Effect of N application on N accumulation in seeds of *Brassica napus* L. cultivar "Yangyou No. 4"

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Abstract

Trials were carried out in 2003-2004 to investigate the N accumulation in seeds of rapeseed cultivar "Yangyou No. 4" under four N applications. The main results were as follows. (1) The Richards equation could be used to describe the process of N accumulation in seeds (R^2=0.9970**-0.9995**); (2) The rate, time and total amount of N accumulation in seeds increased along with the increase of N fertilizer application. Seventy percent of the increased N accumulated in middle stage and 30% in late stage; (3)The ratios of N accumulation time and amount in early stage were 60%-50% and 40%-30% respectively. Both of them decreased along with the increase of N fertilizer application. In middle and late stages, the ratios of N accumulation times were all about 20%-25%, and those for the amounts were 50%-55% and 10%-15%, respectively. They all increased with the increase of N fertilizer application.

Key words: Rapeseed (*Brassica napus* L.); seed; N accumulation; Richards equation

Introduction

Rapeseed is one of the crops which need much nitrogen. To produce equal seed yield, the amount of N which was absorbed by rapeseed was twice or three times as much as that by wheat or rice. Nitrogen absorbed by rapeseed before flowering was mainly distributed in nutritious organs, such as roots, stem, branches, and leaves. After flowering, the nitrogen was gradually transferred into seeds with the growing of pods and seeds (Shan *et al*. 1996; Gao *et al*. 2003). During the decrepition of leaves, about 80% nitrogen in leaves was translocated into seeds and other organs (Leng *et al*. 2001). At the ripen stage, forty to fifty percent of nitrogen in rapeseed lied in seeds. So the seed filling of rapeseed was not only the process of photosynthate accumulation but the one of nitrogen accumulation. There have been many researches on rapeseed growing, nitrogen accumulation (Hu *et al.,* 2002; Kaul *et al.,* 1996) and effects of nitrogen on yields and yield components (Asare *et al.,* 1995; Ozer *et al.,* 2003). During the growing of seeds, the embryo developed firstly and then the seed filled. So the nitrogen accumulation in seeds was different at different stages, and under different conditions, especially under different nitrogen levels. However, no clear information has been reported on the potential differences in nitrogen accumulation in seeds. The objective of this paper was to investigate the characteristics of nitrogen accumulation in seeds under different nitrogen levels, and provide the reasonable principle of nitrogen application so as to increase seed yield and improve seed quality.

Materials and methods

Experimental design

The trials were carried out in 2003-2004 on the Experimental Farm of Yangzhou University, the soil used was sandy. The available nitrogen, phosphorus and potassium in surface layer were 59.0ug/g, 53.5ug/g, and 46.2ug/g, respectively. The cultivar tested was Brassica napus L. Yangyou No.4, provided by Yangzhou Academy of Agricultural Sciences. The cultivar was sown on 23 Sep., transplanted on 25 Oct, 2003, and harvested on 20 May, 2004. The density was $12*10^4$ plants/hm^2 with 45cm row spacing. Four nitrogen levels were 0, 120, 240, 360 kg/hm^2 which were designated as N0, N1, N2, and N3, respectively. Nitrogen fertilizer was urea, the ratio of basal dose, seeding stage dose and bolting stage dose was 5:2:3. A 150 kg/hm^2 P_2O_5 was applied as basal fertilizer, and a 150 kg/hm^2 K_2O was applied, of which 50% was applied as basal dose and 50% was applied at bolting stage. The trials were conducted in a randomized complete block design with triplicate in 20m^2 blocks.

Measuring methods

On 4 April (one week after the start of flowering), flowers which flowered at the same day in main inflorescences were labeled. About 1000 flowers were labeled in each block. Sixty pods were sampled on 12 April in each block and then sampled every five days until pod ripening. The pods were divided into shells and seeds, dried at 70°C for 72 hours and weighed.

The pattern of nitrogen accumulation and the meanings of all parameters

Richards equation described by Gu *et al.*(1998) was adopted to imitate the nitrogen accumulation.

$$W=A/(1+be^{-kt})^m$$

Where W was the amount of nitrogen accumulation at some time, A meant ultimate amount of nitrogen accumulation, b was initial parameter, k was growing rate parameter, t was the days after flowering, m was shape parameter.

In the curve of Richards equation there were two turning points (t_1, t_2), supposing the duration when the nitrogen accumulation reached 99% of the A was the whole time (t_3 or t_{99}), the process of nitrogen accumulation was divided into three stages, early stage (0-t_1), middle stage (t_1-t_2) and late stage (t_2-t_3).

Results

Nitrogen accumulation in seeds under different nitrogen application

The rate of nitrogen accumulation was slow at early stage, fast at middle stage and slow at late stage. Under different nitrogen levels, the trends of nitrogen accumulation were the same, but the amounts of nitrogen accumulation were obviously different (Fig 1). The amount of nitrogen accumulation in seeds increased with the increase of N fertilizer application. On the 48th day after flowering (seeds ripening), the amount of nitrogen in seeds in N0 was 3.06mg per pod. N1, N2 and N3 were 3.20mg, 3.60mg and 3.73mg per pod, respectively. The amounts of nitrogen in seeds in N1, N2 and N3 treatments increased by 4.58%, 17.65% and 21.90% compared with N0, respectively. The difference of nitrogen accumulation in seeds mainly occurred during 20-25 days before ripening.

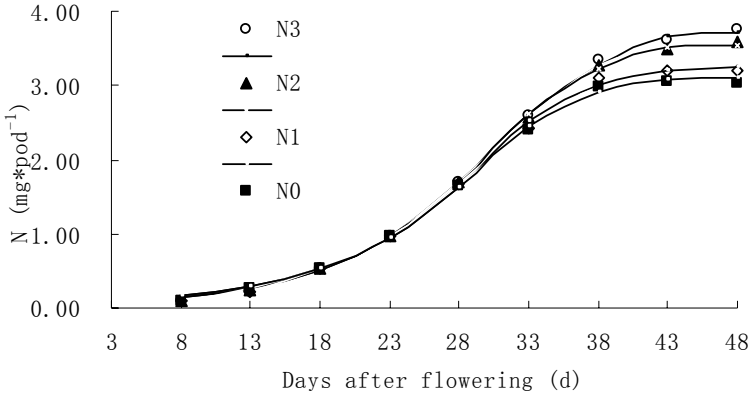

Fig1 Effect of N application on N accumulation in seeds

The pattern and parameters of nitrogen accumulation

The parameters of Richards equation were obviously different in different nitrogen treatments (Table 1). The ultimate amounts of nitrogen accumulation (A) in N1, N2 and N3 treatments increased by 4.85%, 17.15% and 21.68% compared with N0 treatment, respectively. With the increase of N fertilizer application, shape parameters (m) and the growing rate parameters increased, but the initial parameters (b) decreased. Determination coefficients in all treatments were between 0.9970 and 0.9995. It was clear that the fitness of Richards equation and the observing values was very high and the Richards equation could closely express the changes of nitrogen accumulation in seeds.

Table 1. The parameters of Richards equation for the N accumulation of seeds

Treatment	A(mg)	b	k	m	R^2
N0	3.09	105208.00	0.3504	0.3341	0.9980**
N1	3.24	44729.90	0.3239	0.3722	0.9970**
N2	3.62	7158.09	0.2690	0.4796	0.9993**
N3	3.76	5283.60	0.2583	0.5048	0.9995**

The rate and duration of nitrogen accumulation at different stages

Nitrogen accumulation rate increased firstly and then decreased in all treatments, but these curves were not symmetric (Fig 2). The rate of nitrogen accumulation increased slowly (before reaching the maximum value), and reduced rapidly (after reaching the maximum value). As the increase of N fertilizer application, the average rate, the maximum rate and the duration of nitrogen accumulation increased (Table 2). Compared with N0, the increment of average rate was 1.96%, 6.17%, 8.13%, the maximum rate 2.57%, 7.55%, 9.89% and the duration 2.84%, 10.17%, 12.50% in N1, N2, N3, respectively. So the increase of nitrogen application not only increased the rate of nitrogen accumulation but also extended the duration of nitrogen accumulation in seeds.

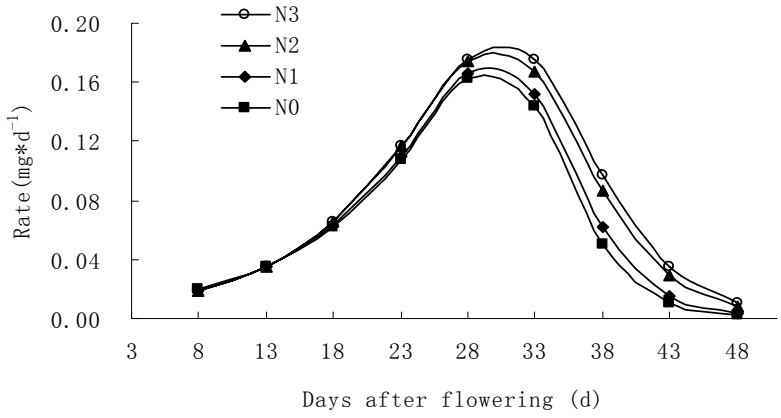

Fig2 Nitrogen accumulation rate curves of seeds

Table 2. The parameters of N accumulation in seeds

Treatment	Vm (mg/d)	Vmax (mg/d)	Tmax (d)	T_{99} (d)
N0	0.0713	0.1709	29.87	42.96
N1	0.0727	0.1753	30.01	44.18
N2	0.0757	0.1838	30.27	47.33
N3	0.0771	0.1878	30.55	48.33

Note: Vm: Mean rate of N accumulation; Vmax: Maximum rate of N accumulation; Tmax: duration before the rate of N accumulation reaching the maximum value; T_{99}: whole duration of N accumulation.

The ratio of nitrogen accumulation at different stages

According to the two turning points (t_1, t_2) in the nitrogen accumulation curve, the whole period of nitrogen accumulation in seeds could be divided into three stages (i.e., early stage, middle stage and late stage) (Table 3). The early stage was the longest among the three stages. The effect of nitrogen fertilizer application on the stage was slight, but the ratio of early stage in whole period decreased along with the increase of N fertilizer application (57.84%, 56.02%, 51.49% and 50.71% in N0, N1, N2 and N3 treatments, respectively). The amount of N accumulation in early stage was stable in different nitrogen treatments, but the ratio of the amount of N accumulation in whole period also decreased with the increase of N fertilizer application (38.16%, 36.17%, 31.74% and 30.89% in N0, N1, N2 and N3 treatments, respectively). The middle stage was shorter than the early stage, but it was affected significantly by nitrogen fertilizer application. The duration of N3 treatment was 2.05 days longer than that of N0 treatment, increased by 20%. The amount of nitrogen accumulation in middle stage was the most, accounted for about half of the amount of nitrogen accumulation in whole period. In the middle stage, the amount of nitrogen accumulation (1.52, 1.64, 1.91 and 2.01 mg/pod in N0, N1, N2 and N3 treatments, respectively) and the ratio of the amount of N accumulation (49.78%, 50.95% 53.43% and 53.88% in N0, N1, N2 and N3 treatments, respectively) in whole period were increased with the increase of N fertilizer application. The late stage was shortest. The effect of nitrogen fertilizer application on the stage was greatly. The duration of N3 treatment was 3.67 days longer than that of N0 treatment, increased by 45.53%. The ratio of the stage in the whole period also increased along with the increase of N fertilizer application. In the late stage, the amount of nitrogen accumulation and the ratio of the amount of N accumulation in whole period were increased with the increase of N fertilizer application. Therefore, the increase of nitrogen fertilizer application could mainly promote the nitrogen accumulation in seeds during the middle and late stages.

Table 3. Characteristics of N accumulation in seeds at different stages

	Early stage				Middle stage				Late stage			
	Duration		Amount of N accumulation		Duration		Amount of N accumulation		Duration		Amount of N accumulation	
	(d)	(%)	(mg/pod)	(%)	(d)	(%)	(mg/pod)	(%)	(d)	(%)	(mg/pod)	(%)
N0	24.85	57.85	1.17	38.16	10.05	23.39	1.52	49.78	8.06	18.76	0.37	12.06
N1	24.75	56.02	1.16	36.17	10.53	23.83	1.64	50.95	8.90	20.14	0.41	12.88
N2	24.37	51.49	1.14	31.74	11.79	24.91	1.91	53.43	11.17	23.60	0.53	14.83
N3	24.51	50.70	1.15	30.89	12.10	25.03	2.01	53.88	11.73	24.27	0.57	15.23

Discussion

The process of the nitrogen accumulation in seeds of rapeseed presented “S” shape. The Richards equation could be used to describe the process of N accumulation in seeds. The nitrogen fertilizer application affected nitrogen accumulation in seeds significantly. The nitrogen accumulation in seeds increased with the increase of N fertilizer application. At maturity stage, the amount of nitrogen in seeds in N3 treatment was 20% higher than that in N0 treatment. The duration and rate of nitrogen accumulation determined the amount of nitrogen in seeds. These two factors all increased along with the increase of N fertilizer application, but the increments were different. The increments of duration ranged from 2.48% to 12.50%, and the

average rate 1.96% to 8.13%. Therefore the nitrogen fertilizer application mainly increased the duration of nitrogen accumulation. The effect of increasing nitrogen application on nitrogen accumulation rate was less.

In early stage, the process of nitrogen accumulation, the duration, the average rate and the amount of nitrogen accumulation were similar in different nitrogen fertilizer application. The effects of nitrogen fertilizer application and other field management on nitrogen accumulation in seeds were slight. These probably related to the embryo development. At early stage, growth of embryo was mainly cell division. This needed little nitrogen. At the middle stage, the duration, the average rates and the amount of nitrogen accumulation increased with the increase of N fertilizer application. The increment of the amount of nitrogen accumulation in N1, N2, N3 treatments increased by 0.11, 0.39, 0.48mg per pod as compared with N0, respectively. Seventy percent or more of the increased nitrogen was accumulated in this stage. At the late stages, the duration, the average rates and the amount of nitrogen accumulation increased as the increase of N fertilizer application also. The increment of the amount of nitrogen accumulation in N1, N2, N3 increased by 0.04, 0.16, 0.20mg per pod, respectively, and about 30% of the nitrogen increment was accumulated in this stage. So the increment of nitrogen accumulation in seeds occurred mainly at middle stage, less at late stage, and least at early stage.

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