problems in the fertilization of rapeseeds, especially in the application of nitrogen fertilizer, have become increasingly prominent. These problems are mainly manifested in inadequate application during a certain growth period, excessive application during a certain growth period, or reapplication in early stages, less or even no application in the later period[7-8]. In addition, nitrogen fertilizer applied in farmland is mostly in quick-acting form, with rapid nutrient release and short fertility. Centralized application easily leads to the loss of nitrogen, which is not only unfavorable for high yield of crops, reducing the nitrogen fertilizer utilization rate, but also causes serious environmental pollution[9]. Therefore, proper application of nitrogen fertilizer is of utmost importance. According to some studies[10-11], reasonable nitrogen fertilizer application and increase in nitrogen fertilizer utilization rate are effective ways to reduce environmental pollution.

Up till now, there have been extensive studies about the nitrogen fertilizer application rate, ratio of base fertilizer to topdressing, nitrogen fertilizer application amount, and application modes. However, the experimental studies are mainly concentrated in the middle and lower reaches of the Yangtze River, few studies are made in Huang-Huai-Hai plain areas; besides, extensive studies have shown that nitrogen has a great effect on the regulation of rapeseed yield, but the effect on increasing the yield is greatly different due to differences in the selection of varieties, soil fertility, fertilization level, cultivation measures and climate characteristics[12-16]. Fengyou 10 is a three-line hybrid of the semi-winter cabbage-type cytoplasmic male sterility, bred and selected by the rapeseed team of Institute of Industrial Crops, Henan Acad-

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emy of Agricultural Science, and certified by Crop Variety Certification Commission of national Huai-Huai region, the upper reaches of the Yangtze River, and the middle reaches of the Yangtze River. With wide adaptability and high resistance to cold and lodging, Fengyou 10 has become the main cultivar of rapeseed in suitable areas. However, at present, there is still no report about the application of nitrogen fertilizer in the production of Fengyou 10. Therefore, in order to explore the effects of nitrogen fertilizer application on the rapeseed yield in Huang-Huai-Hai region, taking Fengyou 10 as the material, under two different soil fertility conditions, we analyzed characteristics and differences of response of nitrogen fertilizer application methods, to provide theoretical data and scientific references for nitrogen fertilizer application management for direct seeding rapeseed in Henan Province, establishing a high yield and high efficient cultivation system for Fengyou 10, and promote high and stable yield of rapeseed.

2 Materials and methods

2.1 Experimental site and materials The field experiment was carried out in the Rice-Rapeseed rotation area in Sanpi Town, Huangchuan County of Xinyang City in Henan Province (Huaihe River Basin), and Maize-Rapeseed rotation area in Wancheng District of Nanyang City in Henan Province (the Yangtze River Valley). The soil in the rice-rapeseed rotation area is paddy soil, and the basic fertility is low; the soil in the maize-rapeseed rotation area is yellow cinnamon soil, and the basic fertility is medium.

Fertilizers tested were urea (containing 46% N), monoammonium phosphate (containing 11% N and 44% P_2O_5), and potassium chloride (containing 60% K_2O). The test material was the local rapeseed variety Fengyou 10. The sowing method is direct seeding in the middle or late September. At the stage of 3 – 5 leaves, it conducted seedling thinning and final seedlings, with density of 300 000 plants/ha. In the middle of May, rapeseed was harvested.

2.2 Experiment design The experiment was divided into four treatments, which were TN_0 (control group, no fertilizer), TN_1 (192 kg/ha of N fertilizer, one-time base application), TN_2 (192 kg/ha of N fertilizer, ratio of base fertilizer and wintering fertilizer 7∶3), and TN_3 (application rate of N fertilizer 192 kg/ha, ratio of base fertilizer, wintering fertilizer and bud fertilizer 5∶3∶2). Each treatment was set with three repetitions, with randomized block arrangement. The area of the plot is 50 m^2 (5 m × 10 m) with the row spacing of 33 cm and plant space of 10 cm. Between plots and between replicates, 50 cm wide walkway was arranged, and 1 m wide protection line was set in surrounding areas. The amount of other fertilizers was consistent throughout the growth period, which were 106 kg/ha of P_2O_5, 108 kg/ha of K_2O, and 8.34 kg/ha of borax, all of which were applied one time as the base fertilizer. Other management measures in the field were the same as those for local field production.

2.3 Measurement items Seed evaluation and sampling: before rapeseed ripening and harvesting, each treatment was sampled, the same position in the 16th row was selected in each plot, 10 plants were sampled continuously, measured the plant height, effective branch height, number of primary branches, effective length of main inflorescence, number of effective pods of main inflorescence, length of pod of main inflorescence, number of effective pods per plant, number of grains per pod, and 1 000-grain weight. Samples with yield recorded: samples were taken before harvesting at the ripening stage of rapeseed. In order to avoid errors, all of them were harvested in the middle 20 rows, separately threshed, dried, grain weight weighed, and the yield was calculated.

3 Results and analyses

3.1 Effects of different nitrogen fertilizer application modes on yield of rapeseed in different fertility soils Different nitrogen fertilizer application modes have different effects on the yield of rapeseed in different fertility soils. From Table 1, it can be seen that, compared with the no-fertilizer application group (control group), the yield of rapeseed in different fertility soils showed an increasing trend. The comparative analysis of the results of various treatments of moderately fertile soil showed that the yield of rapeseed in the treatment of different nitrogen fertilizers was significantly higher than that of the control group. The yield of TN_2 was 792.30 kg/ha higher than that of the control group, increasing by 31.74%, which was the highest in the yield increase; the control group increased the yield by 596.7 kg/ha, increasing by 23.91%, which was the lowest in the yield increase. The experimental results of low fertility soil showed that there was a significant difference in the yield-increasing effect of rapeseed under different application modes. Compared with the control group, the yield of rapeseed TN_2 had increase of 208.65 kg/ha, increasing by 18.12%, which was the highest in the yield increase; the yield of treatment TN_3 slighted increased 35.7 kg/ha, increasing by 3.10%, basically the same as the control group. In summary, in two different fertility soils, higher rapeseed yield was obtained under conditions of taking 106 kg/ha of P_2O_5, 108 kg/ha of K_2O, and 8.34 kg/ha of borax as the base fertilizer applied one time, 192 kg/ha of pure nitrogen fertilizer, and the ratio of base fertilizer to wintering topdressing being 7∶3.

3.2 Effects of different nitrogen fertilizer application modes on yield components of rapeseed in different fertility soils The 1 000-grain weight, number of grains per pod, and number of effective pods per plant are three key components of rapeseed yield. As can be seen from Table 1, compared with the no fertilizer application group (control group), the number of effective pods per plants showed an increasing trend in both fertility soils, and with the increase in nitrogen fertilizer application times, there was similar dynamic changes. When the nitrogen fertilizer was applied as the base fertilizer and wintering fertilizer at the ratio of 7∶3, the number of effective pods per plants was the smallest; when the nitrogen fertilizer was applied as the base fertilizer, wintering fertil-

izer, and bud fertilizer at the ratio of 5∶3∶2, the number of effective pods per plants reached the largest. In other words, treatments with the largest number of effective pods had the same application mode of nitrogen fertilizer in different fertility soils, and treatments with the smallest number of effective pods also had the same application mode of nitrogen fertilizer in different fertility soils. In the fertilizer application treatment, with the increase in the nitrogen application times, the number of grains per pod of rapeseed in two different fertility soils showed a similar decreasing trend, both showed the largest number of grains per pod in one-time treatment of base fertilizer application, the smallest number of grains per pod in two times of topdressing treatments, but there were certain differences in the specific dynamic changes. The analysis of the 1 000-grain weight of rapeseed showed that in the fertilizer application treatment, the 1 000-grain weight in the two different fertility soils was the highest in the one time topdressing treatment; however, the 1 000-grain weight of the rapeseed in the medium-fertility soil was the lowest among the two times of topdressing treatments, and the 1 000-grain weight of rapeseed in low fertility soil was the same in one time base fertilizer application and two times of topdressing treatments. These indicated that dynamic changes of rapeseed yield components in two different fertility soils had similarities and also different characteristics.

Table 1 Effects of different nitrogen fertilizer application modes on yield of rapeseed in different fertility soils and yield components

Experimental site	Experiment treatment	Yield//kg/ha	1 000-grain weight//g	Number of effective pods per plant	Number of grains per pod	Increase compared with CK//%
Wancheng District, Nanyang City (medium fertility)	TN_0 (CK)	2 496.00 b	3.54	178.9	17.0	–
	TN_1	3 226.25 a	3.86	255.9	20.2	29.27
	TN_2	3 288.30 a	3.94	227.1	18.8	31.74
	TN_3	3 092.70 a	3.81	304.8	18.4	23.91
Huangchuan County, Xinyang City (low fertility)	TN_0 (CK)	1 151.25 b	3.24	189.0	15.8	–
	TN_1	1 322.70 a	3.46	208.3	22.6	14.89
	TN_2	1 359.90 a	3.61	194.9	21.9	18.12
	TN_3	1 186.95 b	3.46	249.0	17.5	3.10

Note: Different small letters in the same column indicate significant difference at 0.05 level.

3.3 Effects of different nitrogen fertilizer application modes on main agronomic traits of rapeseed in different fertility soils

From Table 2, it is known that different nitrogen fertilizer application modes had different effects on main agronomic traits of rapeseed in different fertility soils. For the medium fertility soil, compared with no-fertilizer application group (control group), the plant height of rapeseed and the number of effective pods of main inflorescence in the fertilizer application treatments showed an increase trend. Specifically, the plant height of rapeseed with nitrogen fertilizer as the one-time application of nitrogen fertilizer as the base fertilizer was the highest, 17.7 cm higher than that of the control group, the plant height of rapeseed with two times of application of nitrogen fertilizer was the lowest, 12.8 cm higher than that of the control group, the number of effective pods of main inflorescence with three times of application of nitrogen fertilizer showed the highest increase, 30.4 higher than that of the control group, while the number of effective pods of main inflorescence with two times of application of nitrogen fertilizer showed the lowest increase, 18.5 higher than that of the control group. Compared with the control group, the effective length and the length of pod in the main inflorescence with nitrogen fertilizer treatment showed an significant increase trend, the length of main inflorescence with one time application of nitrogen fertilizer as the base fertilizer had the highest increase, 9.6 cm greater than that of the control group, while the length of main inflorescence with two times of application of nitrogen fertilize had the lowest increase, 5.8 cm greater than that of the control group; the length of pod in the main inflorescence with different nitrogen fertilizer treatments was basically the same; with the increase in the application times of nitrogen fertilizer, the length of pod in the main inflorescence in different treatments was 7.4, 7.5, and 7.5 cm, respectively. In the treatments of fertilizer application, with the increase in the application times of nitrogen fertilizer, the effective branch height of rapeseed took on the trend of first rise then decline. For the one time application of nitrogen fertilizer as the base fertilizer, the effective branch height was 0.4 cm slightly lower than that of the control group, while the effective branch height with two times of application of nitrogen fertilizer was 10.5 cm higher than that of the control group; the number of primary branches showed the trend of first decline then rise. Specifically, the number of primary branches with one time of application of nitrogen fertilizer and three times of application of nitrogen fertilizer was the same, while the number of primary branches with two times of application of nitrogen fertilizer was basically the same as that of the control group.

For the low fertility soil, compared with no-fertilizer application group (control group), the plant height of rapeseed and the number of effective pods of main inflorescence in the fertilizer application treatments showed a significant increase trend. Specifically, the plant height of rapeseed with three times of application of nitrogen fertilizer was the lowest, but still 6.2 cm higher than that of the control group, while the plant height of rapeseed was basically the same between one time and two times of application of nitrogen fertilizer, 9.8 and 9.2 cm higher than that of the control group respectively; the effective length of the main inflorescence with one time of application of nitrogen fertilizer as the base fertilizer has the lowest increase, 2.7 cm higher that of the control

group, while the effective length of the main inflorescence with two times of application of nitrogen fertilizer was the highest, 8.6 cm higher than that of the control group. Compared with the control group, the number of primary branches with treatment of nitrogen fertilizer showed an overall increase trend, but the increase was small; the effective branch height of rapeseed took on a decline trend. Specifically, the effective branch height of rapeseed with three times of application of nitrogen fertilizer was the lowest, 3.8 cm lower than that of the control group, while the effective branch height of rapeseed with two times of application of nitrogen fertilizer was the highest, only 0.8 cm lower than that of the control group. Compared with the control group, with the increase in the application times of nitrogen fertilizer, the number of effective pods of main inflorescence greatly increased. Specifically, the number of effective pods of main inflorescence of rapeseed with one time application of nitrogen fertilizer was the smallest, while the number of effective pods of main inflorescence of rapeseed with three times of application of nitrogen fertilizer was the largest. The length of pod of the main inflorescence showed the dynamic change of first rise then decline. Specifically, the length of pod of the main inflorescence of rapeseed with one time application of nitrogen fertilizer was basically the same as the control group, the length of pod of the main inflorescence of rapeseed with two times of application of nitrogen fertilizer was the greatest, while the length of pod of the main inflorescence of rapeseed with three times of application of nitrogen fertilizer was the smallest.

Table 2 Effects of different nitrogen fertilizer application modes on main agronomic traits of rapeseed in different fertility soils

Experimental site	Experiment treatment	Plant height//cm	Effective branch height//cm	Number of primary branches	Main inflorescence		
					Effective length//cm	Number of effective pods	Length of pod//cm
Wancheng District, Nanyang City (medium fertility)	TN_0(CK)	144.2	54.0	7.9	50.1	46.7	6.7
	TN_1	161.9	53.6	9.7	59.7	74.6	7.4
	TN_2	157.0	64.5	7.8	55.9	65.2	7.5
	TN_3	161.8	55.7	9.7	58.9	77.1	7.5
Huangchuan County, Xinyang City (low fertility)	TN_0(CK)	97.3	35.8	6.7	39.0	42.7	7.7
	TN_1	116.5	32.9	7.1	41.7	42.2	7.7
	TN_2	117.1	35.0	6.9	47.6	47.7	7.9
	TN_3	103.5	32.0	7.1	45.7	50.7	7.2

4 Conclusions and discussions

4.1 Appropriate amount of nitrogen fertilizer as base fertilizer is favorable for balancing soil nutrients and increasing the rapeseed yield Adequate supply of nitrogen is a guarantee of high yield[17]. The rapeseed is a crop with large demand of nitrogen. Nitrogen plays a great role in regulation of growth and development of rapeseed, thus the proper application of nitrogen fertilizer can effectively promote the growth and yield formation of rapeseed[6,18]. The results showed that the yield and related economic traits of rapeseed treated by nitrogen fertilizer were higher than the control group; in the nitrogen fertilizer treatment group, when the nitrogen fertilizer was applied as the base fertilizer and wintering fertilizer at the ratio of 7∶3, the rapeseed yield was higher than the control group and reached the highest; when the nitrogen fertilizer was applied as the base fertilizer, wintering fertilizer, and bud fertilizer at the ratio of 5∶3∶2, the rapeseed yield was significantly higher than the control group but was the lowest. In barren soil (low fertility soil), the yield of rapeseed with three times of application of nitrogen fertilizer was slightly higher than that of the control group; in two different fertility soils, the yield of rapeseed with one time of application of nitrogen fertilizer as the base fertilizer was significantly higher than that of the control group, but it had no significant difference with that of the rapeseed with two times of application of nitrogen fertilizer. This indicates that sufficient nitrogen concentration is very important for the growth and development of rapeseed at the seedling stage[7,19]. Proper application of nitrogen fertilizer is not only favorable for balancing nutrients in base fertilizer, but also favorable for satisfying nutrient demands for normal growth and development of rapeseed, regulating the yield components and promoting increase of rapeseed yield. On the contrary, improper application of nitrogen fertilizer is detrimental to the normal growth and development of rapeseed, and to a certain extent, it will also bring bad effect on the yield increase of many times of topdressing. For example, in the range of nitrogen fertilizer set in this experiment, the yield of rapeseed with ratio of 5∶3∶2 base fertilizer to topdressing treatment was the lowest in all treatments of fertilizer application. Therefore, reasonable and appropriate application of nitrogen fertilizer should balance the basic nutrient supply and demand in the early stage of growth and development of rapeseed and lay a foundation for the formation of rapeseed yield and the yield components. The management of nitrogen fertilizer application in the later period has practical significance.

4.2 Number of grains per pod and 1 000-grain weight are main factors influencing the rapeseed yield When the nitrogen fertilizer was applied as the base fertilizer and wintering fertilizer at the ratio of 7∶3, the yield of rapeseed in two different fertility soils was the highest in all treatments; besides, in this nitrogen fertilizer application mode, compared with the respective fertilizer treatment, the 1 000-grain weight of rapeseed in two different fertility soils was the highest, indicating that the 1 000-grain weight is a major yield component of rapeseed in two different fertility soils. Besides, further comparison found that in the three times of application of nitrogen fertilizer, the number of grains per pod of rapeseed in two different fertility soils was the smallest, and both the yield and 1 000-grain weight were the lowest in respective fertilizer treatment, indicating that the number of grains per pod may be also

a major yield component of rapeseed. Therefore, for this experiment, the number of grains per pod and the 1 000-grain weight are major factors influencing the rapeseed yield in medium fertility and low fertility soils. Through increasing the number of grains per pod and the 1 000-grain weight, it is promising to increase the rapeseed yield. Studies about the effects of application of nitrogen fertilizer on the rapeseed yield have shown that the application amount of nitrogen fertilizer has the largest effect on the number of effective pods per plant and has the smallest effect on the number of grains per pod[20]; some studies found that different period of nitrogen fertilizer application has no significant effect on the yield and main economic traits of rapeseed[21-22]. According to results of this experiment, compared with the no-fertilizer group (control group), in different fertility soils, the increase in the number of effective pods per plant of rapeseed with treatment of nitrogen fertilizer is higher than that of the 1 000-grain weight and the number of grains per pods, indicating that the number of effective pods per plant plays a great role in the yield component of rapeseed. However, for the analysis of yield traits, the number of grains per pod and the 1 000-grain weight are still main factors influencing the yield of rapeseed in medium and low fertility soils. The differences in the above results show that due to the differences between the selected species and cultivation measures, the differences between the experimental soil fertility and the climate characteristics, as well as analysis viewpoints of experimental data, there are differences in conclusions. Therefore, in practical applications, the main factors that affect the yield of rapeseed should be analyzed objectively according to the local production conditions, and a reasonable cultivation plan should be formulated based on the analysis results in order to effectively promote the high and stable yield of rapeseed.

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