http://www.pjbs.org

PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

OPEN ACCESS Pakistan Journal of Biological Sciences

ISSN 1028-8880
DOI: 10.3923/pjbs.2019.291.298

Research Article
Optimal Nitrogen Fertilization Management of Seed-sowing Rapeseed in Yangtze River Basin of China

[1+]Hongqiao Li, [1+]Abuzar Ghafoor, [2]Hassan Karim, [1]Shixing Guo, [1]Zhuang Li, [1]Yongcheng Wu, [3]Yuanyuan Sun and [4]Feng Yan

[1]Agricultural College of Sichuan Agricultural University, 211 Huimin Street, Wenjiang District, Chengdu 611130, China
[2]Triticeae Research Institute, Sichuan Agricultural University, 211 Huimin Street, Wenjiang District, Chengdu 611130, China
[3]Institute of Plateau Meteorology, China Meteorological Administration, 20 Guanghuacun Street, Qingyang District, Chengdu 610072, China
[4]Institute of Agronomy and Plant Breeding I, Justus Liebig University, Schubertstrasse 81, D-35392 Giessen, Germany

Abstract
Background and Objective: For cultivation and high yield of oilseed rape (*Brassica napus* L.) in China, traditional seedling transplanting is replaced by seed-sowing but, better nitrogen management is crucial and not established yet. This study aimed to adapt N management to the seed-sowing method for the winter oilseed rape and to minimize the N fertilizer-derived pollution potential in the upper reaches of Yangtze River Basin. **Materials and Methods:** Three field experiments were conducted to check effect of different doses of N fertilizers, split doses of N and different types of N fertilizers for seed-sowing winter oilseed rape with high plant density in upper reaches of Yangtze River Basin in Sichuan province of China. **Results:** In first experiment, among four doses (0, 90, 180 and 270 kg N ha^{-1}) on average 3.54 t ha^{-1} was in 180 kg N ha^{-1} and 3.61 t ha^{-1} in 270 kg N ha^{-1} while cultivars dy6 and cn3 produced 3.23 and 3.29 t ha^{-1} which is significantly higher than zs11. There was no significant difference in N-use efficiency among three cultivars tested and second experiment showed no significant difference in seed yield with split N application. The third experiment compared the effects of different fertilizer types (urea, coated urea, 1:1 mixture of urea and coated urea and compound nitrogen fertilizer) on seed yield and get no significant difference in seed yield. **Conclusion:** This experiment proved that seed sowing method with higher nitrogen had high yield in the upper reaches of Yangtze River Basin in China, but higher N application may cause environment pollution. So, seed sowing method with nitrogen 180 kg N ha^{-1} was proved to be more effective.

Key words: Rapeseed (*Brassica napus* L.), nitrogen management, seed-sowing, Yangtze river basin, oilseed rape, nitrogen fertilizer, environment pollution

Citation: Hongqiao Li, Abuzar Ghafoor, Hassan Karim, Shixing Guo, Zhuang Li, Yongcheng Wu, Yuanyuan Sun and Feng Yan, 2019. Optimal nitrogen fertilization management of seed-sowing rapeseed in the Yangtze River Basin of China. Pak. J. Biol. Sci., 11: 291-298.

Corresponding Author: Yongcheng Wu, Agricultural College of Sichuan Agricultural University, 211 Huimin Street, Wenjiang District, Chengdu 611130, China Tel: +86 177 1356 1646
[+]The first and second authors contributed equally to this paper.

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Oilseed rape is the most important and major oil crop in many countries and in China. An annual production of 14 Mt of rape seed on about 7.3 million ha was recorded[1] in 2012. The Yangtze River Basin (YRB) is the major production area for winter oilseed rape in China and is also the largest oilseed rape cultivation belt in the world, representing approximately 20% of the global oilseed rape cultivation area[2]. Unlike the other countries or territories where rape seeds are sown with a drill machine[3,4], both seed-sowing and transplanting of seedling methods are commonly used for winter oilseed rape in China[5]. Seedling-transplantation of oilseed rape has been traditionally and conventionally used as major establishment method for long time in the region of YRB. Among all *Brassica* species, oilseed rape has a high N demand which varies from 200-330 kg N ha^{-1} in European countries, depending on the soil types and the yield levels[3,6,7] .Currently, the nitrogen application rates varied from 60-400 kg N ha^{-1} with an average of 180$\pm$45 kg N ha^{-1} for winter oil seed rape in this region[8]. In order to produce oilseed rape more economically, seed-sowing for oil seed rape production has been widely adopted throughout south China in recent years[5].

Sichuan province is located in the upper reaches of YRB and it is one of the provinces with the largest winter oilseed rape production in China. Compared with the middle and lower reaches of YRB, the upper reaches of YRB are characterized by high altitude, less annual sunshine hours and warm winter without frost. Correspondingly, winter oilseed rape has no growth arrest during winter period and plants tend to be taller with delay in maturation. The yield of rapeseed in this region is comparatively higher than those found in lower and middle reaches of Yangtze River Basin[9,10]. In comparison with seedling-transplanting, seed-sowing is usually associated with high plant density which is necessary to reach high seed yield. Higher plant density changes N requirement of rapeseed plants and N application management needs to be correspondingly modified[11]. So far, there is little information on the nitrogen fertilization of winter oilseed rape cultivated with seed-sowing method in the upper reaches of YRB in Sichuan province. In this study, oilseed rape was cultivated using seed-sowing method with high plant density in the upper reaches of YRB in Sichuan province in China with objectives: (1) To compare the effects of different N application rates on seed yield, oil yield and N fertilizer use efficiency, (2) To investigate the effects of splitting and timing of N application on seed yield, oil yield and nitrogen uptake, (3) To study the effects of different types of nitrogen fertilizer on seed yield, oil yield and nitrogen uptake of oilseed rape.

MATERIALS AND METHODS

Description of experiment site: The experiment site (102°54 E, 104°53 E, 30°05 N, 31°26 N) is in the Chengdu Plain of the upper reaches of Yangtze River Basin in Sichuan province of China. It is a sub-tropical region with an annual mean temperature of 16°C, precipitation of 900-1300 mm and sunshine duration of1042-1412 h. During the winter, the daily average temperature is above 0°C and precipitation is usually less than 150 mm from December-February. Monthly precipitation and temperature of long-term average and two growing seasons is shown in Fig. 1a and b.

Experiment A

Interaction of N application doses and cultivars: The experiment was designed as a split plot with four N application doses as main plots and three local cultivars as sub-plots with three plot replicates. Each of main plots measured 12$\times$5 m, while the area of sub-plot measured 4$\times$5 m. All plots were fertilized with 90 kg P_2O_5 ha^{-1} (as 750 kg ha^{-1} calcium superphosphate) and 90 kg K_2O ha^{-1} (as 180 kg ha^{-1} potassium sulfate) before sowing. Seeds of cultivars “dy6”, “cn3” and “zs11” were sown to the sub-plot with a density of 3 kg seed ha^{-1} on 23 September, 2011. The tested variety, dy6 is a new medium-maturity and double-low hybrid rape variety[12], cn3 a new hybrid rapeseed with medium maturity and low quality was approved by *Sichuan* crop variety certification[14] committee in 2008, zs11 the variety was developed by a breeding team from the institute of oilseed research, Chinese academy of agricultural sciences[14]. Urea was used as N fertilizer and four doses were applied: 0, 90, 180 and 270 kg N ha^{-1}. The total amount of fertilizer was split into two portions, one was applied as basal fertilization prior to sowing and the other one was top-dressed on late November to the development of 6-leaf stage. Plants were harvested at maturity in the middle of May, 2012.

Experiment B

Effects of fertilizer splitting on oilseed rape yield and nitrogen in shoots: The field experiment B was designed as a completely randomized plot design with three N splitting rates. N fertilizer application was same (225 kg N ha^{-1}) in each treatment. In NT1 total N was applied as basal before sowing. In NT2 half N (112.5 kg N ha^{-1}) was applied as basal before sowing and half as top dressing at 6 leaf stage. In NT3 total N was divided in three portions (75 kg N ha^{-1} for each): One was applied as basal before sowing, second was applied as top dressing at 6 leaf stage and third as top dressing at 11 leaf stage. In addition, 90 kg P_2O_5 ha^{-1} (as 750 kg ha^{-1} calcium

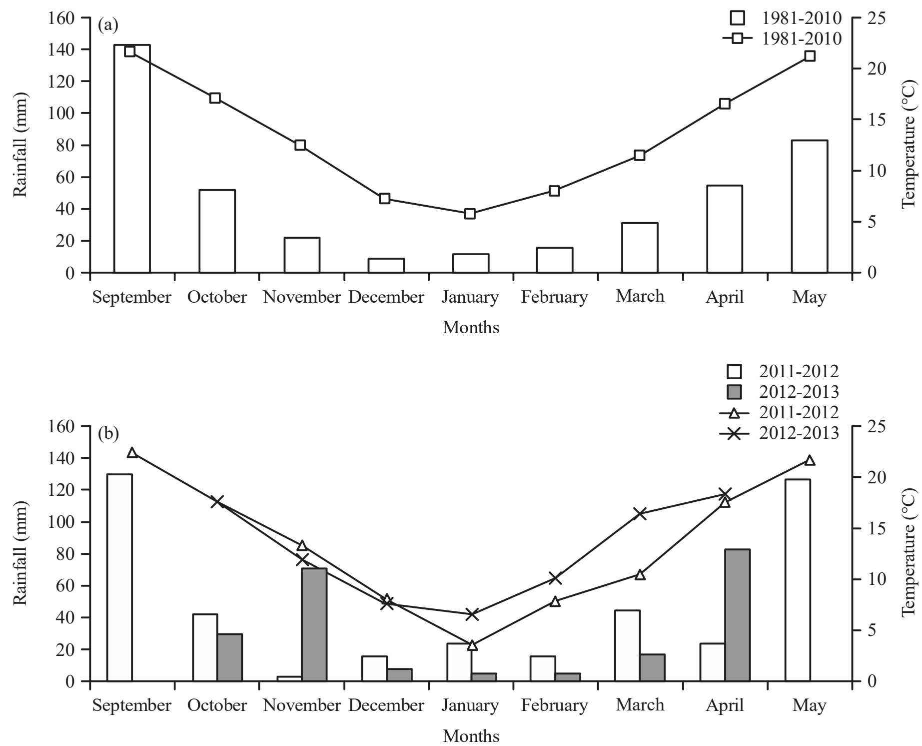

Fig. 1(a-b): Monthly precipitation (bars) and temperature (lines) of long-term average, (a) 1981-2010 and (b) Two growing seasons (2011/2012, 2012/2013)

superphosphate) and 90 kg K_2O ha^{-1} (as 180 kg ha^{-1} potassium sulfate) were applied as basal fertilizers. The plot size was ×5 m. Winter oilseed rape (cv. cn3, 3 kg seed ha^{-1}) was sown on 24 September, 2011 and plants were harvested in the middle of May, 2012.

Experiment C

Effects of different N fertilizer types on oilseed rape yield and nitrogen in shoot: The experiment C was designed as completely randomized plot experiment with four different fertilizer types: urea, coated urea, mixture of urea and coated urea (50% for each based on N), compound fertilizer (N 15%, P_2O_5 5% and K_2O 5%). The amount of nitrogen fertilization was the same (190 kg N ha^{-1}) for all treatments and was applied as basal fertilizers before sowing. The plot size was 4 m×5 m. All plots were additionally fertilized with 90 kg P_2O_5 ha^{-1} and 90 kg K_2O ha^{-1} as basal fertilization. The seeds of winter oilseed rape (cv. cn3) were sown on 13 October, 2011 and harvested in the middle of May, 2012.

Data collection: Above ground part of plants were cut for seed and straw yield determination and also 10 plants per plot was chosen to determine shoot dry matter and N accumulation. Shoot part was heated at 105°C for 30 min to deactivate enzymes in oven and dried at 70°C until constant weight reached. Plant material was grinded and passed from 1 mm sieves and weighed 1 g material and digested[15] with H_2SO_4 and H_2O_2. The total N concentrations of digests were determined by using an automated continuous flow analyzer (Seal, Norderstedt, Germany). Nitrogen accumulation was calculated as the product of dry matter multiplied by nitrogen concentration. The total accumulation of nitrogen in above ground material was calculated as the sum of nitrogen accumulated in seed and straw[16]. Seed yield of oilseed rape was adjusted to 91% dry matter content[17]. The oil content of the seeds was determined by near infrared spectrometer (NIRS) systems (Model 5000, Foss Analysis Instrument, Denmark).

Calculation of nitrogen fertilizer use efficiencies and N harvest index: Nitrogen fertilizer use efficiencies were expressed in four different ways[16,18-20]:

$$\text{Agronomic efficiency of N fertilizer (AEN, kg kg}^{-1}\text{)} = \frac{\text{Seed yield of fertilized plants-seed yield of unfertilized plants}}{\text{N fertilizer applied}}$$

$$\text{Apparent recovery of N fertilizer (ARN, \%)} = \frac{\text{Total N amount of fertilized shoots (kg ha}^{-1}\text{)} - \text{Total N amount of unfertilized shoots (kg ha}^{-1}\text{)}}{\text{Total N applied (kg ha}^{-1}\text{)}} \times 100$$

$$\text{Nitrogen utilization efficiency (NUE, kg kg}^{-1}\text{)} = \frac{\text{Seed produced (kg)}}{\text{N accumulated by shoots at maturity (kg)}}$$

$$\text{Nitrogen physiological efficiency (PEN, kg kg}^{-1}\text{)} = \frac{\text{Seed yield fertilized} - \text{seed yield unfertilized}}{\text{N accumulated fertilized} - \text{N accumulated unfertilized}}$$

Statistical analysis: Data processing was done with Microsoft excel 2003 and variance analysis (one-way ANOVA) was carried out with SPSS 19.0 software (SPSS, Chicago, IL) with one way. Significant differences among treatments were determined using the least significant difference (LSD) at p<0.05.

RESULTS

Experimental A

Interactions between N application rates and cultivars: There was no significant interaction between N application rates and cultivars tested in experiment A. Among three tested cultivars, seed yield of cultivar zs11 was significantly lower than those of cultivars dy6 and cn3, while seed oil content of cultivar zs11 was significantly higher than those of cultivars dy6 and cn3 (Table 1). There were no significant differences in seed yield, oil yield and seed oil content between cultivars dy6 and cn3.

Seed yield, oil yield and seed oil content: As compared with control, the seed yields were significantly increased for the treatments of 90, 180 and 270 kg N ha^{-1}, respectively (Table 1) Furthermore, N application significantly increased oil yield of rapeseed. The increase in oil yield was significant among the treatments N0, N90 and N180, but not between treatments of N180 and N270. The oil content of rapeseed was significantly decreased from 436-418 g kg^{-1} in N90 and N270, respectively.

Nitrogen in shoots at maturity: The accumulation of N in above ground part of oilseed rape increased significantly with the increase in N applied rates from 80 kg N ha^{-1} (N0) to 220 kg N ha^{-1} (N270, Fig. 2). Among three cultivars, there was no significant difference in N accumulation (Fig. 3).

Nitrogen fertilizer use-efficiencies: Agronomic efficiency of N fertilizer (AEN), apparent recovery of N fertilizer (ARN), nitrogen utilization efficiency (NUE), nitrogen physiological efficiency (PEN) and nitrogen harvest index (NHI) all significantly decreased with the increasing N applied rates (Table 2). Among three different cultivars there was no

Table 1: Effect of different doses of N on seed yield, seed oil content and oil yield with respect to different cultivars

Factors	Treatments	Seed yield (t ha^{-1})	Seed oil content (g kg^{-1})	Oil yield (kg ha^{-1})
Nitrogen	N0	2.13^{c}	433^{ab}	913^{c}
	N90	3.08^{b}	436^{a}	1339^{b}
	N180	3.54^{a}	422^{bc}	1492^{a}
	N270	3.61^{a}	418^{c}	1500^{a}
Cultivar	dy6	3.23^{a}	405^{b}	1306^{ab}
	cn3	3.29^{a}	416^{b}	1364^{a}
	zs11	2.76^{b}	461^{a}	1262^{b}

Different letters in each column indicate significant differences at p<0.05

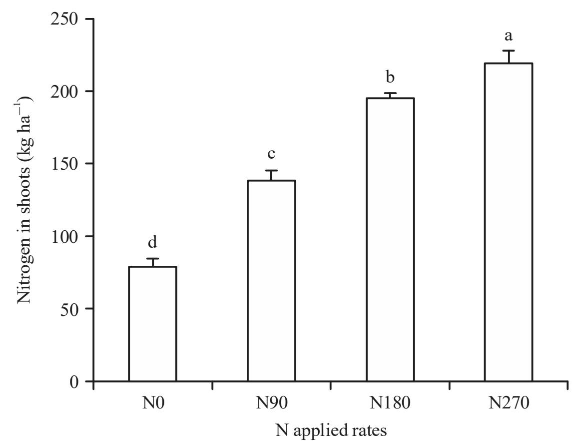

Fig. 2: Nitrogen in shoots at maturity under different N applied rates

Different letters indicate significant differences at p<0.05

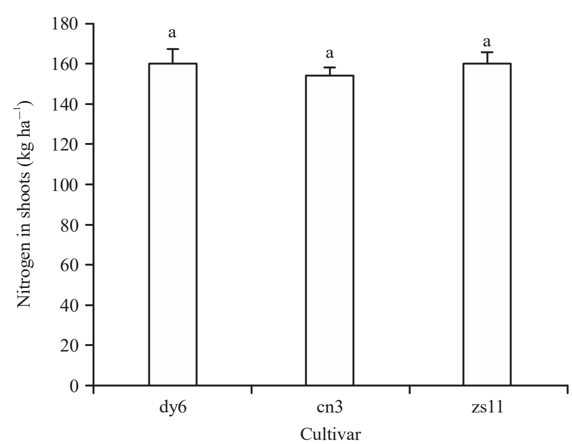

Fig. 3: Nitrogen in shoots at maturity as affected by different cultivars

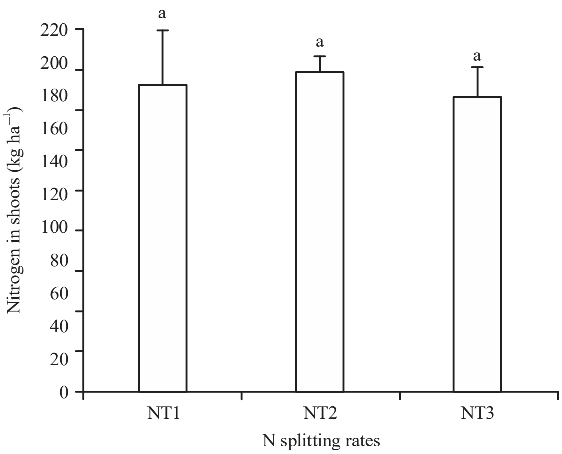

Fig. 4: Nitrogen in shoots as affected by different N splitting rates

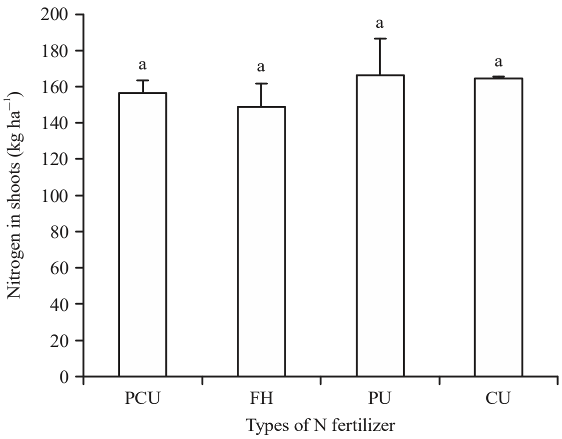

Fig. 5: Nitrogen in shoots as affected by different types of N fertilizer

significant difference for N fertilizer use efficiencies (Table 2). As a trend, "cn3" and "zs11" showed high values of AEN and ARN and "cn3" and "dy6" showed high values of NUE and NHI, respectively. Furthermore, "cn3" showed the lowest value of seed N content (SNC) and the highest value of PEN.

Experimental B

Effects of nitrogen fertilizer in different splitting rates on oilseed rape yield and nitrogen in shoots: In experiment B the applied N amount (225 kg N ha^{-1}) was same for all treatments, but the splitting rates were different from 1-3. The splitting rates of N fertilizer did not significantly change the seed yield, oil content and oil yield (Table 3), although seed yield and oil yield of NT2 treatment were higher than those of NT1 treatment, respectively. The N splitting rates did not have significant effects on the N accumulation in shoots at maturity (Fig. 4).

Table 2: Effect of nitrogen fertilizer doses on agronomic efficiency of N, apparent recovery of nitrogen, nitrogen physiological efficiency, nitrogen utilization efficiency and nitrogen harvest index with respect to different cultivars

Factors	AEN (kg kg^{-1})	ARN (%)	PEN (kg kg^{-1})	NUE (kg kg^{-1})	NHI	SNC (mg g^{-1})
Nitrogen						
N90	10.6^a	66.3^a	16.9^a	22.4^a	0.63^a	30.8^a
N180	7.8^b	64.9^a	12.3^b	18.1^{ab}	0.54^a	32.9^a
N270	5.5^b	52.2^b	10.7^b	16.4^b	0.51^a	34.0^a
Cultivar						
dy6	6.8	56.7	12.0	19.5	0.60	34.2
cn3	8.5	62.5	13.7	20.6	0.59	31.5
zs11	8.5	64.2	12.3	16.8	0.49	32.0

Different letters in each column indicate significant differences at $p<0.05$

Table 3: Seed yield, oil content and oil yield as affected by different N splitting rates

Treatments	Seed yield (kg ha^{-1})	Oil content (g kg^{-1})	Oil yield (kg ha^{-1})
NT1	3.52^a	420^a	1475^a
NT2	3.98^a	408^a	1622^a
NT3	3.66^a	410^a	1502^a

Different letters in each column indicate significant differences at $p<0.05$

Table 4: Seed yield, oil content and oil yield as affected by different types (NCU, CF, NU, CU) of N fertilizer

Treatments	Seed yield (kg ha^{-1})	Oil content (g kg^{-1})	Oil yield (kg ha^{-1})
NCU	3.17^a	409^a	1294^a
CF	3.17^a	410^a	1298^a
NU	3.11^a	410^a	1277^a
CU	3.01^a	404^a	1216^a

Different letters in each column indicate significant differences at $p<0.05$. NU: Normal urea, CU: Coated urea, NCU: Mixture of urea and coated urea (50% for each based on N), CF: Compound fertilizer

Experimental C

Effects of different types of N fertilizer on oilseed rape yield and nitrogen in shoots: There was no significant difference in seed yield, oil content and oil yield among different N fertilizer types at the same N fertilization amount (Table 4). Moreover, no significant difference was found in N accumulation in shoots among different types of N fertilizer (Fig. 5).

DISCUSSION

This study showed that increased nitrogen application in 2011/12 significantly increased the grain yield and oil yield, respectively. This yield level was in the range of the upper parts of the rapeseed yields recorded for the whole area of Yangtze River Basin with seedling-transplanting method, which ranged[8] from 0.85-4.5 t ha^{-1}. In addition, the yield achieved in this study was much higher than those of researchers who grew winter oilseed rape with seed-sowing method and achieved a yield level of about 2.5 t ha^{-1} in the middle reaches of Yangtze River Basin in Hubei province of China[21,22]. In addition, the plant densities differed markedly between current results and Li's findings[21], who studied the plant density of 20 plants m^{-2} while in the present study more than 30 plants m^{-2} were established by a seed-sowing density of 3 kg seed ha^{-1}. This plant density was about three times higher than that used in seedling-transplanting method. Traditionally, plant density of about 10 plants m^{-2} had been used with seedling-transplanting method for the region of Yangtze River Basin[22,23]. In contrast, in European countries where traditionally seed-sowing was practiced, a plant density of 40-60 plants per m^2 were used for oilseed rape cultivation with a yield level as high[24] as 4-5 t ha^{-1}.

The observed response of seed and oil yield of winter oilseed rape to N application rate were the characteristic of this crop and proved by other authors[25-28]. On the base of year and site conditions, optimum seed yield of winter oilseed rape was reached at N application within a range[26] from 180-220 kg N ha^{-1}. The optimal N application rate of 180 kg N ha^{-1} observed in the present study matched exactly to the average level of economically optimal N application rate for the winter oilseed rape cultivation in the Yangtze River Basin, as recently reported[8].

A distinct difference between seed-sowing and seedling-transplanting methods was the plant density. Two to four times higher plant density was used for seed-sowing than for seedling-transplanting methods[5,21]. A previous experiment compared the yield structures of winter rapeseed between seed-sowing and seedling-transplanting methods. At N application rate of 180 kg N ha^{-1}, the number of first and second order of branches of individual oilseed rape plants associated with seed-sowing method were significantly lowered as compared with seedling-transplanting method. This was also true for the number of pods[5]. It was also found that the optimal N application rate was lower for seed-sowing with high plant density (130 kg N ha^{-1}) than seedling-transplanting with lower plant density[15] (228 kg N ha^{-1}). This might be related with a comparatively lower scope of space associated with seed-sowing method, which allows the plant development, especially branching. Although in the present study the splitting of total N amount into two or three applications did not show any benefit effects on the seed yield or oil yield, it is generally recognized that splitting N in several applications may increase seed yield and oil yield of oilseed rape[4,29], since in this way the N supply might be better match the plant N requirement and decreased N lost through leaching. The pre-sowing fertilization with high amount of N in cold autumn and winter caused great N lost by leaching[21]. In this case a splitting of N application adapted to the plant requirement with the development, greatly reduced N leaching and increased N-use efficiency[27].

In the present study, different N-use efficiencies of oilseed rape were determined. For all calculated N-use efficiencies there is a general trend that with increasing N application rates the N-use efficiencies decreased. Similar trends of N-use efficiencies in dependence of N supply rates for oilseed rape were reported by other authors[16,17,21,22]. This experiment could provide future assistance to researchers with a choice of nitrogen application amount of 180 kg, which made high-density direct seeding rape to obtain high yield and was an effective fertilizer application amount which reduced production cost and relatively speaking, cn3 has the characteristics of high yield and high nitrogen utilization rate.

CONCLUSION

It was concluded that the level of seed yield of winter oilseed increased with the increase in N application rate on average 3.54 t ha^{-1} was in 180 kg N ha^{-1} and 3.61 t ha^{-1} in 270 kg N ha^{-1} due to low rainfall, all nitrogen should be applied before sowing and there was no significant difference in N-use efficiency among three cultivars tested. This yield level is comparable with yield level obtained with seedling-transplanting method in the upper reaches of Yangtze River Basin. Higher N application rates decreases N fertilizer use efficiency of oil seed rape and present environment pollution potential. So, seed sowing method with nitrogen 180 kg N ha^{-1} was recommended in this study. In terms of economy urea is a good N fertilizer for the oilseed rape production in this region. No benefit effect was observed for other more expensive fertilizers.

ACKNOWLEDGMENTS

The research was supported with grants from The Cultivation Project of Breeding Research of Sichuan Province (2016NYZ0051) and Rapeseed Special Project of Agricultural Innovation Team of Sichuan Province.

SIGNIFICANCE STATEMENT

This study discovered in the upper reaches of the Yangtze River, the yield of winter rapeseed could not be effectively increased by increasing nitrogen application and the nitrogen efficiency could not be increased. While high yield of winter rape can also be obtained with proper planting density and nitrogen application. There was no difference between the yield of winter rapeseed planted directly and that of winter rapeseed transplanted under the condition of suitable nitrogen application that can be beneficial for reducing the production cost of farmer and raise agricultural income. The study will help researchers compare the effects of common urea and expensive, coated urea on rapeseed production. Therefore, it is concluded that controlled coated urea did not significantly improve rapeseed yield in the upper reaches of the Yangtze river.

REFERENCES

1. Su, W., B. Liu, X. Liu, X. Li, T. Ren, R. Cong and J. Lu, 2015. Effect of depth of fertilizer banded-placement on growth, nutrient uptake and yield of oilseed rape (*Brassica napus* L.). Eur. J Agron., 62: 38-45.
2. Yin, Y., X. Liao, B. Yu and H.Z. Wang, 2010. Regional distribution evolvement and development tendency of Chinese rapeseed production. Chin. J. Oil Crop Sci., 32: 147-151.
3. Schjoerring, J.K., J.G.H. Bock, L. Gammelvind, C.R. Jensen and V.O. Mogensen, 1995. Nitrogen incorporation and remobilization in different shoot components of field-grown winter oilseed rape (*Brassica napus* L.) as affected by rate of nitrogen application and irrigation. Plant Soil, 177: 255-264.
4. Barlog, P. and W. Grzebisz, 2004. Effect of timing and nitrogen fertilizer application on winter oilseed rape (*Brassica napus* L.). I. Growth dynamics and seed yield. J. Agron. Crop Sci., 190: 305-313.
5. Wang, Y., J.W. Lu, X.K. Li, J.F. Li, P.P. Liu, W.M. Xu and Y.Q. Yang, 2011. Study on nitrogen fertilizer effect and optimum fertilizer rate for transplanting and direct-seeding rapeseed. Sci. Agric. Sin., 44: 4406-4414.
6. Aufhammer, W., E. Kubler and M. Bury, 1994. Nitrogen uptake and nitrogen residuals of winter oil-seed rape and fallout rape. J. Agro. Crop Sci., 172: 255-264.
7. Jensen, L.S., L. Christensen, T. Mueller and N.E. Nielsen, 1997. Turnover of residual ^{15}N-labelled fertilizer N in soil following harvest of oilseed rape (*Brassica napus* L.). Plant Soil., 190: 193-202.
8. Li, X., T. Yang, Z. Nie, G. Chen, L. Hu and R. Wang, 2015. A functional leaf may represent the assimilate accumulation characteristics of the whole seedling plant in winter oilseed rape (*Brassica napus* L.). Crop Pasture Sci., 66: 849-856.
9. Honglin, C., C. Shanghng, S. Xuezhen and G. Zhen, 2011. Study on ecological adaptability of rape varieties in hilly area of Sichuan basin. Southwest China J. Agric. Sci., 24: 872-876.
10. Yongcheng, W., N. Yingze, G. Shixing and L. Zhuang, 2011. Analysis of variety characteristics of oilseed rape (*Brassica napus* L.) in Sichuan province past 10 Years. Southwest China J. Agric. Sci., 24: 2054-2056.
11. Miersch, S., A. Gertz and F. Breuer, 2016. Influence of the semi-dwarf growth type on nitrogen use efficiency in winter oilseed rape. Crop Sci., 56: 2952-2961.
12. Wang, H.X., 2009. Influences of cultivation mode to biomass accumulation and yield formation of hybrid oil rape deyou 6. J. Anhui Agric. Sci., 37: 1963-1964.
13. Yongcheng, W., N. Yingze, Guoshixing and L. Zhuang, 2011. A new rape variety chuanongyou 3 and its supporting cultivation technology. Crops, 5: 116-135.
14. Jing, C., Z. Chunlei, L. Shoucheng and W. Yongcheng, 2011. Study on high-yield cultivating techniquefor zhongshuang 11 (*Brassica napus* L.). Crops, 2011: 125-127, 137.
15. Bao, S.D., 2000. Analysis of Soil and Agricultural Products. China Agricultural Press, Beijing, China, pp: 264-267.
16. Erley, G.S.A., T. Behrens, A. Ulas, F. Wiesler and W.J. Horst, 2011. Agronomic traits contributing to nitrogen efficiency of winter oilseed rape cultivars. Field Crops Res., 124: 114-123.
17. Yunfei, Y., L. Shishan and W. Yongcheng, 2017. Effects of nitrogen fertilizer on biological characters, physiological indexes and yield of rapeseed at seedling stage. Agric. Sci. Technol., 18: 2401-2405, 2414.
18. Hocking, P.J., P.J. Randall and D. DeMarco, 1997. The response of dryland canola to nitrogen fertilizer: Partitioning and mobilization of dry matter and nitrogen and nitrogen effects on yield components. Field Crops Res., 54: 201-220.
19. Rathke, G.W., T. Behrens and W. Diepenbrock, 2006. Integrated nitrogen management strategies to improve seed yield, oil content and nitrogen efficiency of winter oilseed rape (*Brassica napus* L.): A review. Agric. Ecosyst. Environ., 117: 80-108.
20. Wang, Y., Y. Huang, M. Xin, S. Yuan and G. Kang *et al*., 2017. Effects of the year-round management model of N, P and K combined application on grain yield and nutrient efficiency of wheat-maize rotation system in lime concretion black soil. Sci. Agric. Sin., 50: 1031-1046.
21. Li, X.H., Q.B. Li, T.W. Yang, Z.N. Nie, G.X. Chen and L.Y. Hu, 2016. Responses of plant development, biomass and seed production of direct sown oilseed rape (*Brassica napus*) to nitrogen application at different stages in Yangtze River Basin. Field Crops Res., 194: 12-20.
22. Li, X.H., Q.B. Li, T.W. Yang, Z.N. Nie, G.X. Chen and L.Y. Hu, 2016. Responses of plant development, biomass and seed production of direct sown oilseed rape (*Brassica napus*) to nitrogen application at different stages in Yangtze River Basin. Field Crops Res., 194: 12-20.
23. Yu, Y.L., Z.G. Wu, Y.Z. Wu, Z.G. Lu, P.N. Zhou, S.N. Wei and F.N. Gu, 2001. Effect of density and nitrogen on the yield and branch characteristics of double-low rapeseed (*Brassica napus* L.) Suyou No.1. Chin. J. Oil Crop Sci., 23: 41-45.

24. Diepenbrock, W., G. Fischbeck, K.U. Heyland and N. Knauer, 1999. Special Crop Production. 3rd Edn., Verlage Eugen Ulmer Stuttgart, Germenay.
25. Rathke, G.W., O. Christen and W. Diepenbrock, 2005. Effects of nitrogen source and rate on productivity and quality of winter oilseed rape (*Brassica napus* L.) grown in different crop rotations. Field Crops Res., 94: 101-113.
26. Sieling, K. and O. Christen, 1997. Effect of preceding crop combination and N fertilization on yield of six oil-seed rape cultivars (*Brassica napus* L.). Eur. J. Agron., 7: 301-306.
27. Jackson, G.D., 2000. Effects of nitrogen and sulfur on canola yield and nutrient uptake. Agron. J., 92: 644-649.
28. Narits, L., 2010. Effect of nitrogen rate and application time to yield and quality of winter oilseed rape (*Brassica napus* L. var. oleifera subvar. biennis). Agron. Res., 8: 671-686.
29. Sieling, K. And H. Kage, 2010. Efficient N management using winter oilseed rape. A review. Agron. Sustainable Dev., 30: 271-279.