Evaluation of effect of autumn nitrogen dose and nitrogen nutrition status on oilseed rape yield

Hodnotenie vplyvu jesennej dávky dusíka a úrovne dusíkatej výživy na úrodu semena kapusty repkovej pravej

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Abstract

The aim of the experiment was to investigate the effect of nitrogen on oilseed rape (*Brassica napus* L.) yield as well as evaluate the level of nitrogen nutrition based on the value N.N.I. (nitrogen nutrition index). 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 three 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 the same dose of nitrogen 240 kg^*ha^{-1}. Treatment 3 was fertilized three times during spring and treatment 2 was fertilized except 3 spring doses also in autumn. Results showed that yield of rapeseed was greatly influenced by weather conditions. Both experimental years were not equable in precipitation and temperatures. The highest average yield (at 12% moisture) 3.69 t^*ha^{-1} was reached at treatment 3, where any autumn dose of nitrogen was not applied. It means an increase by 55.04% and 24.66% compared to unfertilized control treatment and treatment 2. Autumn dose of nitrogen did not influence significantly yield of seeds. Values of N.N.I. ranged from 0.71% to 1.25% and there were not observed any significant differences among treatments as well as between experimental years.

Keywords: oilseed rape, yield of seed, level of nitrogen nutrition, autumn dose of nitrogen

Abstrakt

Cieľom pokusu bolo skúmať vplyv dusíka na úrodu semena kapusty repkovej pravej (*Brassica napus* L.), rovnako ako vyhodnotiť úroveň dusíkatej výživy na základe stanovenia hodnoty N.N.I. Poľný, poloprevádzkový pokus bol založený v rokoch 2013/2014 a 2014/2015 v podmienkach PD Mojmírovce. Vysiaty bol hybrid Artoga.

Boli zostavené tri varianty hnojenia, pričom bola použitá bloková metóda s veľkosťou pokusnej parcely 600 m^2 v troch opakovaniach. Prvý variant bol kontrolný, nehnojený. Ďalšie varianty boli hnojené rovnakou dávkou dusíka 240 kg^*ha^{-1}, pričom variant 3 bol hnojený trikrát počas jari a variant 2 bol hnojený, okrem troch jarných dávok, aj jesennou dávkou dusíka. Výsledky pokusu potvrdili silný vplyv poveternostných podmienok na výšku úrody. Oba roky boli teplotne i zrážkovo nevyrovnané. Najvyššia priemerná úroda (pri 12%-nej vlhkosti) 3,69 t^*ha^{-1} bola dosiahnutá na variante 3, kde nebola aplikovaná jesenná dávka dusíka. V percentuálnom vyjadrení to znamená nárast o 55,04% a 24,66% v porovnaní s kontrolným, nehnojeným variantom 1 a variantom 2. Nebol zistený preukazný vplyv jesennej dávky dusíka na výšku úrody. Hodnoty N.N.I. sa pohybovali v rozpätí od 0,71% do 1,25% a preukazný vplyv medzi variantmi a ani rokmi nebol zistený.

Kľúčové slová: kapusta repková pravá, úroda semena, úroveň dusíkatej výživy, jesenná dávka dusíka

Introduction

Nitrogen is one of the major elements in nutrition of oil crops (Lošák and Richter, 2004; Lošák et al., 2010), especially oilseed rape (Rathke et al., 2005). Nitrogen is an essential component of nucleic acids, proteins, nucleotides, chromosomes, genes, ribosome and other enzymes. The availability of nitrogen for plants can influences plant growth and developmental aspects such as seed germination, development of leaves, flowers and fruit development (Stitt et al., 2002; Walch-Liu et al., 2000). Therefore nitrogen nutrition is one of the basic conditions for achieve high yields (Orlovius and Kirkby, 2003). There is a lot of opinions on level and count of nitrogen doses.

Monitoring of crop nutrition level is really important. At present, status of nitrogen nutrition is evaluated according to nitrogen nutrition index (N.N.I.).

It can be used as a tool for nitrogen diagnosis of winter oilseed rape from emergence to the beginning of flowering (Colnenne et al., 1998).

Materials and methods

The plot-scale experiments were established on 02 September 2013 and on 22 August 2014 in Mojmírovce (48°11´283.6″N, 17°59´32,1″W a 48°12´22″N, 18°02´19.2″W). There was used block method of experimental plots with plot size of 600 m^2 tested in 3 repetitions. 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 a. s. l. 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 weather conditions is stated in the Table 1, 2. Can be concluded, that experimental year 2014/2015 was colder and drier than year 2013/2014.

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)

Tabuľka 1. Priemerné množstvo zrážok v pokusných rokoch 2013/2014 a 2014/2015 (hodnotenie normality množstva mesačných zrážok v porovnaní s dlhodobým priemerom 1982–2013) v Mojmírovciach

Month	Long-term average	2013		2014		2015	
		Precipitation (mm)	Evaluation of normality	Precipitation (mm)	Evaluation of normality	Precipitation (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)

Tabuľka 2. Priemerné mesačné teploty v pokusných rokoch 2013/2014 a 2014/2015 (hodnotenie normality množstva mesačných zrážok v porovnaní s dlhodobým priemerom 1982–2013) v Mojmírovciach

Month	Long-term average	2013		2014		2015	
		Tempe-rature (°C)	Evaluation of normality	Tempe-rature (°C)	Evaluation of normality	Tempe-rature (°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	-	-

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.

Table 3. Agrochemical characteristics of the soil to a depth of 0.3 m on 26 August 2013 and 15 August 2014 before setting the experiment with oilseed rape in experimental years 2013/2014 and 2014/2015 in Mojmírovce

Tabuľka 3. Agrochemická charakteristika pôdy do hĺbky 0,3 m zo dňa 26. augusta 2013 a 15. augusta 2014 pred založením pokusu s kapustou repkovou pravou v pokusných rokoch 2013/2014 a 2014/2015 v Mojmírovciach

Type of soil analysis	Content of available nutrients in $mg^{*}kg^{-1}$	
	2013/2014	2014/2015
N_{an}-N_{min}=mineral nitrogen=$N\text{-}NH_4^+$ and $N\text{-}NO_3^-$	11.4	7.0
$N\text{-}NH_4^+$ (colorimetry, Nessler reagent)	4.8	3.8
$N\text{-}NO_3^-$ (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)	5,450.0	2,170.0
S (ammonium acetate solution)	2.5	1.3
pH/KCl-exchangable reaction (0.2 $mol^{*}dm^{-3}$ KCl)	6.6	6.8

In a plot-scale experiment was studied the effect three and four times divided dose of nitrogen on rapeseed yield and N.N.I. (nitrogen nutrition index) that express the level of nitrogen nutrition. The experiment consisted of three treatments of fertilization. The first treatment was unfertilized control. Treatments 2 and 3 were fertilized by dose of nitrogen 240 $kg^{*}ha^{-1}$ at growth stages BBCH 20 (rosette stage), 30 (beginning of stem elongation) and 51 (bud formation). Dolomite-ammonium nitrate (DAN, 27% N) was applied at both treatment in the growth stage BBCH 20. Nitrogen was used in the liquid form of urea ammonium nitrate (UAN, 39% N) used at other growth stages BBCH 30 and 51 at both treatments. Treatment 2 was fertilized by autumn (BBCH 15) dose of nitrogen in the form of urea (46% N). Doses of nitrogen are stated in the Table 4.

Table 4. Treatments of oilseed rape fertilization in experimental years 2013/2014 and 2014/2015 in Mojmírovce

Tabuľka 4. Varianty hnojenia kapusty repkovej pravej v pokusných rokoch 2013/2014 a 2014/2015 v Mojmírovciach

Treatment	Fertilization level				
	BBCH 15 N ($kg^{*}ha^{-1}$)	BBCH 20 N ($kg^{*}ha^{-1}$)	BBCH 30 N ($kg^{*}ha^{-1}$)	BBCH 51 N ($kg^{*}ha^{-1}$)	The total dose of N ($kg^{*}ha^{-1}$)
1	0	0	0	0	0
2	46	84	80	30	240
3	0	120	90	30	240

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

Plant samples were collected on:

- 14 March 2014 and 24 March 2015 after the second (the first spring) fertilization (I. sampling);
- 29 March 2014 and 02 April 2015 after the third (the second spring) fertilization (II. sampling);
- 21 May 2014 and 02 June 2015 after the last (the third spring) fertilization (III. sampling).

To characterize the N status of plants, the nitrogen nutrition index was used as follows:

$$N.N.I. = N_t / N_c$$

N_t = the total N concentration measured in the aboveground parts

N_c = the critical nitrogen concentration for the same shoot biomass (Lemaire et al., 1989)

For a N.N.I. equal to 1, the N nutrition is considered as optimum, with higher values indicating excess N, and lower values indicating deficiency.

Achievable yields and N.N.I. were evaluated statistically by analysis of variance. Differences among treatments were analysed by LSD test in the program Statgraphics Plus 5.1.

Results

Many studies show that the oilseed rape growth and seed yield are significantly affected by high nitrogen dose (Rathke and Schuster, 2001). The highest average yield of seed 3.69 $t^{*}ha^{-1}$ was reached at treatment 3, where any autumn dose of nitrogen was not applied, in Mojmírovce in experimental years 2013/2014 and 2014/2015. It means a non-significant increase by 30.67% compared to treatment 2, where autumn dose of nitrogen was used. Differences between both experimental years were greatly influenced by different weather conditions. Yield of seed in 2013/2014 was by 66.37% higher than yield in 2014/2015. Difference is highly significant.

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

Tabuľka 5. Vplyv výživy dusíkom na výšku úrody semena kapusty repkovej pravej (pri 12%-nej vlhkosti) v pokusných rokoch 2013/2014 a 2014/2015 v Mojmírovciach

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		3.24	2.67	2.96 abAB	124.37
3		4.62	2.75	3.69 bB	155.04
LSD treatment	0.05	-	-	0.76	-
LSD treatment	0.01	-	-	1.10	-

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

Rozdiely medzi variantmi sú štatisticky preukazné na hladine významnosti α = 0,05 (malé písmená) a α = 0,01 (veľké písmená)

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

Tabuľka 6. Štatistické vyhodnotenie úrody semena kapusty repkovej pravej (pri 12%-nej vlhkosti) v pokusných rokoch 2013/2014 a 2014/2015 v Mojmírovciach (priemer variantov)

Year	Yield in $t^{*}ha^{-1}$	LSD test $_{0.05}$	LSD test $_{0.01}$
2013/2014	3.76 bB	0.62	0.90
2014/2015	2.26 aA		

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

Rozdiely medzi variantmi sú štatisticky preukazné na hladine významnosti α = 0,05 (malé písmená) a α = 0,01 (veľké písmená)

Nitrogen nutrition indexes in both experimental years during samplings are stated in Tables 7, 8. On average, higher values of N.N.I. were reached in experimental year 2014/2015.

Table 7. Nitrogen nutrition indexes during plant sampling in experimental year 2013/2014 in Mojmírovce

Tabuľka 7. Indexy dusíkatej výživy v jednotlivých odberoch rastlín v pokusnom roku 2013/2014 v Mojmírovciach

Treatment	I. sampling N.N.I.	II. sampling N.N.I. %	III. sampling N.N.I.
1	1.85	1.24	0.75
2	2.69	1.38	1.05
3	1.91	1.54	1.10

Table 8. Nitrogen nutrition indexes during plant sampling in experimental year 2014/2015 in Mojmírovce

Table 8. Indexy dusíkatej výživy v jednotlivých odberoch rastlín v pokusnom roku 2014/2015 v Mojmírovciach

Treatment	I. sampling N.N.I.	II. sampling N.N.I.	III. sampling N.N.I.
		%	
1	0.90	0.87	0.67
2	1.09	1.83	1.05
3	1.32	2.00	1.39

Statistical evaluation N.N.I. is stated in Tables 9, 10.

Table 9. Nitrogen nutrition indexes calculated after application of total nitrogen dose (III. sampling) in experimental years 2013/2014 and 2014/2015 in Mojmírovce

Tabuľka 9. Indexy dusíkatej výživy vyjadrené po aplikácii celkovej dávky dusíka (III. odber) v pokusných rokoch 2013/2014 a 2014/2015 v Mojmírovciach

Treatment	N.N.I. in %			
	2013/2014	2014/2015	Average 2013/2014 and 2014/2015	Relatively in %
1	0.75	0.67	0.71 aA	100.00
2	1.05	1.05	1.05 aA	147.89
3	1.10	1.39	1.25 aA	176.06
LSD 0.05 treatment	-	-	0.59	-
LSD 0.01 treatment	-	-	1.37	-

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

Rozdiely medzi variantmi sú štatisticky preukazné na hladine významnosti α = 0,05 (malé písmená) a α = 0,01 (veľké písmená)

Table 10. Statistical evaluation of nitrogen nutrition indexes in experimental years 2013/2014 and 2014/2015 in Mojmírovce (average of treatments)

Tabuľka 10. Štatistické vyhodnotenie indexov dusíkatej výživy v pokusných rokoch 2013/2014 a 2014/2015 v Mojmírovciach (priemer variantov)

Year	N.N.I. in %	LSD test $_{0.05}$	LSD test $_{0.01}$
2013/2014	0.97 aA	0.48	1.12
2014/2015	1.04 aA		

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

Rozdiely medzi variantmi sú štatisticky preukazné na hladine významnosti α = 0,05 (malé písmená) a α = 0,01 (veľké písmená)

The value of N.N.I. less than 1 was found at unfertilized treatment 1 in both years. It indicates the deficiency of nitrogen. On average, the highest value of N.N.I. 1.25% was reached at treatment 3, where any autumn dose of nitrogen was not applied. Differences among treatments and years were not statistically significant.

Discussion

In general it has to be distinguished if the rapeseed crop is actually able to take up autumn dose of nitrogen before winter (Sieling and Kage, 2007). The differences in nitrogen consumption during the growing season shows also the importance of the divided nitrogen doses (Lošák, 2003). As Dejoux et al. (2003) states, if autumn dose of nitrogen, especially in early-sown oilseed rape leads to a better growth and improves nitrogen accumulation before winter, it is a moot question whether the seed yield increases as well. As stated Varga and Ducsay (2011), spring nitrogen doses are essential for quick start of growth and achieve high yield of rapeseed. It is confirmed by Malzer et al. (1989) which added, that high level of nitrogen during the autumn reduces the plant ability to winter due to higher frost-susceptible. As Ogilvy and Bastiman (1992) mentioned, although plots receiving nitrogen in the seedbed or at the two leaf stage appeared more vigorous before winter compared to unfertilized plants, neither the number of plants established, the survival over winter nor the seed yield appeared to be affected by this treatment. Some authors expect that all the time allowed enough growth in autumn to ensure sufficient re-growth in spring. On the other hand, in other experiments autumn nitrogen dose weakly influenced yield of seed. (Chalmers,1989; Chalmers and Darby, 1992). Nitrogen fertilization of oilseed rape in autumn seems to be necessary only if nitrogen really limits crop growth, e.g. on poor soils or in the case of minimum tillage if the seeds germinate within a straw layer. If there is an assumption that the rapeseed need nitrogen during autumn, nitrogen fertilizers should be applied to the crop itself, not before sowing (Sieling and Kage, 2007).

According to Boelcke et al. (1991), divided application ensured that high yield performance and optimum yield stability were achieved simultaneously. Spink (2009) pointed out that late nitrogen is required to maintain pod filling. On the contrary, Bilsborrow et al. (1993) recommended nitrogen dose 150 kg*ha^{-1}. Comparing similar dose of nitrogen, distributions with a larger amount at the earlier stages (beginning of growth) increased the seed yield more than high rates at later stages.

Opinions on the dose of nitrogen varied. On the base of results of other experiment, Sieling (1999) recommended total dose of nitrogen 200 kg*ha^{-1} while 40 kg*ha^{-1} of nitrogen should be applied in autumn. On the other hand, Zhao et al. (1993) suggested a maximum yield response to a nitrogen dose 200 kg*ha^{-1} without autumn application. Similarly, Sieling and Christen (2012) reached higher yield by application dose of nitrogen 240 kg*ha^{-1} without autumn dose than at treatment fertilized by the same dose of nitrogen, where part of the dose was applied in autumn. It is not in accordance to Rathe and Schuster (2001) that recorded the highest increase in yield by application doses of nitrogen from 80 kg*ha^{-1} to 160 kg*ha^{-1}. There was found really low increase in yield, at treatments, where doses of nitrogen ranged from 160 kg*ha^{-1} to 240 kg*ha^{-1}.

Colnenne et al. (2002) observed in their experiments severe nitrogen deficiencies in autumn, described in terms of the nitrogen nutrition index, together with a reduction in shoot biomass, tap root biomass, leaf area index and radiation-use efficiency compared with well supplied treatments. However, despite severe autumn nitrogen deficiencies, no difference in seed yield was apparent.

Fletcher and Chakwizira (2011) found a linear decline in N_c with increasing crop biomass fitted the data equally but it is not in accordance to other experiments (Greenwood et al., 1990; Justes et al., 1994; Colnenne et al., 1998). Values N.N.I. are necessary to establish a critical nitrogen dilution curve. This dilution curve could be used to manage nitrogen fertilizer requirements to ensure that yields are not constrained by nitrogen deficiency and that nitrogen is not applied in excess. However, after fall of leaves during cold periods an important phenomenon in *Cruciferae* the shoot nitrogen concentration becomes higher because of the loss of old tissues and nitrogen reutilization from older parts. In these conditions, the nitrogen diagnosis could be quite imprecise (Colnenne et al., 1998). Values N.N.I. are also useful for quantifying the risk of high N-NO_3^- in plants. When excess of nitrogen is applied, low-yielding brassica crops are at a greater risk of accumulating high NO_3^- contents than high-yielding crops (Fletcher and Chakwizira, 2011).

Conclusions

Effect of nitrogen nutrition on yield and also level of nitrogen nutrition expressed by N.N.I. 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 weather conditions on yield was confirmed in this experiment. The highest average yield 3.69 t*ha^{-1} was reached at treatment 3, where any autumn dose of nitrogen was not applied. Autumn dose of nitrogen did not influence significantly yield level.

Values of N.N.I. were non-significant lower in 2013/2014 by the same doses of nitrogen as in 2014/2015. N.N.I. values in the second year were on average under 1%. It does not mean that the doses of nitrogen were too high. Whereas plants in 2013/2014 were nearly 2 times higher than in 2014/2015, the dilution effect occurred.

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