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Effect of increasing doses of nitrogen on nutrient uptake by oilseed rape (*Brassica napus* L.) in years with different weather conditions

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Abstract

Vicianová, M., Ducsay, L. & Hric, P. (2024). Effect of increasing doses of nitrogen on nutrient uptake by oilseed rape (*Brassica napus* L.) in years with different weather conditions. *Bulg. J. Agric. Sci., 30*(2), 254–262

The main aim of the experiment was to monitor the effect of increasing nitrogen doses on oilseed rape (*Brassica napus* L.) macroelements and microelements uptake by primary and secondary harvest product. The plot–scale experiment was set up in years 2013/2014 and 2014/2015 in terms of agricultural cooperative in Mojmírovce in Slovakia. There were five treatments of fertilization and the block method of experimental plot size of 600 m^2 in triplicate was used in this experiment. The first treatment was unfertilized control treatment. Other treatments were fertilized by increasing doses of nitrogen 120 kg/ha, 160 kg/ha, 200 kg/ha and 240 kg/ha. Results indicates greatly effect of different weather conditions in experimental years on monitored parameters. There were the highest seeds yield, as well as nutrients uptake found in year 2013/2014 that was warmer and more rich in precipitation than year 2014/2015. The highest average nitrogen uptake by both harvest products 41.06 kg/ha was found at unfertilized control treatment 1. Nutrient uptake ratio of seed and straw at control treatment 1 was N : P : K : Ca : Mg : S = 1 : 0.13 : 0.42 : 0.48 : 0.13 : 0.12. There was found nutrient uptake ratio by both harvest products N : P : K : Ca : Mg : S = 1 :0.14 : 0.61 : 0.37 : 0.12 : 0.11 at treatment 4, where the highest yield of seed was reached. On average, manganese transport was higher than return transport. On the contrary, greater amount of iron was return in the form of straw. Generally, macro and microelements uptake was observed in 2013/2014 with more favourable weather conditions and higher average reached yields. The return transport of elements, especially potassium and calcium, in the form of post-harvest residues is important particularly in conditions without animal production and animal manures.

Keywords: oilseed rape; nitrogen nutrition; nutrients uptake

Introduction

Oilseed rape (*Brassica napus* L.) is a very versatile crop and therefore has a significant position in agriculture. It is mostly used in human nutrition. So, precise nutrition of oilseed rape is necessary to reach high yield of rapeseed.

About 40% of seed yield variability could be explained by weather conditions during specific growth phases. During onset of pods and seeds, yield was significantly influenced by temperature, radiation and drought stress. Assimilate availability during this phase determines the number of seeds per m^2. After flowering, only temperature affects yield. Temperature is the major parameter determining the duration of growth stages. Lower temperature elongates the time of assimilate production and translocation to the seeds. During this growth stage, seed weight is determined (Weymann et al., 2015).

Effective fertilization is particularly important in the cultivation of crops that have high nutrient requirements (Jankowski et al., 2018). In the nutrient requirements, oilseed rape is classified as one of the most demanding crops (Ložek, 1998). The macronutrient uptake of winter oilseed rape by seed and straw yield reaches 50-73 kg N, 9-20 kg P, 33-89 kg K, 4-11 kg Mg and 14-20 kg S (Grzebisz, 2011). The nitrogen and potassium uptake ranges from 40 to 80 kg/ha. It is especially large during autumn period (Ložek, 1998).

Changes in the accumulation of microelements and macroelements in the tissues of *Brassica* crops may affect their feeding value (Smulikowska, 2006). The dose and the amount of applications nitrogen fertilizer is the most important factor affecting weight of seeds in pod and yield of rapeseed (Kazemeini et al., 2010).

Phosphorus uptake by plants is determined by the P gradient between the soil solution and the semipermeable membranes of root cells (Kruczek & Szulc, 2006). Phosphorus is characterized by low mobility in the soil, and it is most readily absorbed by roots when phosphorus ions are distributed in the direct proximity of root hairs. For this reason, phosphorus fertilizers should be placed near seeds to promote the growth of a strong root system.

The efficiency of applied potassium fertilizer is significantly affected by straw incorporation (Zhao et al., 2014). Returning crop stover after harvesting can substantially reduce the potassium fertilizer input requirements (Dierolf & Yost, 2000).

The calcium, magnesium and sulphur role in nutrition of oilseed rape is also really important. The sulphur availability may effect**s** the nitrogen utilization efficiency of oilseed rape and vice versa (Fismes et al., 2000). The magnesium availability depends on several factors, such as parent material composition, weathering, climatic and anthropogenic conditions, as well as agricultural management methods (Mikkelsen, 2010). The application of S fertiliser at deficient sites can improve the quality of oilseed rape through a reduction in seed chlorophyll content (Knight & Bingham, 2006). However, excessive S supply may reduce oilseed rape quality by increasing concentrations of glucosinolates (Schnug, 1989).

Although plants need micronutrient only in a small quantities for satisfactory crop growth and production, their deficiency can results in the limitation of physiological and metabolic processes, e.g. photosynthesis and respiration (Nasiri et al., 2010).

The main aim of this experiment was to monitor the effect of increasing nitrogen doses on macronutrients and micronutrients uptake by primary and secondary harvest product of oilseed rape. The hypothesis was that increasing doses of nitrogen increase yield of seed, as well as macro and micronutrients uptake by oilseed rape.

Material and Methods

The plot-scale experiments were established on 02 September 2013 and 22 August 2014 in Mojmírovce (48°11´283.6″N, 17°59´32.1″W and 48°12´22″N, 18°02´19.2″W) in Slovakia. 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 (Varényiová & Ducsay, 2016). The weather conditions were evaluated according to Kožnárová & Klabzuba (2002). Can be concluded, that experimental year 2014/2015 was colder and drier than year 2013/2014. More detailed characteristics of weather conditions is stated in Varényiová & Ducsay (2016). From this it follows that the total precipitation in 2014/2015 for decisive months II. – VI. was by 77.8 mm lower than in year 2013/2014. It is by 65.5 mm fewer in comparison with long-term average. The average temperature for months II. – VI. in year 2014/2015 was by 2.1°C lower than long-term average and by 2.6°C lower compared to year 2013/2014.

Table 1. Agrochemical characteristics of the soil to a depth of 0.3 m before setting the experiment with oilseed rape in experimental years 2013/2014 and 2014/2015 in Mojmírovce (Varényiová & Ducsay, 2016)

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

Table 2. Treatments of oilseed rape nutrition in experimental years 2013/2014 and 2014/2015 in Mojmírovce (Varényiová & Ducsay, 2016)

Treatment	Fertilization level			The total dose of N, kg/ha
	BBCH 20	BBCH 30	BBCH 51	
	N, kg/ha	N, kg/ha	N, kg/ha	
1	0	0	0	0
2	60	30	30	120
3	80	50	30	160
4	100	70	30	200
5	120	90	30	240

The Luvic Chernozem on loess is predominant soil type (Societas pedologica slovaca, 2014).

The results of agrochemical soil analysis are stated in the Table 1. In a plot-scale experiment was studied the effect of increasing doses of nitrogen on yield of seed and uptake of N, P and K by the primary and secondary harvest product. The experiment consisted of five treatments of fertilization. The first treatment was unfertilized control. Other treatments were fertilized by doses of nitrogen 120 kg/ha, 160 kg/ha, 200 kg/ha and 240 kg/ha (Table 2). Stated doses of nitrogen were used in experiment realized by Varényiová & Ducsay (2016), where the effect of increasing nitrogen doses on yield of seed and oil content was observed.

Treatments 2, 3, 4 and 5 were fertilized by nitrogen in the form of dolomite–ammonium nitrate (DAN, 27 % N) in the growth stage BBCH 20 (rosette stage). Nitrogen in the form of urea ammonium nitrate (UAN, 39 % N) was applied at treatments 2, 3, 4 and 5 in the growth stages BBCH 30 (beginning of stem elongation) and BBCH 51 (bud formation).

Soil analyses were performed by routine analytical methods. The harvest was realised on 25 June 2014 and on 07 July 2015 by harvester Claas Lexion 770, like in several similarly experiments realized by Varényiová & Ducsay (2016) were different parameters were monitored.

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

The straw production was calculated as yield of seed multiplied by 1.8.

Macroelements and microelements uptake by seed and straw (kg/ha) was expressed according to the formula:

Macro and microelements uptake = [element content in DM (%)* yield in DM (%)]/100 (kg/ha).

Results and Discussion

Nitrogen fertilizer plays a vital role in enhancing crop yield (Amanullah et al., 2013). Growth traits and seed yield of rapeseed are strongly influenced by nitrogen levels (Ahmadi & Bahrani, 2009). The lowest average yields 2.38 t/ha and 3.69 t/ha was found at unfertilized control treatment 1 and at treatment 5, where the highest dose of nitrogen 240 kg/ha was applied. More detailed information about reached yields are stated in Varényiová & Ducsay (2016). On the contrary, Khorshidi et al. (2014) found the highest average yield at treatment, where the highest dose of nitrogen was used. Also, Alam et al. (2018) observed the highest significant yield 4.58 t/ha at treatment fertilized by the highest dose of nitrogen. These results are in consistent with Kazemeini et al. (2010) and Yousaf et al. (2002) indicating, that increasing nitrogen dose increases the seed yield. On the other hand, there was not confirmed that the highest yield is reached at treatment, where the highest nitrogen dose is applied, in experiment realized by Riar et al. (2020). Compared to treatment 1, there was found statistically significant increase by 68.91%, 74.37% and 81.93% at treatments fertilized by nitrogen doses 120 kg/ha, 160 kg/ha, 200 kg/ha. Statistically significant higher average yield was reached in weather more favourable experimental year 2013/2014.

Nutrition uptake by primary (seed) and secondary (straw) harvest product of oilseed rape is significant effected by nitrogen nutrition (Varga & Ducsay, 2011). As Orlovious and Kirkby (2003) stated, when is the nutrient export by rapeseed lower than total nutrients demand, complete nutrient requirements of the plant during the growing season must be ensured.

The nitrogen, phosphorus, potassium, calcium, magnesium and sulphur uptake by both harvest products is stated in Table 3. The highest average nitrogen uptake by seed and straw 41.06 kg/ha was found at unfertilized control treatment 1. There was observed the highest average phosphorus uptake 7.10 kg/ha at treatment 3, where nitrogen was applied in the dose of 160 kg/ha. The highest average potassium uptake 24.77 kg/ha was reached at treatment 4 fertilized by nitrogen dose 200 kg/ha.

Figures 1, 2 and 3 show the ratio of nitrogen, phosphorus and potassium uptake by seed and straw. The highest average nitrogen export was 80.30% found at treatment 1, where any dose of nitrogen was not applied. The lowest average nitrogen export 73.69% and at the same time the highest average return transport 26.31% was observed at treatment 4, where the highest average yield of rapeseed was reached. Behrens et al. (2001) stated that 70 kg/ha – 80 kg/ha of nitrogen remains in soil in the form of post-harvest residues of oilseed rape, after high nitrogen doses from 240 kg/ha.

There was recorded the highest average phosphorus export 85.05% at treatment 2, where the lowest dose of nitrogen was applied. The highest phosphorus amount 30.28% re-

Table 3. Uptake of nitrogen, phosphorus, potassium, calcium, magnesium and sulphur by 1 t of oilseed rape seed and straw (average of experimental years)

Treatment	Harvest product	Elements uptake in kg per 1 ha of the main product					
		N	P	K	Ca	Mg	S
1	Seed	32.97	4.57	5.91	1.89	2.51	2.09
	Straw	8.09	0.84	11.39	17.68	2.69	2.66
	Seed + straw	41.06	5.41	17.30	19.48	5.20	4.75
2	Seed	30.44	4.72	5.96	1.58	2.21	2.12
	Straw	8.06	0.83	16.74	20.95	3.36	3.34
	Seed + straw	38.50	5.55	22.70	22.53	5.57	5.46
3	Seed	31.97	4.95	5.94	1.47	2.24	1.91
	Straw	8.85	2.15	17.54	16.78	4.35	3.40
	Seed + straw	40.82	7.10	23.48	18.25	6.59	5.31
4	Seed	29.69	4.64	6.07	1.45	2.30	1.99
	Straw	10.60	1.15	18.70	13.40	2.68	2.57
	Seed + straw	40.29	5.79	24.77	14.85	4.98	4.56
5	Seed	31.27	4.69	6.01	1.58	2.18	2.31
	Straw	8.77	0.97	12.93	18.75	3.27	2.74
	Seed + straw	40.04	5.66	18.94	20.33	5.45	5.05

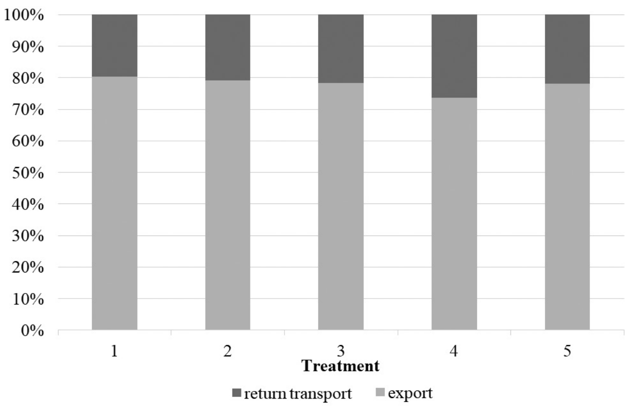

Fig. 1. The nitrogen uptake by primary (seed) and secondary (straw) harvest product of oilseed rape and its return transport in the form of secondary harvest product (average of experimental years)

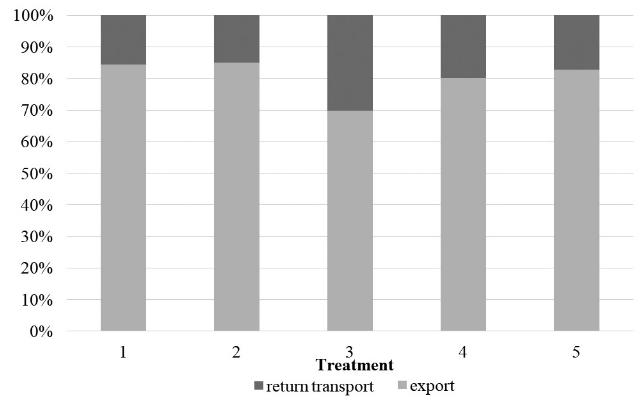

Fig. 2. The phosphorus uptake by primary (seed) and secondary (straw) harvest product of oilseed rape and its return transport in the form of secondary harvest product (average of experimental years)

turned to soil in the form of straw at treatment 3. From this it follows that most of phosphorus is taken by seed and in small quantities is returned to soil in a form of straw. This result is in accordance with Matula (2009), which states that the main reservoir of phosphorus in the plant is the seed, where is more than 80% of the phosphorus removed from the soil.

The potassium export fluctuated from 24.51% to 34.16%. The highest average export was reached at unfertilized control treatment 1. The highest average return transport in a form of straw 75.49% was observed at treatment 4, where the highest average yield of rapeseed was reached. It is well documented that the potassium concentration in the vegetative tissue is much higher than in the grain and that the grain does not accumulate much potassium (Zörb et al., 2014). Also, White (2013) states that the amount of potassium removed by seed represents only a small part of the total potassium content of the plant.

The higher amount of calcium was removed by straw of oilseed rape (Figure 4). It ranged from 90.24% to 92.99%. The highest rate of calcium in the form of straw 92.99% was reached at treatment 2, where the lowest dose of nitrogen was applied. The highest average calcium uptake by seed 9.76% was recorded at treatment 4. As Jakubus (2006) stated, the straw of oilseed crops, genus *Brassica*, is a rich source of

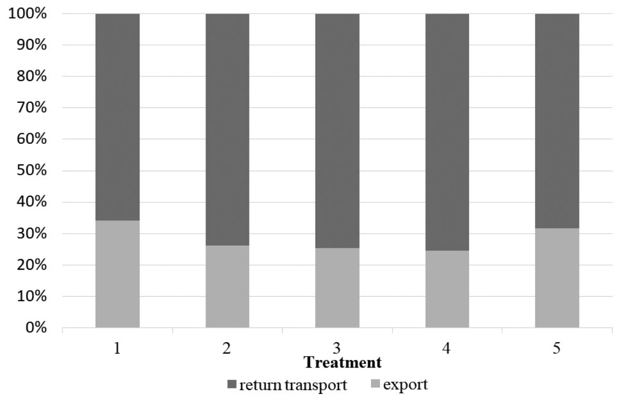

Fig. 3. The potassium uptake by primary (seed) and secondary (straw) harvest product of oilseed rape and its return transport in the form of secondary harvest product (average of experimental years)

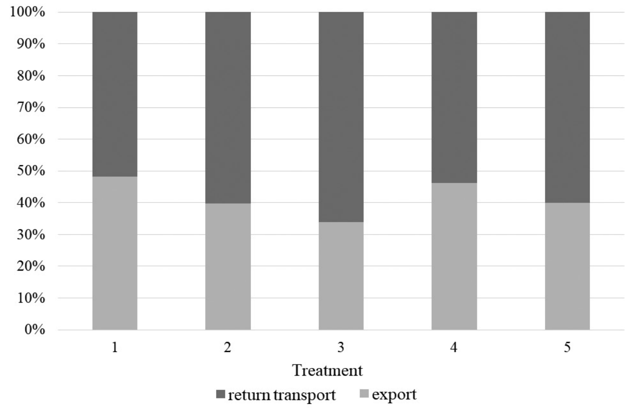

Fig. 5. The magnesium uptake by primary (seed) and secondary (straw) harvest product of oilseed rape and its return transport in the form of secondary harvest product (average of experimental years)

calcium (17–20 g/kg dry mater). Zaberath et al. (1992) and Brodowska et al. (2017) recorded statistically significant decrease of the calcium content in seeds of oilseed rape at treatment without nitrogen application.

Magnesium uptake by seed and straw was nearly equable (Figure 5). The highest average magnesium return transport in a form of straw 66.01% was observed at treatment 3. Similarly, Ložek (2003) found the highest average magnesium uptake by straw 53.50% at treatment fertilized by nitrogen dose 160 kg/ha.

The sulphur uptake by seed varied from 38.83% to 45.74% (Figure 6). The sulphur uptake by primary and secondary harvest product was not recorded increase or decrease depending on increasing doses of nitrogen. This result is in accordance with Varényiová et al. (2017). On the contrary, Siwik-Ziomek & Szcepanek (2017) found increasing rates of nitrogen result in a sulphur growing uptake. The fertilization by sulphur could change content of macroelements in straw. It is in accordance with results of experiment conducted by Ryant & Hlušek (2007), where the sulphur fertilization of white mustard increased nitrogen concentration in plants, decreased nitrogen, potassium and calcium content in the straw, but it did not affect the content of phosphorus and sulphur. The data on per cent nutrients (N, P, K, S) content in seed and straw were significantly influenced after sulphur fertilization (Tripathi et al., 2011).

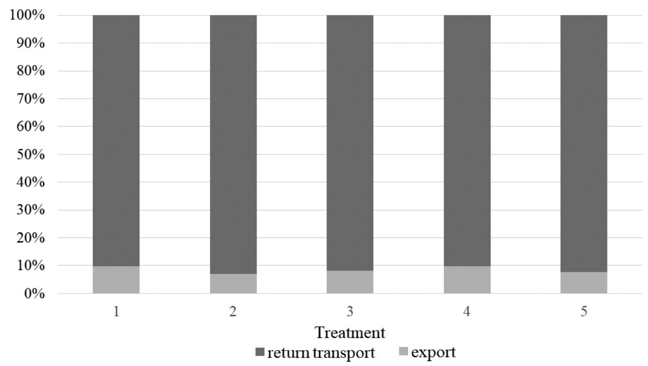

Fig. 4. The calcium uptake by primary (seed) and secondary (straw) harvest product of oilseed rape and its return transport in the form of secondary harvest product (average of experimental years)

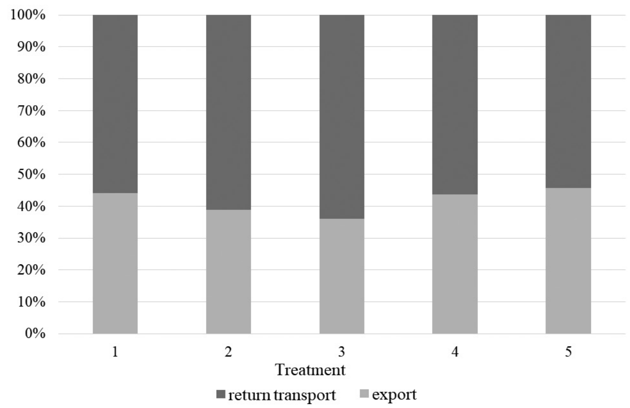

Fig. 6. The sulphur uptake by primary (seed) and secondary (straw) harvest product of oilseed rape and its return transport in the form of secondary harvest product (average of experimental years)

Table 4. Uptake of zinc, manganese, iron and copper by 1 t of oilseed rape seed and straw (average of experimental years).

Treatment	Harvest product	Elements uptake in kg per 1 ha of the main product			
		Zn	Mn	Fe	Cu
1	Seed	0.033	0.255	0.051	0.001
	Straw	0.033	0.052	0.573	0.039
	Seed + straw	0.066	0.307	0.624	0.040
2	Seed	0.032	0.259	0.050	0.001
	Straw	0.016	0.040	0.250	0.005
	Seed + straw	0.049	0.299	0.299	0.006
3	Seed	0.034	0.295	0.054	0.001
	Straw	0.031	0.056	0.834	0.005
	Seed + straw	0.065	0.351	0.887	0.006
4	Seed	0.035	0.278	0.053	0.002
	Straw	0.034	0.062	1.180	0.006
	Seed + straw	0.068	0.340	1.232	0.008
5	Seed	0.034	0.269	0.049	0.001
	Straw	0.021	0.049	0.348	0.011
	Seed + straw	0.054	0.319	0.397	0.012

The zinc, manganese, iron and copper uptake by both harvest products is stated in the Table 4. Similar to nitrogen, the highest average copper uptake by both harvest products was found at unfertilized control treatment 1. The highest average zinc and iron uptake was observed at treatment 4, where the highest average yield of seed was reached. Generally, the lowest average monitored microelements uptake was found at treatment 2, where the lowest dose of nitrogen was applied.

Seeds of winter oilseed rape accumulated more N, P, Ca, Zn, Cu, Mn and Fe than straw. The concentrations of P, Mg and S were higher in straw than in seeds (Jankowski et al., 2016). It was also confirmed, except Ca, Cu and Fe, in experiment in Mojmírovce.

Figures 7, 8, 9 and 10 show the ratio of zinc, manganese, iron and copper uptake by seed and straw. The zinc uptake by seed was higher than return transport, except unfertilized control treatment. The results of other experiments confirmed lower ratio of zinc uptake by straw (Grewal & Graham, 1997; Sakal et al., 1996).

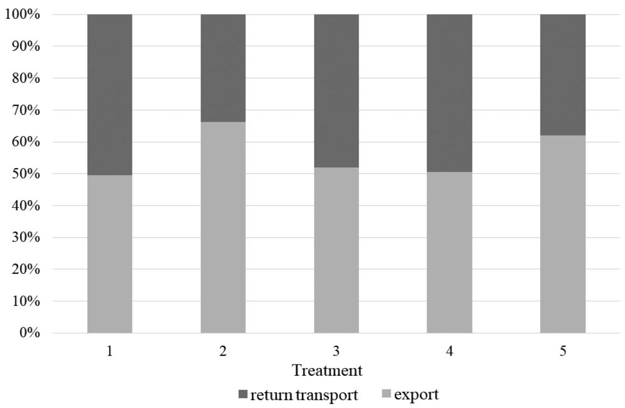

Fig. 7. The zinc uptake by primary (seed) and secondary (straw) harvest product of oilseed rape and its return transport in the form of secondary harvest product (average of experimental years)

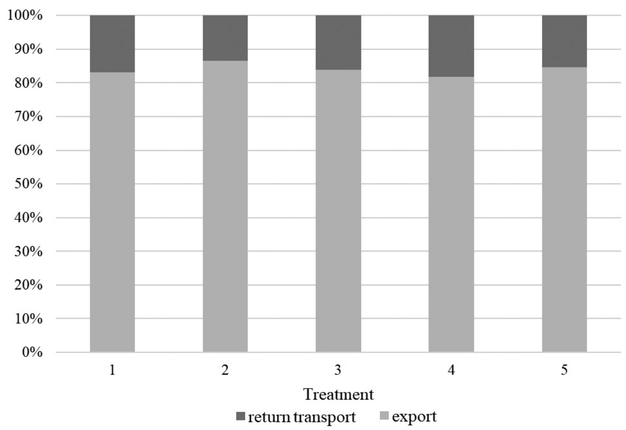

Fig. 8. The manganese uptake by primary (seed) and secondary (straw) harvest product of oilseed rape and its return transport in the form of secondary harvest product (average of experimental years)

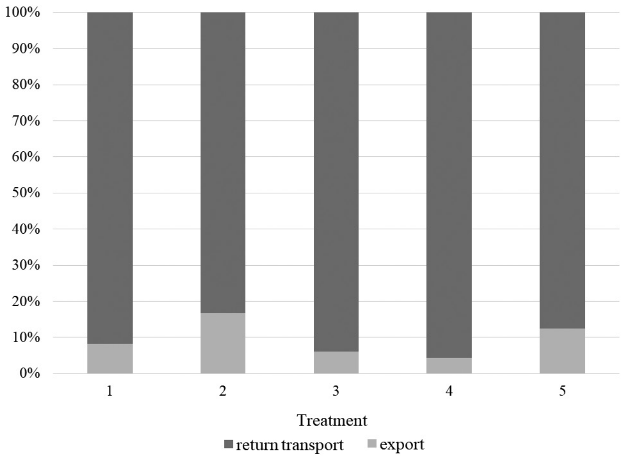

Fig. 9. The iron uptake by primary (seed) and secondary (straw) harvest product of oilseed rape and its return transport in the form of secondary harvest product (average of experimental years)

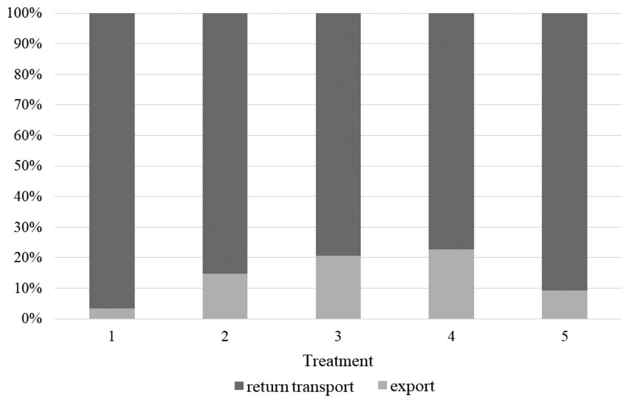

Fig. 10. The copper uptake by primary (seed) and secondary (straw) harvest product of oilseed rape and its return transport in the form of secondary harvest product (average of experimental years)

The manganese return transport fluctuated from 13.49% to 18.26%, while the highest average manganese uptake by straw was found at treatment 4, where the highest average yield of seed was reached. All in all, the manganese export by seed predominated over the return transport at all treatment of experiment. In the case of iron and copper, export was lower than return transport.

The highest average iron return transport, 95.73%, was found at treatment 4, where the highest average yield of seed was detected. The highest average copper return transport, 96.62%, was evaluated at treatment 1 where any nitrogen dose was applied and the lowest yield of seed was obtained, simultaneously.

From results it follows that the concentration of Mn interferes with Fe absorption and translocation. It is in accordance with result of researches realized by Epestein & Stout (1951) and Biddulph & Woodbridge (1952). As Szczepaniak et al. (2015) stated, the accumulation of elements, except P and Zn, in post-harvest residues is closely related to weather conditions and fertilization treatments. It was also found in experiment in Mojmírovce in experimental years 2013/2014 and 2014/2015. The phosphorus and zinc uptake was lower in year 2013/2014 characterized by favourable weather conditions.

Conclusions

Effect of nitrogen nutrition on yield and nitrogen, phosphorus and potassium uptake by primary and secondary harvest product 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 observed parameters was confirmed in this experiment. Generally, higher yields and nutrient uptake was recorded in warmer year 2013/2014 that was also richer in precipitation. The highest average yield 4.33 t/ha was reached at treatment 4 where dose of nitrogen 200 kg/ha was applied. It was not the highest used nitrogen dose. Also, the highest average potassium uptake 24.77 kg/ha was recorded at treatment 4. The highest average nitrogen uptake by both harvest products 41.06 kg/ha was found at unfertilized control treatment 1. There was confirmed that most of phosphorus is taken by seed and in small quantities is returned to soil in a form of straw in this experiment. The highest average phosphorus uptake by seed and straw was found at treatment fertilized by dose 160 kg/ha N.

The hypothesis that the highest average yield and nutrient uptake will be found at treatment fertilized by the highest dose of nitrogen was not confirmed. Straw nutrient uptake ratio N : P : K: Ca : Mg : S was 1 : 0.24 : 1.98 : 1.86 : 0.49 : 0.38 while seed nutrient uptake ratio was equal 1 : 0.15 : 0.19 : 0.05 : 0.07 : 0.01. The lowest microelements (Zn, Mn, Fe and Cu) uptake was found at treatment 2, where the lowest dose of nitrogen was applied.

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