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Effects of different variants of basalt-sulphur improver in the fertilisation of spring oilseed rape

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Abstract. The aim of the research was to test of several variants of basalt-sulphur improver, differing in the ratio of the two components, and to select the most suitable one for oilseed rape. Basalt dust, which is a troublesome by-product of rock processing, and elemental sulphur were used to produce the improver. The study included 3 improver variants with 1, 1.5 and 2% S and a control treatment without an improver. The experiment was conducted in concreted microplots filled with two soils: sandy loam and loamy sand, in a split-block two-factor design, in 4 replicates. The most suitable variant for rapeseed was the variant containing 1.5% S, which resulted in a 12% increase in rapeseed yield on sandy loam. Moreover, for this variant, an increase in seed fat content, an increase in the bioavailable form of sulphur in the soil and an increase in the concentration of this nutrient in oilseed rape straw and seed were observed on both soils.

Keywords: oilseed rape, soil improver, basalt dust, sulphur, seed yield, fat, soil pH

INTRODUCTION

Oilseed rape is one of the crops occupying the largest acreage in Poland, with a sown area of around one million hectares (Statistical Yearbook 2022). This species is particularly sensitive to sulphur deficiency. It is also characterised by a much higher demand for this component than other species, such as cereals or legumes (Zhao et al., 1997). Rapeseed take up about 10 to 25 kg of sulphur per hectare, while legumes take up 5 to 10 kg ha^{-1}, depending on cultivation, soil and environmental factors (Singh, Singh, 2016; Chahal et al., 2020). In an unpublished study of our own, we found that under the same soil conditions, the sulphur content of rape, was about 3 times that of wheat grain and more than 1.5 times that of pea seed. Rapeseed straw contained as much as 6 times more of this nutrient compared to wheat straw and 2.5 times more compared to pea straw (Figure 1). The high S content of rapeseed plants indicates a significant uptake of this element from the soil and the need for fertilisation if a deficiency is found in the soil.

The drastic tightening of environmental standards (Dyrektywa 2010/75/EU) has resulted in an increasing sulfur deficit in Polish soils. While in 1990, SO_2 emissions in Poland were at the level of 2 679 000 tonnes, in 2020 they were only 431 000 tonnes (Raport syntetyczny 2022). The occurrence of sulphur deficiencies in soils was contributed to a significant reduction in SO_2 emissions from industrial sources, a significantly lower consumption of manure and a change in the mix of mineral fertilisers used by farmers, mainly phosphate fertilisers.

In the situation of sulphur deficiency in the soils of our country (Siebielec et al., 2012; Szulc, 2008), fertilisation of rape with this component becomes a necessity, which should bring a beneficial effect in the form of yield increase and improvement of its quality. The beneficial effect of sulphur on rapeseed yield is reported by Dobrokhotov et al. (2023), Egesel et al. (2009) and Varenyiova et al. (2017). In addition to an increase in yield, sulphur fertilisation can also increase the fat content of rape seeds (Malarz et al., 2011; Rameeh et al., 2021; Sienkiewicz-Cholewa, Kieloch, 2015). This is of great benefit to the farmer, as the price of oilseed rape at buying depends on the oil content of the seed. The standard at purchase in Poland for technological oilseed rape is a fat content of 40%. A lower purchase price is applied for contents below 40%. Surcharges are also possible for contents above 40%, which amount to 1.0–1.5% of the initial price for each 1% of oil.

However, sulphur fertilisation often has an acidifying effect on the soil (Akay et al., 2019; Gupta et al., 1988; Karimizarchi et al., 2014; Skwierawska et al., 2008), which is an unfavourable because most soils in Poland are slightly acidic or acidic.

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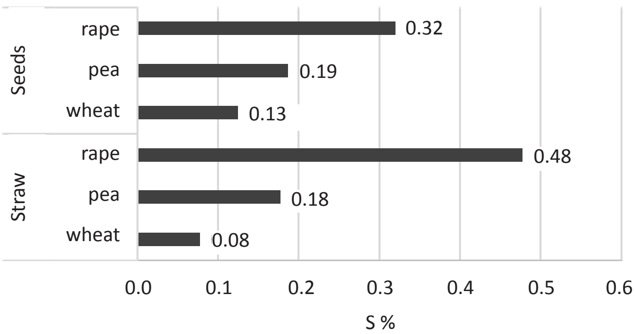

Figure 1. Sulphur content of rapeseed, wheat and peas growing on the same soil (unpublished own research).

One possibility to reduce the acidifying effect of sulphur is its application in combination with basalt dust. Ongoing research using basalt dust in crops has shown that basalt introduced into soils, especially acidic soils, can improve the pH and other physicochemical parameters of the soil (Garbowski et al., 2023; Gillman et al., 2002; Luise et al., 2020).

The combined application of basalt dust with sulphur, in the form of a single product, is a completely new solution. It is particularly advantageous to prepare this product in granular form instead of a dusty mixture, which is troublesome for the farmer during application. Due to the novelty of the idea, there is no information in the literature on the combined application of basalt dust and sulphur. Only reports can be found on the positive effects of the combined application of dust with compost, manure or NPK on soil properties and plant development (Seidel, 2021; Tamfuh et al., 2019; Hendronursito et al., 2019). At the same time, the management of dust generated during basalt processing is a pro-environmental measure. The elimination of nuisance dust dumps, that arise near rock mines, could contribute to improving the landscape value of the surrounding area and reducing air dust. Such dumps are currently a major environmental problem, especially in the Lower Silesia region. The proposed basalt-sulphur product should have an appropriate ratio of sulphur to basalt dust, so that the amount applied under rape ensures that the optimum soil pH is maintained, while at the same time the dose of sulphur introduced together with the dust meets the nutritional needs of rape and is not excessive. Previous studies by the authors on the combination of sulphur and ground phosphate showed that the ratio of the two components was important in both yield-forming and environmental aspects (Korzeniowska et al., 2012).

The aim of the present study was to test the effect of several variants of basalt-sulphur improver differing in the mutual ratio of the two components and to select the most suitable one for spring oilseed rape.

MATERIAL AND METHODS

The microplot experiment

In 2022, a microplot experiment with spring oilseed rape of the Lumen F1 cultivar was conducted at the IUNG-PIB Experimental Station in Jelcz-Laskowice near Wrocław. In the summer of the previous year, concreted microplots measuring 1 m × 1 m × 1 m were filled to a depth of 40 cm with two soils from fields near Jelcz-Laskowice. These soils, labelled A and B, were selected so that they differed in texture and had as low a sulphur content as possible (Table 1). The use of microplots allowed the elimination of uncontrolled soil variability, which reduced experimental error and increased the reliability of the study.

In the experiment, 3 variants of a soil improver made from basalt dust and elemental sulphur were tested against a control treatment without improver application. The soil improvers tested differed in sulphur content: 1%, 1.5% and 2% S, and thus the ratio of dust to sulphur. The '1%S' variant contained the most dust and the least sulphur, while the '2%S' variant contained the least dust and the most sulphur. The basalt dust came from the "BAZALT-GRACZE" Rock Raw Materials Company and the sulphur from the "Siarkopol-Tarnobrzeg" company. The composition of basalt dust is presented in Table 2.

Table 1. Characteristics of experimental soils.

Soil	pH	P_2O_5	K_2O	Mg	S-SO_4	Corg [%]	Fraction in mm			
							2.0–0.05	0.05–0.002	<0.02	<0.002
		mg (100 g)$^{-1}$					%			
A (sandy loam)	6.5	19.1 m	23.0 h	6.3 m	0.65 l	0.8	65.9	30.1	24.4	4.0
B (loamy sand)	6.2	21.3 h	25.7 vh	8.4 vh	0.58 l	0.7	73.2	23.6	19.0	3.2

S assessment according to Lipiński et al. (2003); P, K, Mg assessment according to Fertilizer Recommendations (1990); l – low, m – medium, h – high, vh – very high

Table 2. Composition of basalt dust [%].

SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	SO_3	Cl	F	Loss on ignition
40.71	2.18	10.76	12.01	0.20	14.15	12.83	3.3	0.85	0.94	0.01	0.10	0.01	1.90

The experiment was carried out as a two-factor, split-block experiment, in four repetitions. The experimental design included 2 treatments of the first factor and 4 treatments of the second factor: factor I – soil type: sandy loam (A) and loamy sand (B); factor II – improver variant: control treatment-without improver, 1% S improver, 1.5% S improver and 2% S improver. The experiment contained a total of 32 plots (2 treatments of factor I × 4 treatments of factor II × 4 replicates).

The test improvers were hand-sown in spring 2022 and mixed into the soil 2 weeks before sowing rape. The plant density was 60 plants/m^2. The doses of the improvers were determined on the basis of the sulphur dose, taking 40 kg ha^{-1} S as the optimum dose for oilseed rape (Table 3). NPK fertilisation was applied as background, identical to all experimental plots. Nitrogen was divided, applying 60 kg N pre-sowing and and 40 kg N as top-dressing.

Table 3. Doses of tested improvers and NPK fertilizers [kg ha^{-1}].

Treatment	Improver	N	P_2O_5	K_2O
Control	0	100 (60 + 40)	50	100
1%S	4000 (40 S + 3960 dust)	100 (60 + 40)	50	100
1.5%S	2667 (40 S + 2627 dust)	100 (60 + 40)	50	100
2%S	2000 (40 S + 1960 dust)	100 (60 + 40)	50	100

Emerging weeds were removed by hand. The microplots were screened with netting to protect the maturing plants from birds and watered in case of prolonged dry periods. Plants were cut at full maturity. The pods were cut, dried and then threshed by hand. Seed and straw yields were determined individually for each microplot. Seed and straw samples were ground and chemically analysed. The detailed dates of the agrotechnical treatments are shown in Table 4.

Table 4. Dates of agrotechnical actions of spring oilseed rape.

Action	Date
Application of NPK and improvers	01.03
Sowing of rapeseed	22.03
Emergence	20.04
N top-dressing	13.05
Harvesting rapeseed	27.07
Soil sampling	11.08

Before filling the microplots, soils A and B were sampled to determine their initial properties. After harvesting the plants, soil samples from the 0–20 cm layer were taken from each plot using an Egner soil stick. Five sub-samples were taken within a plot, the collected material was combined and carefully mixed, then dried and sieved through a 2 mm sieve.

Chemical analyses

In soil samples, texture was determined by the areometric method (PN-R-04033:1998), pH – by potentiometric method in KCl solution (ISO10390:2005), organic carbon (Corg) by the Thiurin method (PB 021-issue. IV-28.08.2020), available P and K by the Egner-Riehm method (PN-R-04022:1996) and Mg by the Schachtschabel method (PN-R-04020:1994). Moreover, exchangeable Ca was determined in the soil using the FAAS method (PB 030-issue IV-28.03.2022), total S (S-tot) using the ICP-OES method (PB 111-issue IV-24.02.2020) and S-SO_4 using the ICP-OES method (PB 110.3-issue II-17.06.2013).

Seed and straw samples, after microwave digestion, were determined for S content by ICP-OES (PB 111-issue IV-24.02.2020). N content, after mineralisation with sulphuric acid, was determined by continuous flow analysis (CFA) with spectrophotometric detection (PB 033-issue IV-24.02.2020), and Ca and Mg by FAAS (PB 032-issue IV-24.02.2020).

The fat and protein content of the seeds was determined using the INSTALAB 600 seed composition analyser (DICEY-john Corporation), using Near Infrared Spectroscopy (NIRS).

Chemical analyses were carried out at the Main Chemical Laboratory of the Institute of Soil Science and Plant Cultivation – State Research Institute (IUNG-PIB) in Puławy, accredited by the Polish Centre for Accreditation (certificate number AB 339 on the basis of the PN-EN ISO/IEC 17025 standard).

Statistical calculations

Soil pH and the content of sulphur, calcium and magnesium in soils and plants as well as seed and straw yields were subjected to analysis of variance using the Tukey HSD test ($P < 0.05$) with the AWAR programme developed at IUNG-PIB (Filipiak, Wilkos, 1995).

RESULTS AND DISCUSSION

Soil pH

At the end of the growing season, the pH of both soils was slightly acidic, with no significant differences in pH values between the control and the tested basalt-sulphur improver variants (Table 5). Regardless of the percentage of sulphur in the improver, the pH of both soils remained within the range of 6.0–6.2. It is likely that the basalt component in the improver increased the pH of the soil and thus offset the acidifying effect of sulphur. Similar results were obtained by other authors. Studies by Gillman et al. (2002) and Luise et al. (2020) show that the application

Table 5. Soil pH and soil nutrient concentration after harvest.

Soil	Treatment	pH	Ca	Mg	S-tot	$S\text{-}SO_4$	$S\text{-}SO_4$/S-tot
			mg (100 g)$^{-1}$				[%]
A sandy loam	control	6.1 a	82.8 a	7.7 a	14.0 a	0.510 a	3.6
	1%S	6.2 a	86.8 ab	7.4 a	14.9 ab	0.868 b	5.8
	1.5%S	6.1 a	89.4 b	7.3 a	15.6 b	0.990 b	6.3
	2%S	6.2 a	89.6 b	7.7 a	15.6 b	0.728 a	4.7
B loamy sand	control	6.1 a	75.2 a	8.1 b	13.0 a	0.603 a	4.6
	1%S	6.1 a	74.7 a	9.0 c	14.2 b	0.945 b	6.7
	1.5%S	6.0 a	73.8 a	9.7 c	14.2 b	1.200 b	8.5
	2%S	6.1 a	76.6 a	6.8 a	14.6 b	0.780 b	5.3

Values marked with the same letters within a single soil are not significantly different according to Tukey HSD test, $P < 0.05$. Treatment symbols – see Table 3.

of powdered basalt rock increases the pH of the soil and also significantly reduces its exchangeable acidity and improves its cation exchange capacity.

Soil calcium and magnesium content

Increased exchangeable calcium content was only found in soil A, which as a sandy loam had a higher sorption complex than soil B. However, no significant differences were observed between the different improver variants.

The content of available magnesium did not change compared to the control in soil A, while it differed in soil B. Compared to the control, the 1%S and 1.5%S variants increased the content of available magnesium, while the 2%S variant decreased this content. Conceição et al. (2022) observed a 13–15-fold increase in the availability of magnesium and calcium due to the application of basalt dust alone, as well as an increase in the availability of phosphorus and potassium compared to the treatment without basalt. Perhaps the excessive proportion of sulphur in the 2%S variant had the effect of reducing the available magnesium content compared to the control treatment. Garbowski et al. (2023), citing other researchers, stated that basalt dust is an effective addition to acidified soils as it enriches them with key plant nutrients (Green et al., 2013; Shamshuddin et al., 2011; Ramos et al., 2017).

Soil sulphur content

The tested soils differed slightly in initial total sulphur (S-tot) content. In sandy loam (A) 14 mg (100 g)$^{-1}$, and in loamy sand (B) 13 mg (100 g)$^{-1}$ were found on the control (Table 5). All the soil improver variants tested resulted in a significant increase in S-tot content compared to the control treatment. The differences in the soil content of this nutrient between the variants were not significant. Soil A was enriched in S-tot by 6–11% and soil B by 9–12%.

The most important source of sulphur for plants is sulphate form ($S\text{-}SO_4$). The plant-available $S\text{-}SO_4$ content was 0.51 mg (100 g)$^{-1}$ on the control in soil A and 0.60 mg (100 g)$^{-1}$ on soil B (Table 5). In soil A, the 1% S and 1.5% S variants caused a significant increase in $S\text{-}SO_4$ compared to the control, while the 2% S variant did not. In soil B, on the other hand, all of the improver variants increased the soil $S\text{-}SO_4$ content significantly compared to the control.

The application of basalt-sulphur improver generally increased the proportion of $S\text{-}SO_4$ in the soil S-tot pool. In soil A, sulphate accounted successively for 4.7%, 5.8%, 6.3% of S-tot for the variants, respectively: 2%S, 1%S, 1.5%S. In soil B, the order of variants was the same. The least amount of $S\text{-}SO_4$ relative to S-tot was found after the application of the 2% S improver (5.3%) and the most for the 1.5%S improver (8.5%). According to Scherer (2009), sulphate generally constitute less than 5 % of total S. At the same time, this author, citing earlier publications (Chen et al., 1997; Hu et al. 2005), reports that precipitation of SO_4^{2-} with calcium and magnesium occurs in soils, making sulphur unpalatable to plants. It is reasonable to assume that the different effects of the different improver variants on the $S\text{-}SO_4$ content of the soil were due to the different basalt-to-sulphur ratio, and thus the different ratio of sulphur to the calcium and magnesium contained in the basalt.

Plant yield

Seed yield of rape on the control without basalt-sulphur improver, was at similar levels on both soils and was 310 and 330 g m^{-2}, corresponding to 3.1 and 3.3 t per hectare (Figure 2). The pre-sowing application of basalt with sulphur resulted in a significant 12% increase in seed yield compared to the control. However, this was only true for the sandy loam (A) and the 1.5%S variant. For the other variants, non-significant yield increases of a few per cent were obtained on soil A. On the other hand, on loamy sand (B), no differences in seed yields were found between the control and the three basalt-sulphur improver variants.

Straw yield on soil A, like seed yield, was highest for the 1.5%S variant (Figure 2). The yield increase compared to the control was 12%. The differences between the con-

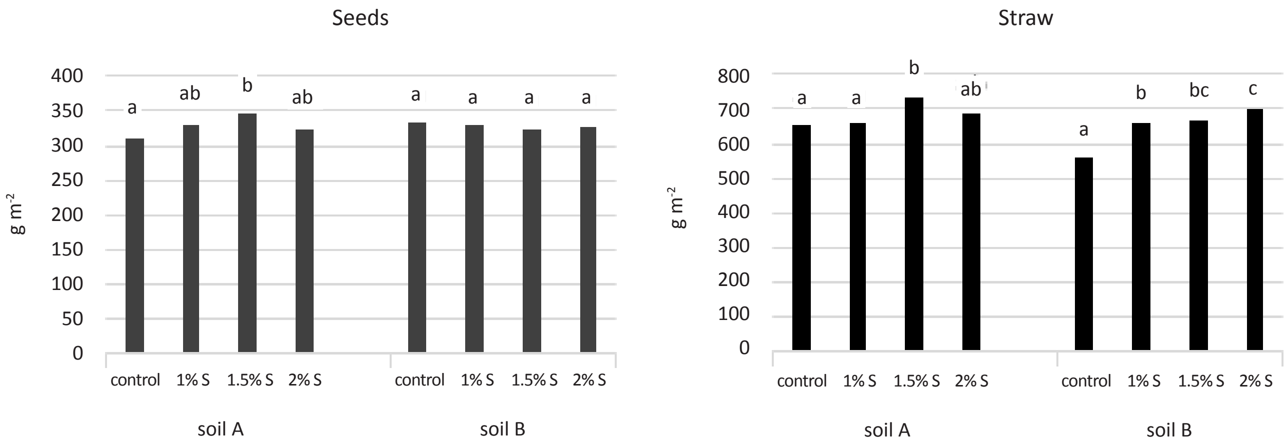

Figure 2. Seed and straw yield of spring oilseed rape on sandy loam (A) and loamy sand (B).
Values marked with the same letters within one soil are not significantly different according to Tukey HSD test, $P < 0.05$. Treatment symbols – see Table 3.

trol and the other variants were not significant. On soil B, on the other hand, each improver variant resulted in a significant increase in straw yield of 17–24% compared to the control. The highest yield increase was obtained with the 2%S variant.

There are no papers in the literature describing the effect of combined basalt dust and sulphur application on oilseed rape yield. However, many authors have reported beneficial effects of basalt dust or sulphur separately on the yield of different crop species. For example, an increase in cassava and maize yields after basalt application has been reported (Hendronursito et al., 2019; Zuffo et al., 2022: Luchese et al., 2023). The positive effect of sulphur on yields of oilseed crops in the Brassicaceae family is a well-known and frequently reported issue in the literature (Chahal et al., 2020; Verma et al., 2022).

Sulphur and other nutrient content of oilseed rape

Rapeseeds grown on the plot without basalt-sulphur improver application contained similar amounts of sulphur on soil A and B, 0.32 and 0.30% DM, respectively (Figure 3). The improver introduced in soil A did not change the concentration of this nutrient in the seeds, regardless of the variant. However, in rapeseeds growing on soil B, the application of the 1.5%S variant significantly increased the sulphur content to the level observed in seeds on soil A. The other improver variants introduced into soil B did not change the sulphur concentration in seeds compared to the control.

The straw of the control on soil A contained more sulphur than on soil B, 0.48% and 0.41% DM, respectively (Figure 3). The improver application significantly

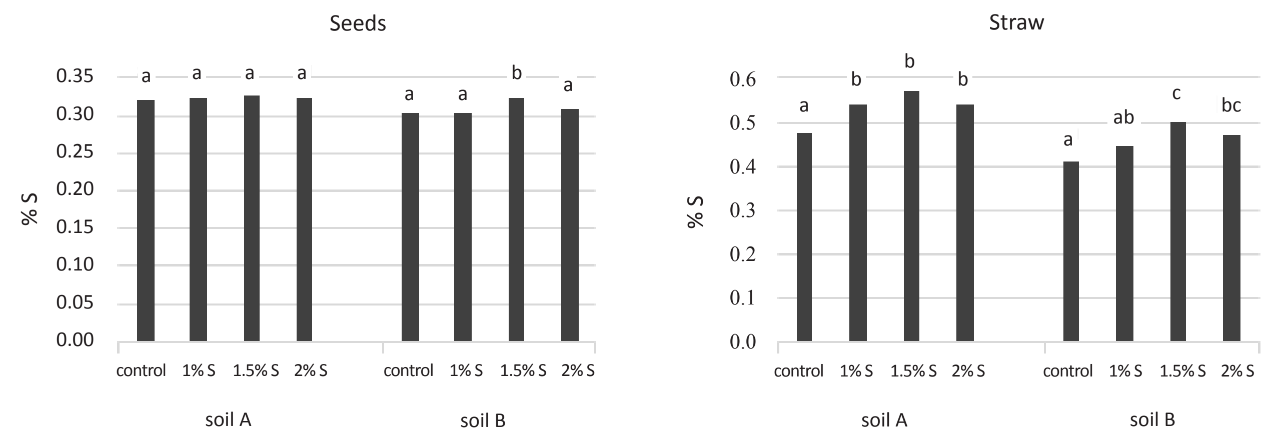

Figure 3. Sulphur content of spring oilseed rape seeds and straw on sandy loam (A) and loamy sand (B).
Values marked with the same letters within one soil are not significantly different according to Tukey HSD test, $P < 0.05$. Treatment symbols – see Table 3.

increased the concentration of this nutrient in the straw on both soils. On soil A, the increase was in the range of 12–19% compared to the control, but no significant differences were proven between the improver variants. On soil B, the highest sulphur content in straw was found after application of the 1.5%S variant, which was 22% higher compared to the control. At the same time, no significant difference was found between the 1.5%S and 2%S variants, and the 1%S variant was not significantly different from the control treatment.

Sulphur is involved in nitrogen metabolism in the plant. Its deficiency may limit the use of this basic yield-forming nutrient.

Under conditions of sulphur deficiency, not only a reduction in plant yield occurs, but also the quality of crop is reduced due to an increase in non-protein nitrogen in plants (Brodowska, 2004; Krauze, Bowszyc, 2000; Scherer, 2001).

The nitrogen content in rape seeds not fertilised with the basalt-sulphur improver was 3.67% DM on sandy loam (A) and 3.39% DM on loamy sand (B). The application of sulphur, contained in the basalt-sulphur improver, did not change the total nitrogen content of the seeds, regardless of soil type and improver variant (Table 6).

In the straw, however, there were differences in the content of this nutrient (Table 6). On soil A, the straw from the control contained 0.58% N, and under fertilisation with the 1.5%S variant there was a significant increase to 0.66% DM. The increase in N concentration for the other basalt-sulphur variants was not statistically significant. On soil B, the straw from the control treatment contained 0.50% N. The application of the 1.5%S and 2%S variants significantly increased the nitrogen concentration in the straw to 0.56% and 0.58%, respectively.

After application of the improver, the calcium and magnesium content of the seeds remained unchanged compared to the control (Table 6). In the straw, however, the calcium content increased significantly on the 1%S and 1.5%S treatments for soil A and on the 1.5%S treatment for soil B. The magnesium content of the straw did not change compared to the control, with the exception of the treatment on soil B, where the 1.5%S variant was used. Other authors have reported a beneficial effect of basalt dust application alone on plant nutrient content. Conceição et al. (2022) observed that maize and beans grown on basalt-enriched soils accumulated up to 5 times more macro- and micronutrients than plants without basalt dust application.

Fat and protein content of the seed

Oilseed rape on the control treatments, without basalt-sulphur improver, contained 38.0 and 38.5% seed fat on soil A and B, respectively (Table 7). Seed crude fat content is a species and varietal trait that is only to some extent affected by natural and agrotechnical factors. However, they play an important role in shaping seed quality (Szczepaniak et al., 2022). Of the natural factors, high temperatures during the growing season can affect the decline in seed fat content (Aksouh-Harradj et al., 2006). Nitrogen fertilisation, which is the main yield-forming factor, has a positive effect on protein content, but a negative effect on seed fat content. Many authors report that these traits are negatively correlated, i.e. the higher the seed protein content, the lower the fat content (Varényiová et al., 2017; Szczepaniak et al., 2022). However, no such regularity was observed in our study. The application of the improver, containing basalt and sulphur, caused a significant increase in the fat concentration in seeds of rape growing on soil A from 38% to 40.5% and 40.2% for the variants 1.5%S and 2%S, respectively (Table 7). At the same time, none of the improver variants significantly changed the protein content of the seeds. For soil B, there was a significant increase in seed fat from 38.5% to 40.5% for the 1.5%S and 1%S variants. At the same time, the seeds were significantly enriched in protein as a result of the 1.5%S improver application. In addition, a trend towards increased protein content was observed with the application of the other variants.

Table 6. Content of selected macronutrients in seeds and straw of spring oilseed rape.

Soil	Treatment	Seeds			Straw		
		N	Ca	Mg	N	Ca	Mg
		% DM					
A sandy loam	control	3.67 a	0.39 a	0.33 a	0.58 a	1.20 a	0.12 a
	1%S	3.67 a	0.41 a	0.34 a	0.61 ab	1.42 b	0.12 a
	1.5%S	3.63 a	0.40 a	0.34 a	0.66 b	1.44 b	0.13 a
	2%S	3.55 a	0.40 a	0.33 a	0.60 ab	1.32 ab	0.12 a
B loamy sand	control	3.39 a	0.40 a	0.35 a	0.50 a	1.20 b	0.11 a
	1%S	3.48 a	0.41 a	0.34 a	0.49 a	1.25 b	0.11 a
	1.5%S	3.46 a	0.41 a	0.35 a	0.56 b	1.38 c	0.14 b
	2%S	3.44 a	0.40 a	0.34 a	0.58 b	1.15 a	0.11 a

Values marked with the same letters within a single soil are not significantly different according to Tukey HSD test, $P < 0.05$. Treatment symbols – see Table 3.

Table 7. Fat and protein content in spring oilseed rape seeds.

Soil	Treatment	Fat [%]	Increase[1] [%]	Protein [%]	Increase[1] [%]
A sandy loam	control	38.0 a	100	19.2 a	100
	1%S	39.3 ab	103	19.7 a	103
	1.5%S	40.5 b	107	19.9 a	104
	2%S	40.2 b	106	19.0 a	99
B loamy sand	control	38.5 a	100	18.5 a	100
	1%S	40.5 b	105	19.1 ab	103
	1.5%S	40.5 b	105	19.4 b	105
	2%S	39.5 ab	103	19.2 ab	104

[1]Increase – relation to control treatment.
Treatment symbols – see Table 3.
Values marked with the same letters within one soil are not significantly different according to Tukey HSD test, $P < 0.05$.

No studies were found in the literature on the effect of the combined application of sulphur and basalt dust on the fat content of oilseed rape or other oilseed crops. In contrast, various reports can be found on the effect of fertilisation with sulphur alone or with sulphur and nitrogen together. Khan et al. (2002) obtained an increase in rapeseed fat content from 40.8 to 44.7% as a result of the application of sulphur alone at a dose of 60 kg S ha^{-1}. However, the above-mentioned dose of sulphur applied together with nitrogen fertilisation (120 kg N ha^{-1}) reduced the fat content in the seeds compared to the treatment where only sulphur was applied. Wang et al. (2008) found that application of sulphur alone increased yield and seed fat content, but had no effect on seed protein content. The application of sulphur together with nitrogen increased seed yield and fat content and in most cases increased seed protein content compared to the effect of fertilisation with nitrogen alone. These authors found that increasing the sulphur rate from 15 to 30 kg S ha^{-1} had no effect on seed fat and protein content. In a study by Varényiová et al. (2017), the fat content of rape seeds reached 45.1%, 45.5% and 44.1% after application of 15, 40 and 65 kg S$^{.}$ ha^{-1}, respectively. The application rate of 65 kg S$^{.}$ ha^{-1} resulted in a significant decrease in yield and a statistically insignificant decrease in seed fat content. Rameeh et al. (2021) report that rape seed fat content ranged from 46.7% to 49.4% and increased significantly with increasing sulphur doses. The increase in rape seed fat content due to sulphur fertilisation may be related to the fact that S is a component of glutathione, which plays an important role in fat synthesis (Verma et al., 2022).

CONCLUSIONS

1. The effects of using a basalt-sulphur soil improver in oilseed rape cultivation varied depending on the percentage of sulphur in the tested product, i.e. the variant containing 1.5% sulphur proved to be the most suitable for oilseed rape among the tested variants.
2. The 1.5%S improver caused a significant increase in soil sulphate, which is the most important source of sulphur for plants. It also contributed to an increase in the proportion of S-SO_4 in the total sulphur pool. Consequently, there was an increase in S content in the straw of rape grown on both soils and in the seeds of rape on loamy sand.
3. The application of the 1.5%S improver resulted in a 12% increase in seed yield and the same increase in straw yield of rape growing on sandy loam, as well as a 19% increase in straw yield on loamy sand.
4. A significant effect of the application of the 1.5%S variant was an increase in the fat content in the seeds to above 40% DM on both soils and an increase in protein content only in the case of loamy sand.
5. The application of the 1.5%S variant resulted in an increase in the concentration of nitrogen and calcium in the straw of oilseed rape growing on both soils and magnesium in the case of loamy sand.
6. Even though the tested variants of the improver contained sulfur, none of them acidified the soil. The high proportion of basalt in the improver balanced the acidifying effect of sulphur.

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