ACTA UNIVERSITATIS AGRICULTURAE ET SILVICULTURAE MENDELIANAE BRUNENSIS

Volume LVIII 46 Number 5, 2010

# EFFECT OF TOPDRESSING WITH NITROGEN AND BORON ON THE YIELD AND QUALITY OF RAPESEED

L. Varga, O. Ložek, L. Ducsay, P. Kováčik, T. Lošák, J. Hlušek

**Received: May 25, 2010**

## Abstract

VARGA, L., LOŽEK, O., DUCSAY, L., KOVÁČIK, P., LOŠÁK, T., HLUŠEK, J.: *Effect of topdressing with nitrogen and boron on the yield and quality of rapeseed.* Acta univ. agric. et silvic. Mendel. Brun., 2010, LVIII, No. 5, pp. 391–398

Field trials with winter rape (*Brassica napus* L. var. *napus*) variety Rasmus were established in August in the years 2002–2004 at the experimental station in Kolíňany which belongs to the Slovak University of Agriculture in Nitra. In the experiments we explore the effect of supplementary spring topdressing of rape with nitrogen and boron in the BBCH 29–30 stage with regard to the yields of seeds and their qualitative parameters (TSW, content of oil and crude protein). In the experiment we applied DAM–390 (solution of ammonium nitrate and urea, 30% N) at a rate of 30 kg N/ha and Humix Bór (humic acids + N, K, B) at a rate of 0.240 kg B/ha. The different climate conditions in the respective years had a significant effect on yields of rapeseed and ranged as follows: 2003: 1.80–2.29 t/ha; 2004: 2.60–3.35 t/ha; 2005: 2.45–3.29 t/ha. The significant decrease in seed yields in the first year of the experiment was caused namely by the deficit in precipitation in January, February and June 2003 and high temperatures in May and June in the same year. In terms of the individual years and the three-year average the application of Humix Bór itself did not significantly improve the yield and qualitative parameters of seeds compared to the unfertilised control. In a three-year average the application of the N fertiliser alone or in combination with Humix Bór increased seed yields and the crude protein content by 22.4–30.7% and 4.0–4.9 rel. %, respectively, compared to the unfertilised control. The significantly highest seed yields (2.98 t/ha) were achieved when the plants were treated with a combination of nitrogen and Humix Bór as compared to all the other treatments (2.28–2.79 t/ha). The oil content in seeds increased significantly to 44.1% only when treated with a combined application of DAM–390 and Humix Bór as against the unfertilised control (42.8%). Fertilisation did not change the TSW which ranged only between 4.47 and 4.67 g.

rapeseed, topdressing, nitrogen, boron, seed yield, TSW, oil, crude protein

In recent years rapeseed has become the most important oil-seed plant in Slovakia. Processing its seeds is of determining significance for the food and chemical industry. It is linked with the processing of rapeseed oil for human consumption, as well as for technical purposes and for the production of bio-oils and bio-fuels (Rathke *et al.*, 2006).

With regard to its high nutrition requirements, rapeseed ranks among the most demanding agricultural crops. The results of many scientific works as well as practical knowledge have confirmed that the optimal supply of biogenic elements for crops, especially with regard to nitrogen in plant nutrition (Šidlauskas and Tarakanovas, 2004; Rathke *et al.*, 2005; Balík *et al.*, 2006; Lošák, 2001, 2003), as well as boron (Wang *et al.*, 1999), is the most determining factor for the quality and amount of the rape seeds. Boron is an important nutrient for other oil plants as well (Lošák *et al.*, 2004).

Rape crops are often cultivated on soils low in B (strongly weathered soils, coarse textured soils, shallow soils, thin soils over calcareous soils, volcanic ash soils) or where plant availability of boron is reduced, for example as a consequence of high soil pH, liming and/or drought periods during growth. For this reason boron deficiency in rape crops is monitored on a worldwide basis (Shorrocks, 1997).

In plants, boron plays an important role especially in the formation of meristems, processes of pollination and, thus, formation of seed yields. Boron is also important for the phloem transport of sucrose. Marschner (2002) demonstrated that it is also necessary for processes of synthesis of cell walls and cytokines and for lignification. It is also necessary for synthesis of nucleic acids, for incorporation of N into RNA synthesis and for proteosynthesis (Mengel and Kirkby, 2001). Chakraborty and Das (2000) found out that, in interaction with sulphur, boron increased the content of oil in seeds.

Symptoms of B deficiency on rapeseed plants did not appear until the upper parts of the plants formed pods, with seed development limited to those pods located on the lower parts of the plant. Also, B deficiency delayed maturity and kept the plants in an indeterminate stage of growth with flowers forming up to the time of the first killing frost. Similarly, B-deficient canola appeared normal in early growth stages, showed red margins and/or intervenal mottling at bloom stage and had a reduced seed set (Nyborg and Hoyt, 1970).

Nowadays the attention focused on exploiting the stimulating effects of humates in nutrition of agricultural plants has grown not only in research works, but also in agricultural practice (Ložek *et al.* 2001). The sorption capacity and mainly the ion-exchange capacity of humus substances have a crucial effect not only on the elution of nutrients from soil but also on the self-purifying function of soil if it is contaminated by xenobiotic pollutants, formation of organo–mineral complexes of soil aggregates and many other factors that are important for potential soil fertility (Kolář *et al.*, 2008). Humates are harmless compounds from the toxicological point of view and with regard to their composition they are environmentally-friendly. Humates, e.g. calcium, sodium, ammonium, etc., have stimulating, adsorption and protection traits and thus it is suitable to apply them together with plant nutrition and plant protection means (Vrba, 1987; Ložek *et al.* 2001).

The focus of this study is on the influence of productive fertilising of rapeseed with nitrogen and boron applied in phase BBCH (29–30) on seed yields and qualitative parameters.

## MATERIALS AND METHODS

The field study including nutrition experiments was carried out in late August between 2002 and 2004 in Kolíňany at the experimental station of the University's agricultural enterprise in Nitra with the rapeseed *(Brassica napus* L. var. *napus.)* variety Rasmus on loamy brown soil in 4 repetitions; the size of the experimental plots was 90 $m^2$ and the sowing rate was 60,000 germinating seeds. Agrochemical characteristics of the soil before laying out the experiments are shown in Table I. The characteristics of weather conditions in 2002–2005 are presented as follows: precipitation (% of the long-term average) in Table II and temperatures (deviations from the long–term average) in Table III (Kožnarová and Klabzuba, 2002). The influence of topdressing of rapeseed with nitrogen and boron applied in phase BBCH (29–30) on the yield of the seeds and qualitative parameters was evaluated. Autumn fertilising was carried out at a rate of 20 kg $N.ha^{-1}$, 40 kg $P.ha^{-1}$ and 160 kg $K.ha^{-1}$ in the form of ammonium-dihydrogenphosphate and potassium chloride every year. Regeneration fertilising was conducted in spring (7 March 2003, 4 March 2004 and 10 March 2005) at a rate of 50 kg $N.ha^{-1}$ with fertilizer LAD (ammonium nitrate with dolomite). Topdressing of rapeseed with nitrogen and boron was carried out later in March (25 March 2003, 23 March 2004 and 30 March 2005) in phase BBCH (29–30). Fertilisers such as Humix boron (humic acids 3 %, nitrogen 1 %, potassium ($K_2O$) min. 1.8 %, pH value = 7–8, boron 40 000 mg/kg, zinc 290 mg/kg, copper 95 mg/kg, manganese 42 mg/kg, iron 40 mg/kg, density 1.2 g/$cm^3$) and DAM–390 (liquid fertiliser–ammonium nitrate and urea, 30% N, density 1.3 g/$cm^3$) were used. The treatments of the experiment are shown in table IV. The crops were harvested with a combine–harvester. Standard methods were used to analyse the soil and plant material. The influence of treatments with fertilisers on the yield of the seeds, mechanical and chemical traits of the seeds was assessed after harvest. The yield parameters were evaluated with statistical methods, the analysis of variance (ANOVA) and significance of the differences between years and treatments with the LSD test ($\alpha = 0.05$).

## RESULTS AND DISCUSSION

Crop nitrogen use efficiency is related to climate conditions, soil properties and interaction between nutrient elements. Brassica plants also need a high

I: *Agrochemical characteristics of the soil before the establishment of the experiments to a depth of 0.3 m*

| Soil analysis | 2002/2003 | 2003/2004 | 2004/2005 |
|---|---|---|---|
| **pH/KCl** | 6.70 | 6.62 | 6.68 |
| **$N_{an}$ (mg/kg)** | 9.6 | 8.8 | 14.5 |
| **P Mehlich II (mg/kg)** | 36.0 | 35.3 | 38.5 |
| **K Mehlich II (mg/kg)** | 155.0 | 172.0 | 185.0 |
| **Content of $C_{ox}$ Tjurin (%)** | 1.77 | 1.85 | 1.89 |

II: *Average monthly precipitation in 2002–2005 (evaluation of standard monthly precipitation based on long-term averages in 1961–2001)*

| Month | Long-term average | 2002 | | 2003 | | 2004 | | 2005 | |
|---|---|---|---|---|---|---|---|---|---|
| | | precipitation in mm | evaluation of standard | precipitation in mm | evaluation of standard | precipitation in mm | evaluation of standard | precipitation in mm | evaluation of standard |
| **I** | 31 | - | - | 4 | extraordinarily dry | 55 | very wet | 36 | normal |
| **II** | 32 | - | - | 8 | very dry | 31 | normal | 53 | wet |
| **III** | 33 | - | - | 2 | extraordinarily dry | 53 | wet | 3 | extraordinarily dry |
| **IV** | 43 | - | - | 28 | normal | 36 | normal | 85 | very wet |
| **V** | 55 | - | - | 50 | normal | 37 | normal | 65 | normal |
| **VI** | 70 | - | - | 15 | very dry | 94 | wet | 32 | very dry |
| **VII** | 64 | - | - | 99 | wet | 34 | dry | 74 | normal |
| **VIII** | 58 | 111 | very wet | 27 | dry | 19 | very dry | 90 | wet |
| **IX** | 37 | 74 | wet | 16 | dry | 37 | normal | - | - |
| **X** | 41 | 92 | very wet | 67 | wet | 47 | normal | - | - |
| **XI** | 54 | 54 | normal | 33 | normal | 49 | normal | - | - |
| **XII** | 43 | 48 | normal | 24 | dry | 10 | very dry | - | - |

III: *Average monthly temperatures in 2002–2005 (the evaluation of monthly standard air temperatures according to the divergences from long-term averages 1961–2001)*

| Month | Long-term average | 2002 | | 2003 | | 2004 | | 2005 | |
|---|---|---|---|---|---|---|---|---|---|
| | | temperature in °C | evaluation of standard | temperature in °C | evaluation of standard | temperature in °C | evaluation of standard | temperature in °C | evaluation of standard |
| **I** | –1.7 | - | - | –1.9 | normal | –3.0 | normal | –0.1 | normal |
| **II** | 0.5 | - | - | –1.9 | cold | 1.6 | normal | –2.7 | cold |
| **III** | 4.7 | - | - | 5.1 | normal | 4.7 | normal | 2.6 | cold |
| **IV** | 10.1 | - | - | 10.7 | normal | 11.7 | warm | 11.0 | normal |
| **V** | 14.8 | - | - | 18.8 | extraordinarily warm | 14.3 | normal | 15.4 | normal |
| **VI** | 18.3 | - | - | 21.3 | extraordinarily warm | 17.9 | normal | 18.1 | normal |
| **VII** | 19.7 | - | - | 21.2 | warm | 20.0 | normal | 20.7 | normal |
| **VIII** | 19.2 | 20.8 | warm | 22.7 | extraordinarily warm | 20.1 | normal | 18.5 | cold |
| **IX** | 15.4 | 14.9 | normal | 15.8 | normal | 15.2 | normal | - | - |
| **X** | 10.1 | 9.7 | normal | 7.9 | cold | 10.7 | normal | - | - |
| **XI** | 4.9 | 7.0 | very warm | 7.0 | very warm | 5.2 | normal | - | - |
| **XII** | 0.5 | 0.1 | normal | 0.9 | normal | 1.0 | normal | - | - |

level of boron in soils (Stangoulis *et al.*, 2000). Different climatic conditions statistically significantly influenced the yield of rapeseed in the individual years of the experiment. The highest yield was gained in experimental years 2003/2004 (the average from all treatments was 2.97 t/ha), when precipitation was favourable from February till May with suitable temperature average against the long-term standard what had a positive effect on the production process (Tab. II). The years 2004/2005 were at the level of a 30-year standard, i.e. both temperature and precipitation averages, and the obtained average yield of the seeds was 2.85 t/ha. In 2002/2003 the yields decreased significantly (the average yield was 2.03 t/ha), when the weak intensity of precipitation (January, February, March, June) and high temperature in May and June negatively influenced the final production of the seeds (Tab. V). It was discovered that the climatic conditions significantly affected yield formation of the selected agricultural crops (Hubík, 1995; Ducsay and Ložek, 2004; Istanbulluoghu, 2010).

Differences among the treatments in the individual years correspond to the differences in terms of average three-year values (Tab. V). Nitrogen applied in the form of topdressing in treatment 3 resulted in a statistically significant increase in seed yield in comparison with the unfertilised control (treatment 1) and with the application of boron (treatment 2). The seed yield of treatments fertilised with boron (2.41 t/ha) was not affected significantly in comparison with the control treatment (2.28 t/ha). In their experiments with foliar applications of boron to rape Karamanos *et al.* (2003) reached the same conclusions. Treatment with joint foliar application of nitrogen and boron (2.98 t/ha) statistically significantly increased the yields in comparison with all the other treatments (tab. V). Moradi-Telefat *et al.* (2008) achieved the same results; rapeseed yields were the highest with the highest rate of nitrogen (250 kg N/ha) and boron (10 kg B/ha) applied

IV: *Treatments of nutrition and average rates of nitrogen and boron on production fertilising of rapeseed in years from 2003 to 2005*

| Treatment | Characteristics of fertilisation | Form of fertilisation | Rate of nitrogen and boron for topdressing (kg/ha) | |
|---|---|---|---|---|
| | | | N | B |
| 1 | Unfertilised | - | - | - |
| 2 | Additional fertilizing with boron | Humix boron[1] | trace | 0.240 |
| 3 | Additional fertilizing with nitrogen | DAM – 390[2] | 30 | - |
| 4 | Additional fertilizing with boron and nitrogen | DAM – 390 + Humix boron | 30 | 0.240 |

[1] humic acids 3 %, nitrogen 1 %, potassium ($K_2O$) min. 1.8 %, pH value = 7–8, boron 40 000 mg/kg, zinc 290 mg/kg, copper 95 mg/kg, manganese 42 mg/kg, iron 40 mg/kg, density 1.2 g/cm$^3$
[2]ammonium nitrate and urea (liquid fertilizer, 30% N, density 1.3 g/cm$^3$)

V: *The influence of fertilisation on the yield of rapeseed seeds (variety Rasmus)*

| Treatments | Seed yields ( t/ha) | | | | 3-year average |
|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 3-year average | rel. % |
| 1 | 1.80 a | 2.60 a | 2.45 a | 2.28 a | 100.0 |
| 2 | 1.83 a | 2.79 a | 2.62 a | 2.41 a | 105.7 |
| 3 | 2.20 b | 3.12 b | 3.05 b | 2.79 b | 122.4 |
| 4 | 2.29 c | 3.35 c | 3.29 c | 2.98 c | 130.7 |

Treatments with different letters (a, b, c) in the columns show statistically significant differences at $\alpha = 0.05$

VI: *The influence of fertilisation on uptake of nutrients by seeds of rapeseed, variety Rasmus (Kolíňany, average of 2003–2005)*

| treatment of nutrition | Nutrient uptake by winter rape seed (kg/ha) | | | | | |
|---|---|---|---|---|---|---|
| | N | P | K | Ca | Mg | S |
| 1 | 74.94 | 9.86 | 13.18 | 9.25 | 5.44 | 8.40 |
| 2 | 79.22 | 10.53 | 13.94 | 9.85 | 5.89 | 8.99 |
| 3 | 93.17 | 12.71 | 16.33 | 12.01 | 7.00 | 11.33 |
| 4 | 99.80 | 13.82 | 17.65 | 13.13 | 7.71 | 12.49 |
| Relative reference % | | | | | | |
| 1 | 100 | 100 | 100 | 100 | 100 | 100 |
| 2 | 105.7 | 106.8 | 105.8 | 106.5 | 108.2 | 107.0 |
| 3 | 124.3 | 128.9 | 123.9 | 129.8 | 128.6 | 134.9 |
| 4 | 133.2 | 140.2 | 133.9 | 141.9 | 141.7 | 148.7 |

to the soil. Malhi *et al.* (2003) discovered that boron application increased grain yields, dry matter and boron absorption. In addition, the increase of grain yields resulting from boron application was due to the increased grain number per silique (Stangoulis *et al.*, 2000).

Applied nitrogen and boron in phase BBCH (29-30) positively affected the uptake of the main macro elements (N, P, K, Ca, Mg, S) by the seeds of tested plants from all treatments (treatment 2 to 4), (Tab. VI). Yang-Yuen *et al.* (1999) found out that the influence of nitrogen and magnesium application positively affected the formation of the rapeseed yield and its nutrients balance.

Joint nitrogen and boron nutrition as production fertilising of winter rape positively affected the selected parameters of seed quality. The seed oil content (44.1%) was the highest in treatment 4 where nitrogen was applied in combination with boron as compared with the unfertilised control (42.8% of oil). Nuttal *et al.* (1987) observed that boron along with nitrogen increased grain oil. Porter (1993) reported that boron application maximised canola yields. Therefore it seems that boron application results in efficient utilisation of nitrogen in canola and maximises oil yield. High rates of nitrogen usually decrease the oil content in rape seed (Lošák, 2001; Moradi-Telefat *et al.*, 2008).

The content of crude protein in seeds (Tab. VII) increased significantly to 23.2% after the application of nitrogen fertilisers and to 23.4% in combination with boron as against the other treatments (22.3–22.5%). However no significant differences were observed between treatments 3 and 4. It was confirmed that nitrogen increased the protein content in rape seed (Moradi-Telefat *et al.*, 2008). Yet in experiments with boron applications Moradi-Telefat *et al.* (2008), Karamanos *et al.* (2003) discovered that boron had no significant effect on grain oil and protein percentage.

The 1000 seeds weight (tab. VII) ranged between 4.47 g (unfertilized treatment) and 4.67 g (treatment 4) with no significant differences among the varieties. Also Moradi-Telefat *et al.* (2008) indicated the insignificant effect of boron application on the TSW of rape, but in their experiments nitrogen fertilisation significantly increased the TSW. Šiaudinis and Lazauskas (2009) referred about the negative correlation between the rate of yield and the thousand-seed weight (r = –0.85).

VII: *The influence of fertilisation on some qualitative parameters of rapeseed seeds, variety Rasmus (Kolíňany, average of 2003–2005)*

| Treatment | Oil (%) | Crude protein (%) | 1000 seed weight (g) |
|---|---|---|---|
| 1 | 42.8 a | 22.3 a | 4.47 a |
| 2 | 43.2 ab | 22.5 a | 4.53 a |
| 3 | 43.7 ab | 23.2 b | 4.60 a |
| 4 | 44.1 bc | 23.4 b | 4.67 a |
| **Relative reference (%)** | | | |
| 1 | 100.0 | 100.0 | 100.0 |
| 2 | 100.9 | 100.9 | 101.3 |
| 3 | 102.1 | 104.0 | 102.9 |
| 4 | 103.0 | 104.9 | 104.5 |

Treatments with different letters (a, b, c) in the columns show statistically significant differences at $\alpha = 0.05$

## SUMMARY

As the results showed it is apparent that in order to achieve the required yields of rape seed and its quality the effect of nitrogen is decisive and irreplaceable. The synergic effect of boron is evident only when combining topdressing with nitrogen fertiliser; it was reflected in the highest seed yields, oil content and crude protein content in the seeds. The most valuable component of the Humix Bór fertiliser is the relatively high content of boron (4%) because rape plants require ca 200–300 g B/ha. The combined application of Humix Bór and liquid nitrogen fertiliser can be recommended for spring productive fertilisation of rape.

## SOUHRN

### Efekt hnojení dusíkem a bórem na výnos a kvalitu řepkového semene

Polní pokusy s ozimou řepkou (*Brassica napus* L. var. *napus*) odrůdy Rasmus byly založeny v měsíci srpen v letech 2002–2004 na experimentální stanici v Kolíňanech, která patří Slovenské polnohospodárské univerzitě v Nitře. V pokusech byl sledován vliv jarního foliárního přihnojení řepky dusíkem a bórem ve fázi BBCH 29-30 s ohledem na výnos semene a jeho kvalitativní parametry (HTS, obsah oleje a hrubého proteinu). Do experimentu byl zařazen DAM-390 (roztok dusičnanu amon-

ného a močoviny, 39% N) v dávce 30 kg N/ha a Humix Bór (huminové kyseliny + N, K, B) v dávce 0,240 kg B/ha.
Výnos řepkového semene byl průkazně ovlivněn v jednotlivých letech působením odlišných klimatických podmínek a kolísal následovně: 2003: 1,80–2,29 t/ha; 2004: 2,60–3,35 t/ha; 2005: 2,45–3,29 t/ha. Průkazný pokles výnosu semene v prvním roce experimentu byl zapříčiněn především deficitem srážek v měsících leden, únor, březen a červen 2003 a vysokými teplotami vzduchu v květnu a červnu téhož roku.
Z hlediska individuálních let i tříletého průměru se samotná aplikace Humix Bór neprojevila signifikantně na nárůstu výnosově-kvalitativních parametrů semene oproti nehnojené kontrole. Aplikací jak samotného dusíkatého hnojiva, tak v kombinaci s Humix Bór byl výnos semene i obsah hrubého proteinu zvýšen v průměru 3 let o 22,4–30,7%, resp. o 4,0– 4,9 rel. % v porovnání s nehnojenou kontrolou. U varianty s kombinací dusíku a Humix Bór bylo dosaženo průkazně nejvyššího výnosu semene (2,98 t/ha) oproti všem ostatním variantám (2,28–2,79 t/ha). Obsah oleje v semeni byl průkazně zvýšen pouze při společné aplikaci DAM-390 a Humix Bór na 44,1% oproti nehnojené kontrole (42,8 %). HTS se vlivem hnojení neměnila a kolísala v úzkém rozpětí 4,47– 4,67 g.

řepkové semeno, přihnojení, dusík, bór, výnos semene, HTS, olej, hrubý protein

Acknowledgement

This study was supported by the Ministry of Education of the Slovak Republic, Projects VEGA No. 1/0435/08 and the Research plan No. MSM6215648905 "Biological and technological aspects of sustainability of controlled ecosystems and their adaptability to climate change", which is financed by the Ministry of Education, Youth and Sports of the Czech Republic.

## REFERENCES

BALÍK, J., PAVLÍKOVÁ, D., TLUSTOŠ, P., SÝKORA, K. and ČERNÝ, J., 2006: The fluctuation of molybdenum content in oilseed rape plants after the application of nitrogen and sulphur fertilizers. *Plant Soil Environ.*, 52: 301–307.

CHAKRABORTY, A. and DAS, D., 2000: Interaction between boron and sulphur on different quality parameters of rape (*Brassica campestris* L.). *Research on Crops*, 1: 326–329.

DUCSAY, L. and LOŽEK, O., 2004: Effect of topdressing with nitrogen on the yield and quality of winter wheat grain. *Plant Soil Environ.*, 50: 309–314.

HUBÍK, K., 1995: The effect of fertilization and year on the bread wheat quality. *Rostl. Výr.*, 41: 521–527. (In Czech)

ISTANBULLUOGLU, A., ARSLAN, B., GOCMEN, E., GEZER, E. and PASA, C., 2010: Effects of deficit irrigation regimes on the yield and growth of oilseed rape (*Brassica napus* L.). *Biosystems Engineering*, 105: 388–394.

KARAMANOS, R. E., GOH, T. B. and STONEHOUSE, T. A., 2003: Canola response to boron in Canadian prairie soils. *Can. J. Plant Sci.*, 83: 249–259.

KOLÁŘ, L., KUŽEL, S., PETERKA, J., ŠTINDL, P. and PLÁT, V., 2008: Agrochemical value of organic matter of fermenter wastes in biomass production. *Plant, Soil, Environment*, 54: 321–328.

KOŽNAROVÁ, V. and KLABZUBA, J., 2002: Recommendation of World Meteorological Organization to describing meteorological or climatological conditions. *Rostl. Výr.*, 48: 190–192. (In Czech)

LOŠÁK, T., 2001: Effect of increasing doses of nitrogen and sulphur on yields, quality and chemical composition of winter rape. *Zeszyty problemowe postepów nauk rolniczych.* 472: 481–487.

LOŠÁK, T., 2003: Effects of nitrogen and sulphur nutrition on seed yields and oil content in winter rape. *Acta agraria et silvestria, Series agraria,* 40: 265–270.

LOŠÁK, T., RICHTER, R. and HLUŠEK, J., 2004: The Effect of Nitrogen and Boron Fertilisation on Poppy (*Papaver somniferum* L.) Yield and Composition. *Zeszyty problemowe postepów nauk rolniczych.* 502: 911–917.

LOŽEK, O., SLAMKA, P. and DUCSAY, L., 2001: Utilization of Sodium Humate in Winter Wheat Nutrition. *Humic Substances in Ecosystems*, 4: 85–90.

MALHI, S. S., RAZA, M., SCHOENAU, J. J., MERMUT, A. R., KUTCHER, R., JOHNSON, A. M. and GILL, K. S., 2003: Feasibility of boron fertilization for yield, seed quality and B uptake of canola in north-eastern Saskatchewan. *Can. J. Soil Sci.*, 83: 99–108.

MARSCHNER, H., 2002: *Mineral nutrition of higher plants*. 2nd edition. London: Academic Press, 889 p.

MENGEL, K. and KIRKBY, E. A., 2001: *Principles of Plant Nutrition*. 5th Edition, Kluwer Academic Publishers, Dordrecht / Boston / London, 849 p.

MORADI-TELAVAT, M. R., SIADAT, S. A., NADIAN, H. and FATHI, G., 2008: Effect of nitrogen and boron on canola yield and yield components in ahwaz, *Iran. Int. J. Agric. Res.*, 3: 415–422.

NUTTAL, W. F., UKRAINETZ, H., STEWART, J. W. B. and SPURR, D. T., 1987: The effect of nitrogen sulphur and boron on yield and quality of rapeseed. *Can. J. Soil Sci.*, 67: 545–559.

NYBORG, M. and HOYT, P. B., 1970: Boron deficiency in turnip rape grown on gray wooded soils. *Can. J. Soil Sci.* 50: 87–88.

PORTER, P. M., 1993: Canola response to boron and nitrogen grown on the southeastern coastal plain. *J. Plant Nutr.,* 16: 2371–2381.

RATHKE, G. W., CHRISTEN, O. and 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 Res.,* 94: 103–113.

RATHKE, G. W., BEHRENS, T. and DIEPENBROCK, W., 2006: Integrated nitrogen management strategies to improve seed yield, oil content and nitrogen efficiency of winter oilseed rape (*Brassica napus* L.): A review. *Agriculture, Ecosystems and Environ.,* 117: 80–108.

SHORROCKS, V., 1997: The occurrence and correction of boron deficiency. *Plant and Soil,* 193: 121–148.

STANGOULIS, J. C. R., GREWAL, H. S., BELL, R. W. and GRAHAM, R. D., 2000: Boron efficiency in oilseed rape: I. Genotypic variation demonstrated in field and pot grown *Brassica napus* L. and *B. juncea* L. *Plant Soil,* 225: 243–251.

ŠIAUDINIS, G. and LAZAUSKAS, S., 2009: The effect of nitrogen and sulphur fertilisers on spring rape growth and yield. *Zemdirbyste,* 96: 71–81. (In Lithuanian).

ŠIDLAUSKAS, G. and TARAKANOVAS, P., 2004: Factors affecting nitrogen concentration in spring oilseed rape (*Brassica napus* L.). *Plant Soil Environ.,* 50: 227–234.

VRBA, V., 1987: The Effect of Humus Concentrate on the Growth of Plants in the Initial Period of Vegetation. *Rostl. Výr.,* 33: 1197–1206. (In Czech).

WANG, K., YANG, Y., BELL, R. W., XUE, J. M., YE, Z. Q. and WEI, Y. Z., 1999: Low risks of toxicity from boron fertiliser in oilseed rape–rice rotations in southeast China. *Nutrient Cycling in Agroecosystems,* 54: 189–197.

YANG-YUEN, P., TLUSTOŠ, P., BALÍK, J. and VANĚK, V., 1999: Effects of magnesium and nitrogen foliar fertilisers on oilseed rape. *Rostl. Výr.,* 45: 299–303. (In Czech).

Address

Ing. Ladislav Varga, Ph.D., prof. Ing. Otto Ložek, CSc., doc. Dr. Ing. Ladislav Ducsay, doc. Ing. Peter Kováčik, CSc., Slovenská poľnohospodárska univerzita, Katedra agrochémie a výživy rastlín, Trieda A. Hlinku 2, 949 76 Nitra, Slovenská republika, e-mail: Ladislav.Varga@uniag.sk, Otto.Lozek@uniag.sk, Ladislav.Ducsay@uniag.sk, Peter.Kovacik@uniag.sk, doc. Ing. Tomáš Lošák, Ph.D., prof. Ing. Jaroslav Hlušek, CSc., Dr.h.c., Ústav agrochemie, půdoznalství, mikrobiologie a výživy rostlin, Mendelova univerzita v Brně, Zemědělská 1, 613 00 Brno, Česká republika, e-mail: losak@mendelu.cz, hlusek@mendelu.cz