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OILSEED RAPE (*BRASSICA NAPUS* L.) NUTRITION BY NITROGEN AND PHOSPHORUS AND ITS EFFECT ON YIELD OF SEED, OIL AND HIGHER FATTY ACIDS CONTENT

Mária Vicianová[1], Ladislav Ducsay[1], Pavel Ryant[2], Marek Provazník[1], Alexandra Zapletalová[1], Marek Slepčan[1]

[1] Department of Agrochemistry and Plant Nutrition, Slovak University of Agriculture in Nitra, Tr. A. Hlinku 2, 949 76 Nitra, Slovak Republic

[2] Department of Agrochemistry, Soil Science, Microbiology and Plant Nutrition, Faculty of AgriSciences, Mendel University in Brno, Zemědělská 1, 613 00 Brno, Czech Republic

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Abstract

The effect of phosphorus (P) and nitrogen (N) application on yield, oil and fatty acids content (especially oleic acid, linoleic acid and linolenic acid) in rapeseed was investigated in the field experiment. Also effect of weather conditions was evaluated. The polyfactorial trial was realized in experimental years 2013/2014 and 2014/2015 in terms of agricultural cooperative in Mojmírovce. The experiment was based on three variants of fertilization treatments by the block method in three replications. The size of each block was created by plots with size 600 m^2. The first level of treatment 1_0 was non-fertilized control. The second level of treatment 2_U was fertilized by nitrogen in dose 240 kg.ha^{-1}. The third level of treatment 3_P was fertilized by the same dose of nitrogen 240 kg.ha^{-1} and by phosphorus in dose 88 kg.ha^{-1}. The highest average yield 3.9 t.ha^{-1} was achieved at treatment 3_P, where phosphorus was applied. It means statistically significant yield increase by 30% compared to treatment 2_U, where no phosphorus was not applied. There was statistically non-significant difference in oil content, in the range of treatments. The content of oleic acid fluctuated from 63.3% to 65.9% and the highest was reached at unfertilized control treatments in both experimental years. The linoleic acid content ranged from 20.3% to 21.2% and content of linolenic acid varied between 6.9% and 8.9%. Application of nitrogen and nitrogen + phosphorus high statistically significant decreased oleic acid content in both experimental years. Opposite effect was observed, where content of linoleic and linolenic acid was high statistically significant increased after nitrogen and nitrogen-phosphorus fertilization. Effect of unequal weather conditions and treatments of nitrogen and nitrogen-phosphorus nutrition can influence the percentage ratio of higher fatty acids composition.

Keywords: phosphorus and nitrogen nutrition of oilseed rape, yield of rapeseed, oil and higher fatty acids content in rapeseed

INTRODUCTION

Oilseed rape began to become one of the most important oil crops within the last two decades. Yield and quality of rapeseed mostly depend on the genetic power of the growing varieties and the environmental conditions (Suzer, 2015). Nitrogen (N) is the decisive nutrient for oilseed rape affected vegetative and reproductive both during vegetative and reproductive growing phases. Amount of biomass production depends on nitrogen treatment, what is a determining factor for both dry matter creation and its subsequent partition among plant tissues (Barłóg and Grzebisz, 2004).

In oilseed rape growth, phosphorus (P) is one of basic plant nutrient. The ability of the crop react to the other nutrients is limited by phosphorus nutrition availability in the soil. The inadequate levels of phosphorus supply cause impairment of genetic processes such as cell division and plant growth. Hence, the plants with phosphorus deficiency may mature slower than plants with adequate phosphorus amounts.

The stunted growth caused by deficiency of phosphorus was in correlation with smaller leaf area and decreasing amount of leaves (Zambrosi *et al.*, 2014). The lack of phosphorus in the soil is a global problem. More than 70% of the world's soil has very low phosphorus content and thus is restricted to plant growth. Long-term phosphorus pumping from soil reserves is caused by an imbalance in phosphorus inputs and outputs, when increased inputs mainly due to the cultivation of more efficient varieties and unilateral increase of production by nitrogen fertilization (Kulhánek *et al.*, 2017).

Oilseed rape is a specific type of oilseed plant associated with high quality oil. Rapeseed oil is a distinguished edible oil which is also determined by a relatively high proportion of unsaturated fatty acids such as linoleic acid (C18:2), α-linolenic acid (C18:3) and oleic acid (C18:1) that are classified as essential unsaturated fatty acids (EFAs) (Narits, 2010). The average content of these main fatty acids (FA) in oil of currently grown cultivars of oilseed rape is for oleic acid 59%–68%, linoleic acid 17%–21% and linolenic acid 7.8%–10% (Scarth and McVetty, 1999). Rapeseed oil has very low content of saturated fatty acids than other oil plants and a relatively high content of basic fatty acids and at optimal 2: 1 ratios (Zatonski *et al.*, 2008). It has less than 2% erucic acid and its meal has less than 30 µg of glucosinolates (El-Nakhlawy and Bakhashwain, 2009). Moreover it contains 40%–45% oil and 39% protein (Molazem *et al.*, 2013). Oil quality may be improved by developing cultivars with a reduced content of polyunsaturated FA and an increased content of oleic acid (Scarth and McVetty, 1999). The reduction of linolenic acid to 2%–3% in rapeseed and the increase of oleic and linoleic acid to 80% and 35%, respectively, has been an important breeding objective (Carré *et al.*, 2003).

The aim of the present study was to monitor the effect of increasing doses of phosphorus on yield, oil and higher fatty acids content in rapeseed.

MATERIALS AND METHODS

The polyfactorial experiments were realized on 02 September 2013 and on 22 August 2014 in Mojmírovce (48°11´283.6″N, 17°59´32.1″W). Hybrid Artoga was used in both experimental years. The trials were established by split plot design with randomized blocks in three replications, where plot size was 600 m^2. As the previous crop was used the winter wheat (*Triticum aestivum* L.) in yaer 2013 and also 2014. Experimental field in Mojmírovce belongs to the corn production area with altitude of 140 m a.s.l. Climatic region is very warm, dry with mild winters. Climatic conditions of experimental area are defined by the average annual temperature 11.9 °C and average annual precipitations 436.7 mm. More precise indications of weather conditions are stated in Tab. I and II. Observed years 2013/2014 and 2014/2015 in experimental field were not equal in precipitation and temperatures. It was evaluated according to Kožnárová and Klabzuba (2002). There was the average temperature for months II.–VI. higher than long-term average, in experimental year 2013/2014. Compared to the long-term average, there was fall of average temperature by 3.1 °C in months III.–V. Total precipitation for months II.–VI. was by 12.0 mm higher than long-term average. The average temperature for months II.–VI. fall by 2.1 °C compared to long-term average in experimental year 2014/2015. It means a decrease by 49.1% in relative percentage for months III.–V. Total precipitation for months II.–VI. was by 65.5 mm lower than the long-term average. It represents a decrease by 43.1%.

Predominant soil type is created by the Luvic Chernozem on loess (Societas pedologica slovaca, 2014). The results of agrochemical soil analysis (26 August 2013 and 15 August 2014) are stated in Tab. III. The table shows that phosphorus content in soil was low in both experimental years.

In a split plot trial was observed the influence of phosphorus addition to nitrogen nutrition on yield, oil and higher fatty acids content in rapeseed. The experiment was based on three variations of fertilizer treatments. The first treatment was control without fertilization. Treatments 2_U and 3_P were fertilized by the same total dose of nitrogen 240 kg.ha^{-1}. Treatment 2_U was fertilized by Urea (46% N) and treatment 3_P by Amofos (12% N, 23% P) at growth stage BBCH 15 (5–6 leaves unfolded). There was applied CAN (27% N) at growth stage BBCH 20 (rosette stage) and UAN (39% N) at growth stages BBCH 30 (beginning of stem elongation) and BBCH 51 (bud formation), at both treatments. Doses of nitrogen and phosphorus are stated in Tab. IV.

I: *The sum monthly precipitation in experimental years 2013/2014 and 2014/2015 in Mojmírovce*

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	-	-

(the evaluation of month precipitation normality according to the long-term average of 1982–2013)

II: *The average monthly temperatures in experimental years 2013/2014 and 2014/2015 in Mojmírovce*

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	-	-

(the evaluation of month air temperature normality according to the long–term average of 1982–2013)

The influence of phosphorus supply on production and quality of rapeseed was analysed after the harvest on 25 June 2014 and on 7 July 2015 by harvester Claas Lexion 770. The quality of achieved rapeseed was performed according to the slovak standard STN 4610111-28. The oiliness was determined by the extraction method with using petroleum ether (50/70). For extraction was used the apparatus DET-GRAS N (JP Selecta S.A., Spain). A superfluous extractant was distilled after the extraction. The achieved oil was drained and weighed. Fatty acids were determined by gas chromatography.

III: *Agrochemical characteristics of soil before trial establishment*

Type of soil analysis	Content of available nutrients in $mg.kg^{-1}$	
	2013/2014	2014/2015
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)	18	28
K-available (Mehlich III–flame photometry)	165	233
Mg-available (Mehlich III–AAS)	393	353
Ca-available (Mehlich III–flame photometry)	5,450	2,170
S-available (ammonium acetate solution)	2.5	1.3
pH/KCl-exchangable reaction	6.6	6.8

IV: *Treatments of oilseed rape nutrition in experimental years 2013/2014 and 2014/2015 in Mojmírovce*

Treatment	Fertilization level in $kg.ha^{-1}$								The total dose in $kg.ha^{-1}$	
	BBCH 15		BBCH 20		BBCH 30		BBCH 51			
	N	P	N	P	N	P	N	P	N	P
1_0	0	0	0	0	0	0	0	0	0	0
2_U	46	0	84	0	80	0	30	0	240	0
3_P	46	88	84	0	80	0	30	0	240	88

For statistically evaluation of achieved production and quality was used analysis of variance. By LSD test were tested differences between variants of treatment in program Statgraphics Plus 5.1 (Statgraphics Technologies, Inc., Virginia).

RESULTS AND DISCUSSION

Macroelements nitrogen and phosphorus are considered very important in oilseed rape nutrition. There was observed effect of nitrogen and phosphorus nutrition on yield, oil and higher fatty acids content in rapeseeds, in two years experiment. The highest average yield ($3.9\ t.ha^{-1}$) was reached at treatment 3_P, where nitrogen and phosphorus was applied (Tab. V). There was found statistically significant difference between treatment 3_P and control treatment, as well as between treatment 3_P and treatment 2_U, where no phosphorus was applied, in this experiment. Similarly, Brennan and Bolland (2009) used doses of nitrogen, doses of phosphorus and combination of nitrogen and phosphorus. Significantly higher yield of seeds was found at treatment, where nitrogen was applied with phosphorus. Also Cheema *et al.* (2001) used fertilizer at $90\ kg.ha^{-1}$ N and $26\ kg.ha^{-1}$ P. It significantly increased seed yield in both experimental years. All in all, reached yield at treatment 3_P was by 44.1% and 53.1% higher compared to treatment 1_0 and 2_U in experimental year 2013/2014,

V: *Effect of nitrogen and phosphorus nutrition on yield of oilseed rape*

Treatment	Yield in $t.ha^{-1}$				
	2013/2014	2014/2015	Average 2013/2014 and 2014/2015	Relatively in %	P-value
1_0	3.4	1.4	2.4 aA	100.0	0.0070*
2_U	3.2	2.8	3.0 aAB	125.0	
3_P	4.9	2.9	3.9 bA	162.5	
LSD treatment $_{0.05}$	-	-	0.8	-	
LSD treatment $_{0.01}$	-	-	1.2	-	

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

*P-value is statistically significant ($P < 0.05$)

VI: *Average yield of oilseed rape*

Year	Yield in $t.ha^{-1}$	LSD test $_{0.05}$	LSD test $_{0.01}$	P-value
2013/2014	3.9 bB	0.7	1.0	0.0006*
2014/2015	2.3 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)
*P-value *is* statistically significant (P < 0.05)

VII: *Effect of nitrogen and phosphorus nutrition on oil content in seed of oilseed*

Treatment	Oil content in %				
	2013/2014	2014/2015	Average 2013/2014 and 2014/2015	Relatively in %	P-value
1_0	47.4	43.6	45.5 aA	100.0	0.1202
2_U	46.0	43.5	44.7 aA	98.2	
3_P	45.8	43.4	44.6 aA	98.0	
LSD treatment $_{0.05}$	-	-	1.0	-	
LSD treatment $_{0.01}$	-	-	1.4	-	

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)
*P-value is statistically significant (P < 0.05)

VIII: *Statistical evaluation of oil content in oilseed rape during experimental years 2013/2014 and 2014/2015 in Mojmírovce (average of treatments)*

Year	Oil content in %	LSD test $_{0.05}$	LSD test $_{0.01}$	P-value
2013/2014	46.4 bB	0.8	1.2	0.0000*
2014/2015	43.5 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)
*P-value is statistically significant (P < 0.05)

Both experimental years were unequal in precipitation and temperatures. Yields were strongly affected by different weather conditions. The average yield in experimental year 2013/2014 was by 41.0% higher than average yield in year 2014/2015 (Tab. VI). The difference is statistically highly significant.

According to Süzer (2007) using high doses of nitrogen fertilizers can increase amount of seed protein rate and cause to decrease the oiliness. However for higher achieved yield from per hectare may the crop decrease the oiliness. Using high doses of nitrogen fertilizer during vegetation of oilseed rape can decrease the oil of the harvested crop. The average oil content fluctuated from 44.6% to 45.5% (Tab. VII). The highest average oil content was reached at treatment 1_0, where any nitrogen was not applied. But the difference among treatments is not statistically significant. Also Cheema *et al.* (2001) found the highest average oil content 43.0% at control treatment. Oil content decreased when doses of nutrients, especially nitrogen, increased. Similar results were recorded by Asare and Scarisbrick (1995) and Hocking *et al.* (1997). According to Forster (1977) and Süzer (2007, 2010) phosphorus supply in amount of commercial dosage have not any influence oiliness of rapeseed. Also Brennan and Bolland (2006) stated that application of phosphorus had no effect on concentration of oil and protein in seeds. For rapeseed production, responses to applied nitrogen always occur whereas responses to applied phosphorus are rare, but if soil phosphorus testing indicates likely phosphorus deficiency, both phosphorus and nitrogen fertilizer need to be applied. On the contrary, Motlagh *et al.* (2012), Said-Al Ahl *et al.* (2016) and Ahmed (2018) reported that phosphorus significantly increased oil content in rapeseed.

Unequal weather conditions were reflected in oil content (Tab. VIII). There was statistically highly significant higher average oil content by 6.7% in year 2013/2014 characterized by higher temperatures and higher rainfall than experimental year 2014/2015.

The amount of saturated (SFAs-without double bonds) and monounsaturated (MUFAs-with one double bond) and polyunsaturated fatty acids (PUFAs-with two or up to six double bonds) was significantly affected by the growth season, sowing date, vermicompost, genotype and interaction effect of sowing date, genotype and nutrition (Joughi *et al.*, 2018). Unbalanced nitrogen fertilization in oilseed rape growing season may change harvested seed fatty acid profile and glucosinolate contents (Süzer, 2010).

IX: *Content of fatty acids in rapeseed in experimental years 2013/2014 and 2014/2015 in Mojmírovce*

Fatty acid	Content of fatty acids in %							
	Experimental year 2013/2014				Experimental year 2014/2015			
	Treatment				Treatment			
	1_0	2_U	3_P	P-value	1_0	2_U	3_P	P-value
capric acid	0.0	0.0	0.0	-	0.0	0.0	0.0	-
lauric acid	0.0	0.0	0.0	-	0.0	0.0	0.0	-
myristic acid	0.0	0.0	0.0	-	0.0	0.0	0.0	-
palmitic acid	4.7 abA	4.7 aA	4.8 bA	0.0590	4.3 aA	4.5 bB	4.5 bB	0.0019*
palmitoleic acid	0.2 aA	0.2 aA	0.2 aA	0.3617	0.1 aA	0.1 aA	0.1 aA	1.0000
stearic acid	1.1 aA	1.1 aA	1.1 aA	0.8869	1.6 bB	1.5 aA	1.5 aAB	0.0113*
oleic acid	64.6 bB	63.4 aA	63.3 aA	0.0003*	65.9 bB	64.7 aA	64.7 aA	0.0091*
linoleic acid	20.3 aA	20.9 bB	21.0 bB	0.0002*	20.3 aA	21.2 cC	21.1 bB	0.0000*
linolenic acid	8.3 aA	8.9 cB	8.7 bB	0.0015*	6.9 aA	7.0 bB	7.0 bB	0.0082*
arachidic acid	0.9 aA	0.9 bA	1.0 cB	0.0020*	0.5 abA	0.5 aA	0.5 bA	0.0362*
arachidonic acid	0.0	0.0	0.0	-	0.0	0.0	0.0	-
behenic acid	0.0	0.0	0.0	-	0.0	0.0	0.0	-
erucic acid	0.0	0.0	0.0	-	0.4	0.4	0.4	-
lignoceric acid	0.0	0.0	0.0	-	0.1	0.2	0.4	-

Averages indicated by different letters are statistically significantly different on the significance level of $\alpha \leq 0.05$ (small letters) and $\alpha \leq 0.01$ (capital letters). There are differences in fatty acids content for each experimental year, in rows
*P-value is statistically significant ($P < 0.05$)

Effect of nitrogen and phosphorus nutrition on higher fatty acids in rapeseed was also observed in this experiment (Tab. IX). Oleic acid (MUFA) is the most represented in rapeseed. Its content fluctuated from 63.3% to 64.6% in year 2013/2014 and from 64.7% to 65.9% in year 2014/2015. Its content depends on dose of nitrogen. Mostly it is in negative correlation. Phosphorus application stabilized content of arachidic and palmitic (SFAs) acid. Content of these acids was lower at other treatments of nutrition. There were only little differences in content of other observed acids, among treatments. Škarpa and Lošák (2008) found no significant change of fatty acids content after nitrogen and phosphorus application. But nitrogen fertilization increased the concentration of oleic acid and decreased linoleic acid (essential PUFA) content. The concentration of observed fatty acids was not markedly effected by phosphorus application. As Zhang *et al.* (2015) stated, analysis of seven fatty acids revealed as light decrease in the contents of erucic acid (MUFA) and arachidonic acid (essential PUFA) with the increase in nitrogen application level, but no obvious change in the contents of palmitic acid, stearic acid, oleic acid, linoleic acid and linolenic acid.

CONCLUSION

Effect of phosphorus and nitrogen nutrition and its effect on yield of seed, oil and higher fatty acids in rapeseed was monitored in experiment based in experimental years 2013/2014 and 2014/2015 in terms of agricultural cooperative in Mojmírovce. The highest average yield 3.9 $t.ha^{-1}$ was reached at treatment 3_P, where phosphorus was applied. It means statistically significant yield increase by 30% compared to treatment 2_U, where any phosphorus was not applied. Oil content was not statistically significant affected by phosphorus nutrition. Nitrogen and nitrogen-phosphorus nutrition at treatments 3_P and 2_U high statistically decreased oleic acid content and increased content of linoleic and linolenic acid in both experimental years. Percentage ratio of higher fatty acids composition changed in dependence on nitrogen and phosphorus application, as well as on different weather conditions in both experimental years.

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REFERENCES

AHMED, R. M. 2018. Oil percent and unsaturated fatty acid respose of rapeseed cultivars to nitrogen and phosphorus fertilizers in two different sowing date. *Tikrit Journal for Agricultural Science,* 18(4): 29–38.

ASARE, E. and SCARISBRICK, D. H. 1995. Rate of nitrogen and sulfur fertilizers on yield, yield components and seed quality of oilseed rape (*Brassica napus). Field Crops Research*, 44(1): 41–46.

BARŁÓG, P. and GRZEBISZ, W. 2004. Effect of timing and nitrogen fertilizer application on winter oilseed rape (*Brassica napus* L.). I. Growth dynamics and seed yield. *Journal of Agronomy and Crop Science,* 190(5): 305–313.

BRENNAN, R. F. and BOLLAND, M. D. A. 2006. Effect of fertiliser phosphorus and nitrogen on the concentrations of oil and protein in grain and the grain yield of canola (*Brassica napus* L.) grown in south-western Australia. *Australian Journal of Experimental Agriculture*, 47(8): 984–991.

BRENNAN, R. F. and BOLLAND, M. D. A. 2009. Comparing the nitrogen and phosphorus requirements of canola and wheat for grain yield and quality. *Crop and Pasture Science*, 60(6): 566–577.

CARRÉ, P., DARTENUC, C., EVRARD, J., JUDDE, A., LABALETTE, F., RAOUX, E. and RENARD, M. 2003. Frying stability of rapeseed oils with modified fatty acid composition. In: *Proceedings of the 11th International Rapeseed Congress*. 6–10 July. Copenhagen: The Royal Veterinary and Agricultural University, pp. 540–543.

CHEEMA, M. A., MALIK, M. A., HUSSAIN, A., SHAH, S. H. and BASRA, M. A. 2001. Effects of time and rate of nitrogen and phosphorus application on the growth and the seed and oil yields of canola (*Brassica napus* L.). *Journal of Agronomy & Crop Science*, 186(2): 103–110.

EL-NAKHLAWY, S. and BAKHASHWAIN, A. 2009. Performance of canola (*Brassica napus* L.) seed yield, yield components and seed quality under the effects of four genotypes and nitrogen fertilizer rates. *Meteorology, Environment & Arid Land Agriculture Science* 20(2): 33–47.

HOCKING, P. J., RANDALL, P. J., DEMARCO, D. and BAMFORTH, I. 1997. Assesment of the nitrogen status of field grown canola (*Brassica napus* L.) by plant analysis. *Australian Journal of Experimental Agriculture*, 37(1): 83–92.

JOUGHI, E. S. G., HERVAN, E. M., RAD, A. H. S. and NOORMOHAMADI, G. H. 2018. Fatty acid composition of oilseed genotypes as affected by vermicompost application and different thermal regimems. *Agronomy Research*, 16(1): 230–242.

KOŽNÁROVÁ, V. and KLABZUBA, J. 2002. Recommendation of World Meteorological Organization to describing meteorological or climatological conditions [in Czech: Doporučení WMO pro popis meteorologických, resp. klimatologických podmínek definovaného období]. *Rostlinná výroba*, 48(4): 190–192.

KULHÁNEK, M., ČERNÝ, J., BALÍK, J., SEDLÁŘ, O. and SURAN, P. 2017. Soil phosphorus fractionation [in Czech: Frakcionace půdního fosforu]. In: *Proceendigs of 23nd International Conference on Reasonable Use of Fertilizers.* 30 November. Prague: Czech University of Life Sciences Prague, pp. 57–64.

MOLAZEM, D., AZIMI, J. and DIDEBAN, T. 2013. Measuring the yield and its components, in the Canola in different planting date and plant density of the west Guilan. *International Journal of Agriculture and Crop Sciences*, 6(12): 869–872.

MOTLAGH, S. M., PIRZAD, A. and DELKHOSH, B. 2012. Effect of irrigation disruption and biological phosphorus on the biomass and seed yield of canola (*Brassica napus* L.). *International Journal of Agriculture and Crop Sciences*, 4(1): 489–495.

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*). *Agronomy Research*, 8(3): 671–686.

SAID-AL AHL, H. A. H., MEHANNA, H. M. and RAMADAN, M. F. 2016. Impact of water regime and phosphorus fertilization and their interaction on the characteristics of rapeseed (*Brassica napus*) and fatty acid profile of extracted oil. *Communications in Biometry and Crop Science*, 11(1): 64–76.

SCARTH, R. and MCVETTY, P. 1999. Designer oil canola a review of new food-grade *Brassica* oils with focus on high oleic, low linoleic types. In: *Proceedings of the 10th International Rapeseed Congress*. Canberra.

SOCIETAS PEDOLOGICA SLOVACA. 2014. Morphogenetic soil classification system of Slovakia. Basal reference taxonomy [in Slovak: Morfogenetickcý klasifikačný systéme pôd Slovenska. Bazálna referenčná taxonómia]. Bratislava: NPPC-VÚPOP Bratislava.

SÜZER, S. 2007. Production and importance of canola in crop rotation in Turkey. In: *1st National Oil Seed Crops and Biodiesel Symposium in Turkey*. Samsun, 28–31 May, pp. 277–283.

SÜZER, S. 2010. Effects of potassium fertilization on sunflower (*Helianthus annuus* L.) and canola (*Brassica napus* ssp. *oleifera* L.) growth. In: *Proceedings of the regional workshop of the international potash institute in Turkey*. Antalya, 22–25 November.

SÜZER, S. 2015. Effects of plant nutrition on canola (*Brassica napus* L.) *Growth. Trakya University Journal of Natural Sciences*, 16(2): 87–90.

ŠKARPA, P. and LOŠÁK, T. 2008. Changes in selected production parameters and fatty acid composition of sunflower (*Helianthus annuus*, L.). *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis,* 56(5): 203–210.

ZAMBROSI, F. C. B., RIBEIRO, R. V., MARCHIORI, P. E. R., CANTARELLA, H. and LANDELL, M. G. A. 2014. Sugarcane performance under phosphorus deficiency: physiological responses and genotypic variation. *Plant and Soil*, 386(1): 273–283.

ZATONSKI, W., CAMPOS, H. and WILLETT, W. 2008. Rapid declines in coronary heart disease mortality in Eastern Europe are associated with increased consumption of oils rich in alphalinolenic acid. *European Journal of Epidemiology*, 23(1): 3–10.

ZHANG, Z., SONG, H., LIU, Q., RONG, X., PENG, J., XIE, G., ZHANG, Y., CHEN, L., GUAN, C. and GU, J. 2015. Responses of seed yield and quality to nitrogen application levels in two oilseed rape (*Brassica napus* L.) varieties differing in nitrogen efficiency. *Plant Production Science,* 15(4): 265–269.

Contact information

Ladislav Ducsay: ladislav.ducsay@uniag.sk