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Effect of nitrogen rate and application time to yield and quality of winter oilseed rape (*Brassica napus L. var. oleifera subvar. biennis*)

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Abstract. Oilseed rape is one of the most important sources of vegetable oil in the world. Nitrogen is one of important components of oilseed rape and has strong effect on seed yield and quality. The objective of the study was to evaluate the influence of nitrogen rate and application time to yield and quality of winter oilseed rape. Field trials were carried out at the Jõgeva Plant Breeding Institute in 2007/2008 and 2008/2009. Ammonium nitrate (nitrogen content 34.4%) was used as top-fertilizer. Three different nitrogen rates: 120, 140 and 160 kg ha^{-1} (in active ingredient) and three different application timings were used: A) once at the beginning of spring vegetation, B) A + when the main stem was 10 cm, C) B + start of flowering in equal portions. By the results can be concluded that the amount of fertilizer had not as strong impact to seed yield and quality as fertilizer application time. The highest yields of seed and raw oil were obtained from the variant of split-N treatment (40+40+40) of 120 kg ha^{-1}.

Key words: winter oilseed rape, nitrogen fertilizer, yield, quality

INTRODUCTION

Oilseed rape is one of the most important sources of vegetable oil in the world. Rapeseed cultivation area has continuously enlarged in the world (Table 1).

Table 1. Total cultivation area of rapeseed in the world and average seed yield in the world and in EU in 2006–2008 (FAOSTAT).

Indicator	2006	2007	2008
Rapeseed cultivation area in world, million ha	27.4	29.7	30.3
Average seed yield of rapeseed in world, t ha^{-1}	1.75	1.73	1.91
Average seed yield of rapeseed in EU, t ha^{-1}	2.98	2.82	3.09

The nutrient demand of oilseed rape is considerably higher than that of cereals. Compared to cereals, winter oilseed rape requires more available nitrogen (Rathke et al., 2005; Hocking et al., 1997). High yields can be realized only if the special characteristics of this crop are considered. Although oilseed rape develops an impressive root mass, ability to take up nutrients is not always high (Orlovius, 2003).

Nitrogen is an integral component of amino nucleic acids, proteins, nucleotides, chlorophyll, chromosomes, genes, ribosomes and is also a constituent of all enzymes.

This wide range of different nitrogen containing plant compounds explains the important role of nitrogen for plant growth. The nitrogen supply of oilseed rape is of central importance to ensure high yields. As all *Brassica*-species, oilseed rape has high nitrogen demand (about 200–300 kg ha^{-1} of N) depending on the type of subspecies and yield (Orlovius, 2003). Available nitrogen and proper sowing data are the most important factors affecting seed yield of oilseed rape (Almond et al, 1986). Rollier's (1970) report on maximum uptake of nitrogen being at the rosette stage in winter oilseed rape is supported by Holmes (1980), although Anderson et al. (1958) found maximum nitrogen uptake in winter oilseed rape to be at 220 kg ha^{-1}. Optimal spring top-nitrogen rate ranged from 120 to 240 kg ha^{-1} of N (Bilsborrow et al., 1993; Sieling et al., 1998; Sieling et al., 1999).

The first nitrogen application was made at the beginning of growth, the second at the beginning of shooting and the third at the late bud stage (Sauermann, 2000). Choosing the correct rate and timing of nitrogen fertilizer application is one of the most important aspects of successful oilseed rape production (Holmes, 1980). Therefore, good nitrogen fertility is necessary to produce large, photosynthetically efficient leaf area that will support high number of flowers, pods and finally seed yield.

The objective of the present study was to evaluate the effect of nitrogen rate and different application times to yield and quality of oilseed rape.

MATERIALS AND METHODS

The trials were carried out at the Jõgeva Plant Breeding Institute (PBI) (N 58°76'; E 26°40') in 2007/2008 and 2008/2009. The soil was soddy-calcarous podzolic, soil texture was sandy-clay. Chemical composition of the soil (analyses made by the Estonian Agricultural Research Centre) is accounted in the Table 2.

Table 2. Chemical composition of the soil of the trial area in 2007 and 2008.

Year	P	K	Ca mg kg^{-1}	Mg	Cu	pH	Organic matter, %
2007	104	143	1,670	110	4.5	6.1	2.5
2008	244	195	1,710	85	1.2	6.3	2.2

Fore-crop of both years was black fallow. Before sowing the trial area was fertilized by Kemira Power 5–10–25, 300 kg ha^{-1} (N–15; P–13.2; K–62.3; S–21; Fe–6; B–0.06 kg ha^{-1}). In both years sowing was carried out in August 15th. The trial was established on 10 m^2 plots using NNA (nearest neighbour adjustment) randomised design in three replications. The sowing rate was 100 germinated seeds per m^2. The conventional winter oilseed rape variety Silvia was used for testing. The winter hardiness of the both trial years was 9 points – very good (1 point – destroyed, 9 points – very good). No chemical plant protection was used during the growing period.

Ammonium nitrate (nitrogen content 34.4%) was used as top-fertilizer. Three different nitrogen rates: 120, 140 and 160 kg N ha^{-1} and three different application times were used: A) once at the beginnings of spring vegetation (oilseed rape growing code 26), B) A + when the main stem was 10 cm (code 33), C) B + start of flowering (code 60) (the total of nine different variants) in equal portions. Timing of nitrogen application was based on the growth stages described by Paul (1988).

The trials were harvested on August 7th (2008) and August 11th (2009). Seeds were dried to the moisture content of 7.5%, and cleaned. The seed yield of each replication was determined. Raw fat, raw protein and glycosinolates content in seeds were analysed by NIR at the laboratory of the Jõgeva PBI. Raw fat yield per hectare was calculated by mathematical formula:

$$\frac{\text{Seed yield} \times \text{raw fat content}}{100}$$

Seed yield and raw fat content were calculated by seed moisture content of 7.5%. The Least Significant Difference (LSD) procedure was used when the F-test was significant ($P > 0.05$) and correlation analyse was carried out ($r < 0.05$). The program Statistica 4.5 processed the results of the tests.

RESULTS AND DISCUSSION

The average seed yield was 4,463 kg ha^{-1} in 2008 and 5,179 kg ha^{-1} in 2009. Many studies concluded that yield increased with the increase of N fertilizer rate (Pellet, 2002; Sidlauskas & Bernotas, 2003; Söchtling & Verret, 2004; Rathke et al., 2005; Zhang et al., 2009). The positive significant correlation occurred between seed yield and N application time (r = 0.41), which indicated that increasing the N applications increased seed yield (Table 3). The highest yields were achieved at the rate of N 120 kg ha^{-1} divided into three equal applications (Table 4). Barlog & Grzebisz (2004) and Boelce et al. (2008) have indicated that three-splitting rate N treatment guaranteed optimum yield stability, as also suggested by Hanus & Sieling (1998) who reported a good response of the third N rate applied at the budding stage, to seed yield. In the case of similar treatments, reported as classical, winter oilseed rape received N generally in two sub-rates, i.e. at the beginning of growth and at stem elongation (Sieling et al., 1998).

Table 3. Correlation matrix between N-fertilizer and valuations.

	N rates	N appli-cation	Seed yield	Raw oil content	Raw oil yield	Raw protein content	Gluco-sinolate content
N rates	1.00						
N app-lication	0.00	1.00					
Seed yield	0.05	0.41***	1.00				
Raw oil content	-0.45***	-0.41***	-0.66***	1.00			
Raw oil yield	-0.01	0.50***	0.90***	-0.66***	1.00		
Raw protein content	0.16	0.27	0.72***	-0.77***	0.72***	1.00	
Glucosinolate content	0.03	0.48***	0.67***	-0.81***	0.72***	0.76***	1.00

***statistically significant P < 0.001

The most important quality factor of oilseed rape is oil content, which however, is linked to protein content (Brennan et al., 2000). High protein content at high level of N may be due to the negative correlation between oil content and protein content (Hao et al., 2004). Negative correlation occurred also in this experiment (r = –0.77).

Table 4. Seed yield and raw oil yield (kg ha^{-1}), raw oil and protein content (%) and glucosinolate content (µmol g^{-1}) of winter oilseed rape in 2008 and 2009 (seed moisture 7.5%).

Year	Nitrogen rate, kg ha^{-1}	Using application	Seed yield kg ha^{-1}	Raw oil content, %	Raw oil yield, kg ha^{-1}	Raw protein content, %	Gluco-sinolate content, µmol g^{-1}
2008	120	A	3,323	43.0	1429	18.4	9.0
		B	4,604*	41.6*	1915*	20.8*	16.7*
		C	5,293*	41.2*	2181*	21.2*	17.5*
	140	A	3,033	42.7	1295	18.5	9.9
		B	4,896*	40.5*	1983*	21.5*	18.2*
		C	4,864*	40.3*	1960*	22.0*	18.5*
	160	A	3,645	42.2	1538	18.7	7.8
		B	4,962*	40.6*	2015*	21.4*	17.2*
		C	5,186*	41.3*	2142*	21.4*	15.5*
2009	120	A	5,232	41.3	2161	23.9	17.2
		B	5,075	41.5	2106	23.6	15.8
		C	5,762	41.5	2391	23.7	16.1
	140	A	4,807	40.9	1966	24.3	17.9
		B	5,551	40.5	2248	24.6	15.9
		C	4,445*	41.1	1827*	24.2	19.0
	160	A	5,201	40.7	2117	24.6	18.4
		B	5,605	39.5*	2214	25.8	18.2
		C	4,936	40.2*	1984	24.9	16.8

*statistically significant P < 0.05

The average raw oil content of the trials was low, 41.5% in 2008 and only 40.8% in 2009. The raw oil content is negatively correlated with N fertilizer rate (Holmes, 1980; Söchtling & Verret, 2004; Rathke et al., 2005; Ahmad et al, 2007). Negative significant correlation was found between raw oil content and N rates (r = –0.45) as well as raw oil content and N application (r = –0.41). Higher raw oil contents were produced by the lower N rates. Increasing N levels had a depressing effect on the raw oil content.

The average raw oil yield was 1,845 kg ha^{-1} in 2008 and 2,113 kg ha^{-1} in 2009. Raw oil yield was the highest at N 120 kg ha^{-1} divided into three equal applications (Table 4). It is thus obvious that N nutrition must be optimized to obtain compromise between seed yield and seed quality (Orlovski, 2003). The positive significant correlation was found between raw oil and seed yield (r = 0.90) and between raw oil yield and N application time (r = 0.50), which indicates that increasing the N applications oil yield increased.

Several researchers (Asare, 1995; Pellet, 2002; Söchtling & Verret, 2004; Rathke et al., 2005; Ahmad et al., 2007) noticed that protein contents increased with the increase of N fertilizer rate. The average raw protein content in the trial was 20.4% in 2008 and 24.4% in 2009. Although the results of 2008 showed significant differences, between raw protein content and N application time there was no significant correlation (r = 0.27).

The average glucosinolate content was 14.5 µmol g^{-1} in 2008 and 17.3 µmol g^{-1} in 2009. The Söchtling & Verret (2004) and Ahmad et al. (2007) have indicated that N fertilizer does not affect glucosinolate content significantly. Bilsborrow et al. (1993), Thakral et al. (1996), Chen et al. (2006), Zhao et al. (2006), Omirou et al. (2009) reported that glucosinolate content increased with the increasing rate of N. In our trial significant positive correlation between glucosinolate content and N application time (r = 0.48) was found, which indicates that increasing the N applications increased glucosinolate content in seeds. The highest glucosinolate content was obtained in variant with N 140 kg ha^{-1} (split in three applications) (Table 4).

CONCLUSIONS

Nitrogen fertilization had positive effect on seed yield and seed protein content. On the other hand, nitrogen fertilization, especially in higher rates, had negative effect on oil content. By the results can be concluded that the quantity of the fertilizer had not as strong impact to seed yield and quality as fertilizer application time. The highest yields of seed and raw oil were obtained from the variant of split-N treatment (40+40+40) 120 kg ha^{-1}. Three split N applications was carried out, the first at the beginning of spring vegetation, the second when stem length was 10 cm and the third at the beginning of flowering.

REFERENCES

Ahmad, G., Jan, A., Arif, M., Jan, M.T. & Khattak, R.A. 2007. Influence of nitrogen and sulfur fertilization on quality of canola (*Brassica napus* L.) under rainfed conditions. *Journal of Zhejiang University Science B*, **8** (10), 731–737.

Almond, J.A., Dawkins, T.C.K. & Askew, M.F. 1986. Aspects of crop husbandry. Scarisbrick, D.H. & Daniels, R.W. (ed.). *Oilseed Rape*. Collins, London, 350 pp.

Anderson, G., Olered, R. & Olsson, G. 1958. Zur Nahrstoffaufnahme des Winterraps. *Zeitschrift für Acker- und Pflanzenbau*. **107**, 171–179 (in German).

Asare, E. & Scarisbrick, D.H. 1995. Rate of nitrogen and sulphur fertileization on yield, yield components and seed quality on oilseed rape (*Brassica napus* L.). *Field Crops Research*, **44**, 41–46.

Barlog, P. & Grzebisz, W. 2004. Effect of Timing and Nitrogen Fertilizes Application on Winter Oilseed Rape (*Brassica napus* L.) I. *Growth Dynamics and Seed Yield, Journal Argonomy & Crop Science*, **190**, 305–313.

Bilsborrow, P.E., Evans, J. & Zhao, F. 1993. The influence of spring nitrogen on yield, yield components and glucosinolate concentration of autumn-sown oilseed rape (Brassica napus). *Journal Agric. Sci.* **120**, 219–224.

Boelce, B., Leon, J., Schulz, R.R., Schröder, G. & Diepenbrock, W. 2006. Yield Stability of Winter Oil-Seed Rape (*Brassica napus* L.) as Affected by Stand Establishment and Nitrogen Fertilization. *Journal of Agronomy and Crop Science*, **167**, 4, 241–248.

Brennan, R.F., Mason, M.G. & Walton, G.H. 2000. Effect of nitrogen fertilizer on the concentration of oil and protein in Canola (*Brassica napus*) seed. *Journal on Plant Nutrition*, **23** (3), 339–348.

Chen, X.J., Zhu, Z.J. Ni, X.L. & Qian Q,Q. 2006. Effect of Nitrogen and Sulfur Supply on Glucosinolates in *Brassica campestris ssp. chiensis*. *Agricultural Sciences in China*, **5**, 8, 603–608.

FAOSTAT. http://faostat.fao.org/**.** accessed on 26.02.2010.

Hanus, H. & Sieling, K. 1998. Zur optimalen N-Versorgung von Rapsbeständen. *Raps* **16**, 12-15 (in German).

Hao, X., Chang, C. & Travis, G.J. 2004. Short communication: effect of long-term cattle manure application on relations between nitrogen and oil content in canola seed. *J Plant Nutr Sci*, **167** (2), 214–215.

Hocking, P.J., Kirkegaard, J.A., Angus, J.F., Gibson, A.H. & Koetz, E.A. 1997. Comparison of canola, Indian mustard and Linola in two contrasting environments. I. Effects of nitrogen fertilizer on dry-matter production seed yield and seed quality. *Field Crops Res*. **49**, (2-3), 107–125.

Holmes, M.R.J. 1980. *Nutrition of the Oilseed Rape Crop*. Applied Science Publishers LTD London. P. 158.

Omirou, M.D., Papadopoulou, K.K., Papastylianou, I., Constantinou, M., Karpouzas, D.G., Asimakopoulos, I. & Ehaliotis, C. 2009. Impact on Nitrogen and Sulfur Fertilization on the Composition of Glucosinolates in Relation to Sulfur Assimilation in Different Plant Organs of Broccoli. *Journal of Agricultural and Food Chemistry,* **57** (20), 9408–9417.

Orlovius, K. 2003. Oilseed rape. In: Kirbky, E.A. (ed.). Fertilizing for High Yield and Quality, *IPI Bulletin*, Basel, **16**, p.125.

Paul, V.H. 1988. *Krankheiten und Schädlinge des Rapses*. Verlag Th. Mann. Gelsenkirchen-Buer, p.121 (in German).

Pellet, D. 2002. Oilseed rape varietal response to nitrogen fertilization. GCIRC *Bulletin* **18**.

Rathke, G.-W., Christen, O. & Diepenbrock, W. 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 Research*, **94**, 2–3, 103–113.

Rollier, M. 1970. Le colza et Pazote. *Oleagineux,* **25**, 91–96 (in French).

Sauermann, W. 2000. Anbautechnik Hybridraps. *Raps*, **18** (1), 4–8 (in German).

Sidlauskas, G. & Bernotas, S. 2003. Some factors affecting seed yield of spring oilseed rape (*Brassica napus* L.). *Agronomy Research*, **1** (2), 229–243.

Sieling, K., Schröder, H. & Hanus, H. 1998. Mineral and slurry nitrogen effects on yield, N uptake, and apparent N-use efficiency of oilseed rape (*Brassica napus*). *Journal Agricultural Science Cambridge*, **130**, 165–172.

Sieling, K., Günther-Borstel, O., Teebken, T. & Hanus, H. 1999. Soil mineral N and N net mineralization during autumn and winter under an oilseed rape-winter wheat-winter barley rotation in differentcrop management systems. *Journal Agricultural Sci. Cambridge*, **132**, 127–137.

Söchtling, H.P. & Verret, J.A. 2004. Effects of different cultivation systems (soil management and nitrogen fertilization) on the epidemics of fungal diseases in oilseed rape (*Brassica napus* L. *var. napus*). *Journal of Plant Disease and Protection,* **111**, 1–29.

Zhang, Z.H., Song, H.X., Liu, Q., Rong, X.M., Peng, J.W., Xie, G.X. & Zhang, Y.P. 2009. Study on differences of nitrogen efficiency and nitrogen response in different oilseed rape (*Brassica napus* L.) varieties. *Asian Journal Crop Science,* **1**, 105–112.

Zhao, F., Evans, E.J., Bilsborrow, P.E. & Syers, J.K. 2006. Influence of nitrogen and sulphur on the glucosinolate profile of rapeseed (*Brassica napus* L.). *Journal of the Science of Food and Agriculture*, **64**, 3, 295–304.

Thakral, S.K., Singh, B.P., Faroda, A.S. & Gupta, S.K. 1996. Effect of irrigation and fertility levels on the oil yield and quality of *Brassica* species. *Annals of Agric Res.* **17** (4), 416–418.