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Original Paper

Effect of increasing spring doses of nitrogen on yield and oil content in seeds of oilseed rape (*Brassica napus* L.)

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The aim of the experiment was to investigate the importance of nitrogen on oilseed rape (*Brassica napus* L.) yield as well as monitor the effect of rising nitrogen doses on rapeseed yield and oiliness. The plot–scale experiment was based in years 2013–2014 and 2014–2015 in terms of agricultural cooperative in Mojmírovce. Hybrid Artoga was seeded. There were five treatments of fertilization and the block method of experimental plot size of 600 m^2 in triplicate was used in this experiment. The first treatment was unfertilized control treatment. Other treatments were fertilized by increasing doses of nitrogen 120 kg ha^{-1}, 160 kg ha^{-1}, 200 kg ha^{-1} and 240 kg ha^{-1}. Results showed that yield of seed and oil content were greatly influenced by climatic conditions. Both experimental years were not equable in precipitation and temperature. The highest average yield (at 12% moisture) 4.33 t ha^{-1} was found at treatment where the dose of nitrogen 200 kg ha^{-1} was used. It means an increase by 81.93% compared to unfertilized control treatment. The positive correlation between yield and dose of nitrogen was proved in this experiment. The highest average oil content 45.43% was reached at treatment 2. The negative correlation between oil content and dose of nitrogen was also confirmed in this experiment.

Keywords: oilseed rape, nitrogen nutrition, yield, oil content

1 Introduction

Oilseed rape is the second most common oil-bearing crop in the world, after soybean, and the European Union is the highest producer and consumer of the crop worldwide (López-Mosquera et al., 2015). Oilseed rape is a member of the mustard family that is grown for the production of animal feed and vegetable oil for human consumption (Aminpanah, 2013). In nutrient consumption, oilseed rape is ranked among very demanding crops (Ložek and Varga, 2008). The results of many scientific research works and knowledge of practice confirm that the optimal vegetation ensuring by all biogenic elements is crucial for quality and quantity of rapeseed (Balík et al., 2006). Nitrogen is one of the most important elements in plant nutrition, especially in yield formation (Rathke et al., 2005; Balint and Rengel, 2008). Nitrogen nutrition is therefore one of the essential conditions for reaching high yields (Orlovius and Kirgby, 2003). Spring doses of nitrogen are particularly important (Varga and Ducsay, 2011). It can be concluded that the dose and the amount of applications nitrogen fertilizer is the most important factor affecting weight of seeds in pod and yield of rapeseed (Kazemeini et al., 2010). Nitrogen nutrition also influences the oil content in rapeseed. Generally, the higher dose of nitrogen and its content in seeds causes an accumulation of the protein in the seeds and at the same time decreases oil content. So, there is antagonistic relationship between protein content and oil content in seeds (Hassan et al., 2007).

In this experiment we focused on monitoring the effect of increasing doses of nitrogen on yield and oiliness of rapeseed.

2 Material and methods

The plot-scale nutritionist experiments were established on 02 September 2013 and on 22 August 2014 in Mojmírovce (48° 12′ 25″ S / 18° 03′ 50″ V). There was used block method of experimental plots with plot size of 600 m^2 tested in triplicate. Hybrid Artoga was seeded. Quantity of seeds was 0.45 million germinable seeds per 1 ha. The winter wheat (*Triticum aestivum* L.) was a previous crop in both experimental years. Mojmírovce belongs to the corn growing region at an altitude of 140 m. Climatic region is very warm, dry with mild winters. The average annual temperature during the growing season is 11.9 °C. Average annual rainfall is 436.7 mm. More detailed characteristics of climatic conditions is stated in the Table 1, 2.

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Table 1 The average monthly precipitation in experimental years 2013–2014 and 2014–2015 in Mojmírovce (the evaluation of month precipitation normality according to the long-term average of 1982–2013)

Month	Long-term average	2013		2014		2015	
		Percipi tation (mm)	Evaluation of normality	Percipitation (mm)	Evaluation of normality	Percipitation (mm)	Evaluation of normality
I.	32.9	67.3	very wet	38.2	normal	82.0	extraordinary wet
II.	29.2	70.1	very wet	39.5	normal	18.5	normal
III.	31.9	71.0	very wet	19.5	normal	31.5	normal
IV.	36.9	45.5	normal	51.5	wet	19.5	dry
V.	60.5	104.2	wet	84.7	wet	74.5	normal
VI.	59.0	21.5	very dry	34.6	dry	8.0	extraordinary dry
VII.	55.3	0.0	extraordinary dry	56.2	normal	19.0	very dry
VIII.	48.7	56.5	normal	116.1	extraordinary wet	74.4	wet
IX.	46.1	59.5	normal	107.2	very wet	63.5	normal
X.	35.9	31.4	normal	38.0	normal	–	–
XI.	45.4	89.5	very wet	21.5	dry	–	–
XII.	42.3	8.5	very dry	67.5	wet	–	–

Table 2 The average monthly temperatures in experimental years 2013–2014 and 2014–2015 in Mojmírovce (the evaluation of month air temperature normality according to the long-term average of 1982–2013)

Month	Long-term average	2013		2014		2015	
		Temperature (°C)	Evaluation of normality	Temperature (°C)	Evaluation of normality	Temperature (°C)	Evaluation of normality
I.	0.9	-0.7	normal	-0.5	normal	-0.6	normal
II.	0.5	2.3	normal	2.5	normal	-0.6	cold
III.	5.0	3.6	normal	3.6	normal	2.5	cold
IV.	10.9	11.7	normal	7.6	very cold	4.2	extraordinary cold
V.	15.9	17.2	normal	11.2	extraordinary cold	10.2	extraordinary cold
VI.	18.7	20.7	warm	14.2	extraordinary cold	14.9	extraordinary cold
VII.	20.9	23.6	extraordinary warm	17.2	extraordinary cold	17.4	extraordinary cold
VIII.	20.5	23.9	extraordinary warm	16.2	extraordinary cold	18.2	cold
IX.	15.6	17.5	warm	12.8	very cold	13.1	cold
X.	10.3	13.7	extraordinary warm	9.3	normal	–	–
XI.	4.8	7.0	very warm	5.5	normal	–	–
XII.	0.3	3.4	very warm	0.6	normal	–	–

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Table 3 Agrochemical characteristics of the soil to a depth of 0.3 m before setting the experiment with oilseed rape in experimental years 2013–2014 and 2014–2015 in Mojmírovce

Type of soil analysis	Content of available nutrients (mg kg^{-1})	
	2013–2014	2014–2015
N_{an}-N_{min} = mineral nitrogen = N-NH_4^+ and N-NO_3^-	11.4	7.0
N-NH_4^+ (colorimetry, Nessler reagent)	4.8	3.8
N-NO_3^- (colorimetry, phenol acid 2.4-disulphonic	6.6	3.2
P-available (Mehlich III-colorimetry)	17.5	27.5
K-available (Mehlich III-flame photometry)	165.0	232.5
Mg-available (Mehlich III-AAS)	393.0	352.6
Ca-available (Mehlich III-flame photometry)	5450.0	2170.0
S (ammonium acetate solution)	2.5	1.3
pH/KCl-exchangable reaction (0.2 mol dm^{-3} KCl)	6.6	6.8

Table 4 Treatments of oilseed rape nutrition (hybrid Artoga) in experimental years 2013–2014 and 2014–2015 in Mojmírovce

Treatment	Fertilization level			The total dose of N (kg ha^{-1})
	BBCH 20	BBCH 30	BBCH 51	
	N (kg ha^{-1})	N (kg ha^{-1})	N (kg ha^{-1})	
1	0	0	0	0
2	60	30	30	120
3	80	50	30	160
4	100	70	30	200
5	120	90	30	240

The Luvic Chernozem on loess is predominant soil type (Societas pedologica slovaca, 2014). The results of agrochemical soil analysis are stated in the Table 3.

In a plot-scale experiment was studied the effect of nitrogen doses on yield and oil content in oilseed rape seeds. The experiment consisted of five treatments of fertilization. The first treatment was unfertilized control. Four other treatments were fertilized by increasing doses of nitrogen 120 kg ha^{-1}, 160 kg ha^{-1}, 200 kg ha^{-1} and 240 kg ha^{-1}. Treatments 2 and 3 were fertilized by nitrogen in the form of limestone ammonium nitrate (LAN, 27% N) in the growth stage BBCH 20. Treatments 4 and 5 were fertilized by nitrogen in the form of dolomite-ammonium nitrate (DAN, 27% N) in the growth stage BBCH 20. Nitrogen in the form of urea ammonium nitrate (UAN, 39% N) was applied at treatments 2, 3, 4 and 5 in the growth stages BBCH 30 and BBCH 51. Doses of nitrogen are stated in the Table 4.

Soil analyses were performed by routine analytical methods. The effect of different nitrogen nutrition on yield and oil content in seed was monitored after the harvesting. It was realized on 25 June 2014 and on 7 July 2015 by harvester Claas Lexion 770.

The oil content was performed according to the standard STN 4610111-28. The determination was realized by the extraction for assistance to petroleum ether (50/70). The apparatus DET-GRAS N (P Selecta) was used for this determination. A superfluous extractant was distilled after the extraction. The obtained oil was drained and weighed. Oil content was calculated according the following equation:

$$W = (m_1/m_2) \times 100$$

where:
m_1 – amount of extracted oil (g)
m_2 – mass of the test sample (g)

Achievable yields and oil content were evaluated statistically by analysis of variance. Differences among treatments were analysed by LSD test and the significance of correlation was assessed using the correlation coefficient in the program Statgraphics Plus 5.1.

3 Results and discussion

A lot of researches focuse on the optimization of nitrogen nutrition of oilseed rape, at present. Many studies concluded that yield increased with the increase of nitrogen fertilizer rate (Buttar et al., 2006). It is in accordance with Sielig et al. (2006) who stated that the application of nitrogen in the total dose of 240 kg ha^{-1} significantly increased seed yield of oilseed rape. Barłóg and Grzebisz (2004) used dose of nitrogen 160 kg ha^{-1}. The yield of rapeseed ranged from 3.13 t ha^{-1} to 3.81 t ha^{-1}. Compared to the control treatment it was the increase by 38.55–87.13%. Rathke and Schuster (2001) recommended the dose of nitrogen 150 kg ha^{-1}. Narits (2010) reported the highest reached yield at treatment, where the lowest dose of nitrogen (120 kg ha^{-1}) was applied. Other experiment of Rathke and Schuster (2001) showed the highest increase of yield at treatments, where the doses of nitrogen ranged from 80 kg ha^{-1} to 160 kg ha^{-1} and negligible increase of yield was found at treatments fertilized by doses of nitrogen from 160 kg ha^{-1} to 240 kg ha^{-1}. On the contrary, the highest average yield 4.33 t ha^{-1} was found at treatment fertilized by the second highest dose of nitrogen 200 kg ha^{-1} in experiment realized in Mojmírovce in experimental years 2013–2014 and 2014–2015 (Table 5). It means an increase by 81.93% compared to unfertilized control treatment. But there is not any statistically significant difference among treatments 2, 3 and 4. Among treatments fertilized by nitrogen, the lowest average yield 3.69 t ha^{-1} was observed at treatment 5, where the highest dose of nitrogen 240 kg ha^{-1} was applied. Overall, there was statistically high significant difference between experimental years (Table 6). Average yield in experimental year 2014–2015 decreased by 39.4% in comparison to experimental year 2013–2014. High significant positive correlation between dose of nitrogen and yield was found in this experiment (Table 7).

The most important factor of oilseed rape quality is the oil content. Walton et al. (1999) declared, that high temperatures during the ripening (BBCH 80–BBCH 89) reduce oil content while protein content increase. Balík et al. (1998) confirmed it and added that water stress increases the nitrogen content and reduces oiliness. The fact that nitrogen is the main component of protein is the possible cause of increasing oil content in rapeseed. Protein level increases and oil percentage decreases, because oil is in inverse relationship with protein level (Öztürk, 2010). On the contrary, the results of other experiments indicated that dose of nitrogen did not effect on decreasing oil

Table 5 Effect of nitrogen fertilization on yield (12% moisture) of oilseed rape (hybrid Artoga) in experimental years 2013–2014 and 2014–2015 in Mojmírovce

Treatment	Yield in t ha^{-1}			
	2013–2014	2014–2015	Average 2013–2014 and 2014–2015	Relatively in %
1	3.41	1.35	2.38 aA	100.00
2	4.83	3.21	4.02 cBC	168.91
3	4.81	3.49	4.15 cC	174.37
4	5.43	3.22	4.33 cC	181.93
5	4.62	2.75	3.69 bB	155.04
$LSD_{0.05}$ treatment	–	–	0.31	–
$LSD_{0.01}$ treatment	–	–	0.43	–

Averages indicated by different letters are statistically significantly different on the significance level of $\alpha = 0.05$ (small letters) and $\alpha = 0.01$ (capital letters)

Table 6 Statistical evaluation of yield (12% moisture) of oilseed rape (hybrid Artoga) in experimental years 2013–2014 and 2014–2015 in Mojmírovce (average of treatments)

Year	Yield in t ha^{-1}	LSD $test_{0.05}$	LSD $test_{0.01}$
2013–2014	4.62 bB	0.19	0.27
2014–2015	2.81 aA		

Averages indicated by different letters are statistically significantly different on the significance level of $\alpha = 0.05$ (small letters) and $\alpha = 0.01$ (capital letters)

Table 7 The relationships between dose of nitrogen and yield expressed as a correlation coefficient

Parameter		Average of experimental years 2013–2014 and 2014–2015
Dependent	Independent	r
Yield	Dose of nitrogen	0.77 **

*P <0.05, **P <0.01

Table 8 Effect of nitrogen fertilization on oil content in seed of oilseed rape (hybrid Artoga) in experimental years 2013–2014 and 2014–2015 in Mojmírovce

Treatment	Oil content in %			
	2013–2014	2014–2015	Average 2013–2014 and 2014–2015	Relatively (%)
1	47.41	43.32	45.36 bB	100.00
2	47.36	43.51	45.43 bB	100.15
3	45.91	43.00	44.45 aA	97.99
4	45.96	43.28	44.62 aAB	98.36
5	46.77	42.60	44.68 aAB	98.50
$LSD_{0.05}$ treatment	–	–	0.63	–
$LSD_{0.01}$ treatment	–	–	0.87	–

Averages indicated by different letters are statistically significantly different on the significance level of $\alpha = 0.05$ (small letters) and $\alpha = 0.01$ (capital letters)

Table 9 Statistical evaluation of oil content in oilseed rape (hybrid Artoga) during experimental years 2013–2014 and 2014–2015 in Mojmírovce (average of treatments)

Year	Oil content (%)	$LSD\ test_{0.05}$	$LSD\ test_{0.01}$
2013–2014	46.68 bB	0.39	0.55
2014–2015	43.14 aA		

Averages indicated by different letters are statistically significantly different on the significance level of $\alpha = 0.05$ (small letters) and $\alpha = 0.01$ (capital letters)

Table 10 The relationships between dose of nitrogen and oil content expressed as a correlation coefficient

Parameter		Average of experimental years 2013–2014 and 2014–2015
Dependent	Independent	r
Oil content	Dose of nitrogen	-0.73 *

*P <0.05, **P <0.01

content (Dreccer et al., 2000; Mirzashahi et al., 2010). Narits (2010) found the highest oil content at treatment fertilized by total dose of nitrogen 120 kg ha^{-1}. Rathke et al. (2006) found the highest oil content at unfertilized control treatment and the lowest at treatment fertilized by the highest dose of nitrogen. Also Varga et al. (2011) in his experiment found that oil content in rapeseed decreased with increasing dose of nitrogen. Different results were found in experiment held in Mojmírovce in experimental years 2013–2014 and 2014–2015 (Table 8). The highest average oil content 45.43% was not recorded at unfertilized control treatment, but at treatment fertilized by the lowest dose of nitrogen 120 kg ha^{-1}. Oil content fluctuated from 44.45% to 44.68% at treatments fertilized by dose of nitrogen 160 kg ha^{-1}, 200 kg ha^{-1} and 240 kg ha^{-1}. There was not any statistically significant difference among these treatments. There is statistically high significant difference in oil content among treatments, but there was found statistically high significant difference between both experimental years (Table 9). The average oil content was by 7.58% lower in experimental year 2014–2015 compared to experimental year 2013–2014.

Prevailing opinion is that there is a negative correlation between dose of nitrogen and oil content in seeds of oilseed rape. It is confirmed by results of several experiments (Ahmad et al., 2007; Karaaslan, 2008; Rathke et al., 2005). There was also found statistically significant negative correlation between these parameters, in experiment in Mojmírovce (Table 10). It is out of line with Dreccer et al. (2000) that did not record any significant negative correlation between dose of nitrogen and oil content.

4 Conclusions

Effect of nitrogen nutrition on yield and oiliness of rapeseed was monitored in experiment based in experimental years 2013–2014 and 2014–2015 in terms of agricultural cooperative in Mojmírovce. The strong effect of unequal climatic conditions on yield and oil content was confirmed in this experiment. Regarding the yield, the most effective was treatment with dose of nitrogen 200 kg ha^{-1} where was found the highest average yield 4.33 t ha^{-1}. Considering the yield, there was not any significant difference among doses of nitrogen 120 kg ha^{-1}, 160 kg ha^{-1} and 240 kg ha^{-1}. The lowest average yield 2.38 t ha^{-1} was observed at unfertilized control treatment. This experiment confirmed high significant positive correlation between yield and dose of nitrogen.

The oiliness of seeds were 45.43%, 44.45%, 44.62% and 44.68% at treatments, where the doses of nitrogen were 120 kg ha^{-1}, 160 kg ha^{-1}, 200 kg ha^{-1} and 240 kg ha^{-1}. There was non-significant difference between treatment 2, with the highest average oil content in seeds and unfertilized control treatment. A negative correlation between dose of nitrogen and oiliness of seeds was proved.

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