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Study on Differences of Nitrogen Efficiency and Nitrogen Response in Different Oilseed Rape (*Brassica napus* L.) Varieties

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Abstract: Field experiment was carried out to evaluate the nitrogen efficiency and nitrogen response under no nitrogen application and nitrogen application conditions. The differences of grain yield, nitrogen absorption amount, nitrogen response and nitrogen use efficiency among 16 winter varieties of oilseed rape (*Brassica napus* L.) were systematically studied and the contribution of nitrogen absorption efficiency and nitrogen use efficiency to nitrogen efficiency in different oilseed rape varieties were preliminarily discussed. Results showed that, the differences of grain yield, nitrogen use efficiency and nitrogen response among the 16 oilseed rape varieties were significantly, regardless of N application level; but ouly under no N application conditions, the differences of nitrogen absorption amount among varieties were significantly. The 16 oilseed rape varieties were divided into four different genotypes in accordance with the nitrogen use efficiency and nitrogen response under no nitrogen application condition: (1) Nitrogen High Efficiency-Nitrogen High Response, included Xy1, Xy16, Xy17, Xh19, Xh20 and Xy21. (2) Nitrogen Low Efficiency-Nitrogen Low Response (NLE-NLR), included Xy6, Xy8 and Xy9. (3) Nitrogen High Efficiency-Nitrogen Low Response (NHE-NLR), included Xy7, Xy12, Xy14, Xy15 and Xy24. (4) Nitrogen Low Efficiency-Nitrogen High Response (NLE-NHR), included Xy11 and Xy13. The variation coefficient of nitrogen use efficiency was higher than nitrogen absorption efficiency, regardless of N application level; it was also showed that the contribution of nitrogen use efficiency to nitrogen efficiency was higher than nitrogen absorption efficiency. However, variation coefficient of nitrogen absorption efficiency under nitrogen application condition was higher than under no N application condition; variation coefficient of nitrogen use efficiency was reverse. It was indicated that, under no N application condition, the variation of nitrogen efficiency because of nitrogen use efficiency was decreased and variation of nitrogen efficiency because of nitrogen absorption efficiency was increased.

Key words: Oilseed rape (*Brassica napus* L.), nitrogen efficiency, nitrogen response, nitrogen use efficiency, N application level, yield

INTRODUCTION

Nitrogen fertilizer application can guarantee the high yield of crop, it was a general method to improve the yield of crop. However, not ouly N use efficiency was declined, but also environment contamination was seriously day by day because of N fertilizer over application. So, control and decline the N fertilizer application amount is very important; it is necessary to dredge up the potential of N absorption and N use efficiency of crop. Oilseed rape (*Brassica napus* L.) is an important oil production crop in China. However, the N use efficiency and N efficiency of oilseed rape are very low (Schjoerring *et al*., 1995). The N application amount has been reached 200-330 kg N ha^{-1}

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(Schjoerring *et al*., 1995; Wiesler *et al*., 2001a) and increasing year by year. But the studies on differences of N efficiency in different oilseed rape varieties and breeding research of the oilseed rape with high N efficiency were relatively slower than other cereal. Oilseed rape requires high amounts of N for growth, but the N efficiency (seed yield per unit of accumulated N in plant) is very low. Consequently, it is necessary to improve the N efficiency (Rathke *et al*., 2006). In generally, N efficiency has two components: uptake efficiency and utilization efficiency (Sattelmacher *et al*., 1994). The differences of N efficiency between oilseed rape genotypes were significantly (Wiesler *et al*., 2001b; Christian *et al*., 1999; Kessel and Becker, 1999), measured the N concentration of organs in different oilseed rape varieties suggested that, the oilseed rape with low N concentration in dropped leaves and with high N harvesting index has higher N efficiency also; The development of N efficient genotypes and improvement of N management will require to understand the relationship between physiological processes and biomass, yield formation of crop under no N application conditions (Dreccer *et al*., 2000). Kamh *et al*. (2005) compared the differences of root growth and nitrate N exhaust in cultivar culture between high N efficiency and low N efficiency oilseed rape; larger amount of root biomass, higher root uptake activity and higher exhausted nitrate N amount were found in the high N efficiency oilseed rape; Nitrate-N uptake from soil depends on root growth and uptake activity, the amount of N depleted from the compartments significantly correlated with root-length density (Kamh *et al*., 2005). Seiffert *et al*. (2004) suggested that the N use efficiency can be increased significantly by strengthen the activities of asparagine synthetase and glutamine synthetase through transgenic methods. Obviously, it is necessary to system study on N uptake and N use efficiency in different oilseed rape. The differences of yield, N absorption and N use efficiency in different oilseed rape varieties should be compared and preliminarily discussed the contribution different of N absorption efficiency and N use efficiency to the N efficiency under different N application levels, in order to supply scientific basic and plant materials for the future study.

MATERIALS AND METHODS

Plant Materials and Experiment Design

The experiment was conducted at Agricultural Resources and Enviroumental College Experiment Field in Hunan Agricultural University during Sep. 2004 to May. 2005. Sixteen oilseed rape varieties were used as plant materials, the number were showed in Table 1, plant materials were supplied by China National Oilseed Crop Improvement Center, Hunan Branch. The soil used was an alluvial for vegetable cultivation derived from river flow alluvial material, containing organic matter 27.79 g kg^{-1}, total N 1.90 g kg^{-1} and total P 0.79 g kg^{-1} total K 19.76 g kg^{-1}. The NaOH hydrolyzed N was 108.31 mg kg^{-1} of soil, Olsen-P 15.85 mg kg^{-1} of soil, available K 19.76 g kg^{-1} of soil with pH 5.67. Urea was used as N fertilizer, calcium magnesium phosphate as P fertilizer (containing P_2O_5 12%) and potassium chloride (containing K_2O 60%) as K fertilizer.

The experiment had two N treatments; N application and no N application, 16 oilseed rape varieties used as plant materials, 32 treatments, 3 replicates, 96 districts, 10.5 m^2 per district, randomized block. N application treatment: 225 kg N, 75 kg P_2O_5 and 150 kg K_2O h^{-1}, 50% N fertilizer used as basal fertilizer, 20% N fertilizer used as added fertilizer during winter, 30% N fertilizer used at stem elongation stage, all P and K fertilizer were used as basal fertilizer; no N application treatment: the same with N application treatment except of non-N fertilizer applied. Seedling on Sep. 25, 2004, transplanted on Nov. 2, 2004, transplanted density was 100 thousand plants per ha, management as normal.

Sampling, Determination and Calculation

Sampled whole plant at harvesting stage, separated it according to organs after clear, dried until constant weight, measured dry weight and total N. The measurement methods followed by the general agricultural chemistry analysis methods; the plant total N measured by Kjedahl method (Hardy *et al*., 1968). Below formula was used to calculate N use efficiency based on total N:

$$\text{N use efficiency} = \text{Grain yield/Plant total N}$$

All data were carried out t-test by SPSS statistic software (Norusis, 1990), cultivars with the same letter(s) are not significantly different at the $p<0.05$ level using SPSS software analysis.

RESULTS

The Differences of Grain Yield Between Different Oilseed Rape Varieties

The results of grain yield showed that (Table 1) , the differences of grain yield between different oilseed rape varieties were significant, regardless N application level. The rang of yield variation in 16 varieties were 1060-1913 kg h^{-2} under no N application condition; the yields of Xy1, Xy7 and Xh20 were higher (≥2720 kg hm^{-2}), the yields of Xy8, Xy9, Xy11 were lower (≤1105 kg hm^{-2}). N response can be expressed by ratio of (yield with N application-yield with no N application)/N application amount. Because the N application amount of all varieties under N application treatment were the same in this study; so, the N response can be indirectly expressed by the differences of yield under N application condition and no N application condition. N responses of Xy13, Xh19 and Xh20 were higher than other varieties significantly; N responses of Xy14, Xy15 were lower than other varieties significantly. Excepted Xy15, grain yield can be increased by N application significantly, average increased of yield in sixteen cultivars were 35%.

N Absorption Amount and N Use Efficiency in Different Oilseed Rape Varieties

Results of Table 2 showed the relationship between N absorption amount and grain yield; N absorbed amount of different oilseed rape varieties were different under different N application level conditions; the differences of N absorption amount between varieties were significantly under no N application condition; however, the differences were smaller under N application condition. N absorption amount of Xy1, Xy21 and Xy24 (≥1.688 g $plant^{-1}$) were more than other varieties Xy8, Xy9 and Xy13 (≤1.293 g $plant^{-1}$) significantly. The relationship between N absorption amount and grain yield showed that, the correlation between N absorption amount and grain yield was significantly under no N application condition, correlation coefficient was 0.685** ($R_{0.01}$=0.623); but under N

Table 1: Grain yield of different oilseed rape varieties (kg hm^{-2})

Variety No.	No N application	N application	N application-No N application
Xy1	1913a	2490ab	577bc
Xy6	1132de	1630e	498bcd
Xy7	1908a	2290bc	382cd
Xy8	1105e	1620e	515bcd
Xy9	1060e	1550e	490bcd
Xy11	1063e	1650e	587bc
Xy12	1730ab	2070cd	340d
Xy13	1381cd	2429abc	1048a
Xy14	1659ab	1770de	111e
Xy15	1742ab	1720de	-22e
Xy16	1696ab	2290bc	594bc
Xy17	1813ab	2445ab	632b
Xh19	1801ab	2720a	918a
Xh20	1908a	2786a	878a
Xy21	1837ab	2480ab	643b
Xy24	1588bc	1920de	332d

Mean values with the same letter(s) are not significantly different with each other application condition, there was no significantly correlation and the correlation coefficient was 0.415 ($R_{0.05}$ = 0.497). It was indicated that only under the no N application condition, grain yield can be increased significantly by increased N absorption amount. The differences of N use efficiency between varieties were significantly according to the differences of N absorption amount, regardless of N application level. The changes scope of N use efficiency in sixteen varieties was 7.1-12.6, the highest was Xh20 of 7.1 and the lowest was Xy6 of 12.6.

The Differences of N Efficiency in Different Varieties and its Analysis

Resnlts of Table 1 and 2 showed that, the differences of N efficiency, N absorption efficiency and N use efficiency between varieties were significantly under no N application condition and the differences of N efficiency and N use efficiency between varieties were significantly under N application condition; while there were no differences of N absorption efficiency between varieties almost. Grain yield of variety is higher than average yield of 16 varieties under no N application condition was the high N efficiency varieties; contrary it was low N efficiency variety; D-value of grain yield of variety between no N application and N application conditions was higher than average D-value of 16 varieties was high N response varieties; contrary it was low N response variety. The 16 varieties can be divided into 4 genotypes according to the above definitions (Table 3): (1) N high efficiency-N high response; yield was higher under no N application condition; yield was increased significantly under N application condition; included Xy1,Xy16,Xy17,Xh19,Xh20 and Xy21; (2) N low efficiency-N low response; yield was lower under no N application condition; yield increased was indistinct under N application condition; included Xy6, Xy8 and Xy9; (3) N high efficiency-N low response, yield was higher under no N application condition; but the yield increased was indistinct under N application condition; included Xy7,Xy12,Xy14,Xy15 and Xy24; (4) N low efficiency-N high response; yield was lower under no N application condition, but the yield was increased significantly under N application condition; included Xy11 and Xy13.

Table 2: N absorption and use efficiency of different oilseed rape varieties

	N absorption (g plant^{-1})		N use efficiency (g g^{-1})	
Variety No.	No N application	N application	No N application	N application
Xy1	1.744a	2.200a	11.0bc	11.4abc
Xy6	1.467d	2.207a	7.7ef	7.4e
Xy7	1.448d	2.209a	13.2a	10.4bc
Xy8	1.254e	2.151a	8.8def	7.6e
Xy9	1.285e	2.186a	8.2ef	7.1e
Xy11	1.456d	2.154a	7.3f	7.7e
Xy12	1.545bc	2.149a	11.2abc	9.6cd
Xy13	1.293e	2.245a	10.7bcd	10.8abc
Xy14	1.462d	2.192a	11.4abc	8.1de
Xy15	1.518cd	2.177a	11.5ab	7.9de
Xy16	1.489cd	2.177a	11.4abc	10.5bc
Xy17	1.500cd	2.158a	12.1ab	11.4abc
Xh19	1.550bc	2.206a	11.6ab	12.3ab
Xh20	1.603b	2.224a	11.9ab	12.6a
Xy21	1.688a	2.224a	10.9bc	11.2abc
Xy24	1.688a	2.242a	9.4cde	8.6de

Mean values with same letter(s) are not significant different with each other

Table 3: N efficiency and response type of oilseed rape

Type	NHE-NHR	NLE-NLR	NHE-NLR	NLE-NHR
Variety	Xy1	Xy6	Xy7	Xy11
	Xy16	Xy8	Xy12	Xy13
	Xy17	Xy9	Xy14	
	Xy19		Xy15	
	Xy20		Xy24	
	Xy21			

Table 4: Variation of Grain yield, N absorption and use efficiency of different oilseed rape varieties

N Levels	Mean	S	CV(%)
No N application			
Grain yield (kg h m^{-2})	1584	323	20.4
N absorption (g $plant^{-1}$)	1.499	0.142	9.5
N use efficiency (g g^{-1})	10.5	1.7	16.2
N application			
Grain yield (kg h m^{-2})	2116	424	20.0
N absorption (g $plant^{-1}$)	2.194	0.031	1.4
N use efficiency (g g^{-1})	9.7	1.9	19.5
Subtraction of both	533	277	52.1

Results of Table 4 showed that, variation coefficient of grain yield was almost the same regardless of N application level; variation coefficient of N use efficiency was higher than variation coefficient of N absorption amount under the two N application level conditions; it was suggested that, the contribution of N use efficiency to N efficiency was higher than N absorption efficiency in oilseed rape under the field condition, regardless of N application level. The differences of variation coefficient between N absorption amount and N use efficiency were smaller under no N application condition, compared with N application condition; it was suggested that, variation coefficient of N use efficiency was declined, but variation coefficient of N absorption amount was increased under N stress condition; it was indicated that, the contribution of N absorption efficiency to N efficiency was increased with N application level was declined, but the contribution of N use efficiency to N efficiency was decreased.

DISCUSSION

Evaluate the Differences of N Efficiency in Different Oil Seed Rape Varieties

Environmental contamination was reduced by less N fertilizer application, so, breeding and spreading new crop varieties with high N efficiency was an interesting topic recently (Xu *et al*., 2006; Pei *et al*., 2007; Wang *et al*., 2003). Many studies and reports were involved in N agriculture efficiency, N physiological efficiency and N absorption efficiency. N physiological efficiency and N absorption efficiency were parts of the N agriculture efficiency; there were relationships between the three efficiency indexes. Wheat breeders were identified selection standards based on physiological indexes, such as high yield and high protein content (Monaghan *et al*., 2001). Results showed that, the differences of N efficiency in 16 oilseed rape varieties were significantly, regardless of N application level, it was the same with other results (Beauchamp *et al*., 1976; Pollmer *et al*., 1979; Balko and Russell, 1980a; Reed *et al*., 1980; Russell, 1984; Moll *et al*., 1987; Landbeck, 1995; Bertin and Gallais, 2000). It was necessary to select high N efficiency varieties from variety recourses. However, few of oilseed rape varieties were used in these studies, more varieties were needed to be selected and estimated in the future. Sixteen oilseed rape varieties were used as plant materials in this experiment, N high efficiency types were be better plant materials and can tolerant low N stress, these materials have high economic benefit under low N condition; N high response types were be better plant materials and can tolerant high N stress, these materials have high economic benefit under high N condition. It can be seen that, the type of N high efficiency-N high response varieties was the ideal variety.

N Efficiency of Oilseed Rape under Different N Application Level

Breeding procedure was usually conducted under N application conditions recently; so, the varieties have high yield under N application condition, it was only for N application condition; however, it was necessary to select high N efficiency varieties under the low N stress condition in generally, selected the varieties have high yield under no N application level. The correlation of various agronomic traits (grain protein, yield and its component) were different with the changes of N application level (Balko and Russell, 1980b; Di Fonzo *et al*., 1982; Rizzi *et al*., 1993; Bertin and Gallais, 2000). Therefore, the response differences of varieties under different N application level conditions were obscured; these problems are needed to be further studied in the future. Möllers *et al*. (2000) studies suggested that, the differences of N efficiency between different N application levels and between varieties were big, observed significant interactions between genotype and N level suggested that the high yielding genotypes in high N supply were not necessarily high yielding in the low N supply. This study has the same results, the varieties have the same yield under N application condition, but under no N application condition, the differences of yield between varieties were big; The 16 oilseed rape varieties can be divided into 4 different genotypes according to yield under N application and no N application conditions (Table 3), (1) double high efficiency genotype, yield of these varieties were higher than average yield of varieties, regardless of N application level; included Xy1,Xy7,Xy16,Xy17,Xh19,Xh20 and Xy21; (2) double low efficiency genotype, yield of these varieties were lower than average yield of varieties, regardless of N application level; included Xy6,Xy8,Xy9 and Xy11; (3) high N-high efficiency genotype, yield of these varieties were lower than average yield of varieties under no N application condition and the result was reverse under N application condition; included Xy12,Xy14,Xy15 and Xy24; (4) low N-high efficiency genotype, yield of these varieties were higher than average yield of varieties under no N application condition and the result was reverse under N application condition; included Xy13. However, the results of Grami *et al*. (1977) studied with spring rapeseed reported direct relationship between N uptake and seed N content and concluded that, high seed N content was good for N uptake and translocation efficiency improved, it was contrary with this study. The above results suggested that, both of N application condition and no N application conditions should be considered during the breeding and selecting procedure of crop (Liu *et al*., 1999; Lafitte and Edmeades, 1994).

The Contribution of N Absorption Efficiency and N Use Efficiency to N Efficiency

Many studies were involved in contribution of N absorption efficiency and N use efficiency to N efficiency, but the results were different. High seed protein content will cost of grain yield, this agrees with former results which observed negative relationship between protein content of seed and grain yield (Dudley *et al*., 1977; Simmsonds, 1995). Wheat breeders have reported selection standards combined with high yield and high protein content (Monaghan *et al*., 2001). Some results showed the N use efficiency was the main reason for changes of N efficiency under low N condition and the main reason was N absorption efficiency under high N condition (Moll *et al*., 1982); the effect of N absorption efficiency on N efficiency was higher than N use efficiency significantly under low N condition and the effect of N absorption efficiency and N use efficiency on N efficiency were almost the same under high N condition (Mi *et al*., 1998); the absorption efficiency was the main reason for changes of N efficiency regardless of N application level (Liu *et al*., 2002); N absorption efficiency and N use efficiency of oilseed rape were studied by Yan and Thurling (1987a), there were differences of N use efficiency between varieties under high N condition and there were differences of N absorption efficiency between varieties under low N condition. The results of this study showed that, the changes of N use efficiency was the main reason of the changes of N efficiency under low and high N conditions, but Yan and Thurling (1987b) has the different results. In this study (Table 4) also showed that, variation coefficient of N absorption efficiency was increased under low N condition, while the variation coefficient of N use efficiency was declined, it was suggested that, the contribution of N absorption efficiency to N efficiency was increased under low N condition. However, the results were ouly for the varieties which used in this experiment and more varieties are necessary to be used in the future, to reveal more exactly and generally conclusions.

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