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SULPHUR AS A FACTOR THAT AFFECTS NITROGEN EFFECTIVENESS IN SPRING RAPESEED AGROTECHNICS. PART I. CHOSEN YIELD COMPONENTS

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Abstract. Strict, three-year-long field experiment was performed on degraded Phaeozems, IIIb soil valuation class, with pH ranging from 6.5 to 7.1, of high richness in phosphorus and potassium, medium in magnesium, and low in sulphur. The experiment was carried out in a split-block design with two factors in four repetitions. The aim of the study was to evaluate the effect of various doses of nitrogen (0, 60, 120, and 180 kg·ha^{-1}) and sulphur (0, 20, and 60 kg·ha^{-1}), taking into account their different application methods (in-soil and as foliar fertiliser), on the yield components of spring rapeseed cultivar Star. Fertilisation only with nitrogen significantly increased the values of all the studied components, while the sulphur-only fertilisation increased the number of seeds in siliques, as well as the mass of 1000 grains. The number of seeds per silique in none of the research years was significantly affected by the interaction between nitrogen and sulphur. As far as other characteristics are concerned, considering sulphur alongside nitrogen fertilisation, in general, resulted in a significant increase in their values, in comparison with the control plants.

Key words: fertilisation, nitrogen, spring rapeseed, sulphur, yield components

INTRODUCTION

Growing rapeseed cultivars deprived of erucic acid in fat caused rapeseed seed oil to become a balanced food product, and significant decrease in glucosinolate content in the seeds made it possible to use solvent cake as fodder component [Bartkowiak-Broda *et al*. 2005]. In recent years in Poland, interest in rapeseed cultivation increased due to the use of its seeds also for the production of fuel for diesel engines [Kaczor *et al*. 2003].

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Due to a high demand for oilseed crop seeds, spring rapeseed growth has become an alternative for producers. Breeders' response to an increasing role of spring rapeseed is the introduction of new, improved cultivars, including hybrids, with significantly higher yield potential. Utilization of spring rapeseed yield potential, like the ones of other cultivated plants, is determined by environmental, as well as agrotechnical factors. In rapeseed cultivation, among agrotechnical factors, nitrogen fertilisation is of particular importance, as it is considered to be one of the most important yield-forming factors. Sulphur fertilisation has a significant effect on nitrogen uptake and effectiveness [Bartkowiak-Broda *et al*. 2005]. Sulphur, due to the effect of on the metabolism of this component, determines protein content and quality, as well as fat synthesis, in the seeds of oilseed crops [Cieśliński *et al*. 2007, De Pascale *et al*. 2007, Abdallah *et al*. 2010, Król and Wiśniewski 2014]. Proper plant supply in sulphur, by protein biosynthesis improvement, significantly decreases the number of micromolecular nitrogen compounds in the cells, which are the main factor conducive to pathogenic infections. Many studies [Figas *et al*. 2008, Gaj and Klikocka 2011] point to the improvement in plant resistance to biotic stress through its proper nutrition with sulphur.

Rapeseed, alongside other species from the *Brassicaceae* family, is classified as a plant with high nutritional needs regarding sulphur. Reports from recent years indicate unambiguously progressive shortage of this element in the soils of many regions of the world [Ceccotti *et al*. 1998, McGrath *et al*. 2003, Zhao *et al*. 2003], also of Poland [Wielebski and Wójtowicz 2000, Szulc 2008]. This results first of all from limiting the emission of sulphur compounds to the atmosphere from anthropogenic sources [Stern 2005], changes in the assortment of fertilisers that contain sulphur, and limiting manure use [Rutkowska *et al*. 2009].

Although the problem of yield-forming effectiveness of nitrogen and sulphur in plant agrotechnics from the *Brassicaceae* family has been the subject of numerous studies for some time [Asare and Scarisbrick 1995, Lošak and Richter 2003], the problem of the effect of fertilisation with these elements on the formation of the particular yield components has not reached too many studies so far.

In relation to the prognoses for deepening deficit of this element in plant production [Morris 2007], study was set up, the aim of which was to determine the effect of spring rapeseed supply in nitrogen and sulphur, and also the interaction of those elements, on the formation of yield components.

MATERIAL AND METHODS

Three-year-long field experiment was located in Kaźmierzewo (52^{o}73' N; 18^{o}88' E), a town in the commune of Mrocza, in the Kuyavian-Pomeranian Voivodeship. Kaźmierzewo is situated circa 25 km north-west of Bydgoszcz, in the river Brda watershed, on the south-east edge of the Krajeńskie Lake District. The experiment was set up on degraded Phaeozems, defective wheat complex, IIIb soil valuation class. The soil was of neutral pH, of high richness in the assimilable forms of phosphorus, average in magnesium and low in sulphur (Table 1). Open pollinated spring rapeseed cultivar Star (DLF Trifolium, Denmark) was grown on the plot after sugar beet.

On one plot, two experiments were located next to one another in identical designs, differing only in the methods of sulphur application, and between them a control plot joint for both experiments was situated, with no sulphur fertilisation. In the first experiment, sulphur was applied pre-sowing (in-soil), and in the second one top--dressing (foliar). They were set up in a split-block design with two factors in four repetitions. Plot area for harvest amounted to 18 m^2.

In the experiment, the following factors were taken into account:
- first degree factor (A): nitrogen fertilisation doses (in kg $N \cdot ha^{-1}$: 0 (control plot), 60, 120,180),
- second degree factor (B): sulphur fertilisation doses (in kg $S \cdot ha^{-1}$: 0 (control plot), 20, 60).

Table 1. Chemical properties of soil humus layer (0-25 cm) prior to the plot experiment

pH_{KCl}	P	K	Mg	$S\text{-}SO_4^{2-}$
	$mg \cdot kg^{-1}$			
6.5-7.1	230-246	125-225	35-38	1.90-1.96
	Content in soil			
pH neutral	high	high	medium	low

In the experiment with pre-sowing (in-soil) sulphur application, both doses were applied at the same time, after field smoothing. In the experiment with top-dressing (foliar) sulphur application, the doses were split, and at full emergence on all the fertilised plots, 20 kg $S \cdot ha^{-1}$ was applied once, and on the plots with the dose of 60 kg $S \cdot ha^{-1}$, additional 20 kg $S \cdot ha^{-1}$ was applied after stem formation and 20 kg $S \cdot ha^{-1}$ at the beginning of flowering. Apart from the described diversification in sulphur doses, all the other agrotechnical elements were the same in both experiments. Nitrogen fertilisation was applied in split doses of 60 kg $N \cdot ha^{-1}$. The first dose was applied pre-sowing in the form of borated salpetere and ammonium nitrate (1:1), and the subsequent doses (the first one 3-4 weeks between flowering, the second one at the beginning of flowering) only in the form of ammonium nitrate. Sulphur was applied in the form of sodium sulphate.

Before winter ploughing, phosphorus-potassium-magnesium fertilisation was applied in the form of multiple fertiliser, through introducing 100 kg $K \cdot ha^{-1}$, 26 kg $P \cdot ha^{-1}$, and 29 kg $Mg \cdot ha^{-1}$. Forecrop for spring rapeseed was sugar beet. In the subsequent years, sowing was performed on April 7th, 15th, and 8th. Threshings were conducted, respectively, on August 12th, 17th, and 2nd.

In every growth season, chemical plant protection was applied. Against *Ceutorhynchus spp.*, cypermethrin (Cyperkill 25 EC) was applied every year at the beginning of budding at the dose of 0.12 $dm^3 \cdot ha^{-1}$, and *Meligethes aeneus* was controlled as it appeared with the use of deltamethrin (Decis 2,5 EC) at the dose of 0.3 $dm^3 \cdot ha^{-1}$. Also fungicide control was applied with the use of chemicals that contained active substances from imidazol and triazol groups (Toprex 375 SC and Timor 240 EC).

Directly before spring rapeseed harvest, for 20 randomly chosen plants from the inside of the lowland meadow of each plot, the number of siliques per plant and seeds per silique were marked. Additionally, the mass of 1000 grains was calculated.

The most favourable weather conditions for spring rapeseed growth and development occurred in the first year of the experiment. Systematic showers after sowing, both in April and May, favourable precipitation distribution in June and high precipitation in July positively affected rapeseed growth. In May of the second year, precipitation sum was high, but its distribution was unfavourable. After rainy first days of the month, nearly four-week-long dry period occurred, which fell on the rosette-formation stage. On the other hand, abundant precipitation in late July and early August contributed to plant lodging, particularly on the plots with the highest nitrogen doses. In the third year of the experiment, three subsequent months were characterized by small precipitation. Total precipitation sum from May to July amounted to only 136.0 mm (65% of the many-years' average for those months), the result of which were significantly lower values of the Sielianinov coefficients, characteristic for the weather conditions of that growth season (Table 2).

Table 2. Temperature and precipitation distribution throughout the field experiment

Month	Study year	Temperature, ^{o}C	Precipitation, mm	Sielianinov coefficient
April	I	5.7	28.7	1.68
	II	10.0	29.5	0.98
	III	9.8	83.5	2.84
	long term	7.2	32.0	1.48
May	I	12.9	80.1	2.00
	II	15.2	57.8	1.23
	III	14.0	45.6	1.05
	long term	13.0	49.0	1.22
June	I	17.4	85.9	1.65
	II	18.9	83.0	1.46
	III	17.7	53.6	1.01
	long term	16.1	68.0	1.41
July	I	18.7	110.7	1.91
	II	17.9	100.6	1.81
	III	21.5	36.8	0.55
	long term	18.0	71.0	1.27
August	I	19.9	15.1	0.24
	II	15.5	65.8	1.37
	III	17.4	53.8	1.00
	long term	17.4	51.9	0.96
April-July	I	13.7	305.4	1.83
	II	15.5	270.9	1.43
	III	15.8	219.5	1.14
	long term	13.6	222.0	1.33
May-June	I	15.1	166.0	1.80
	II	17.0	140.8	1.36
	III	15.8	99.2	1.03
	long term	14.5	117.0	1.32

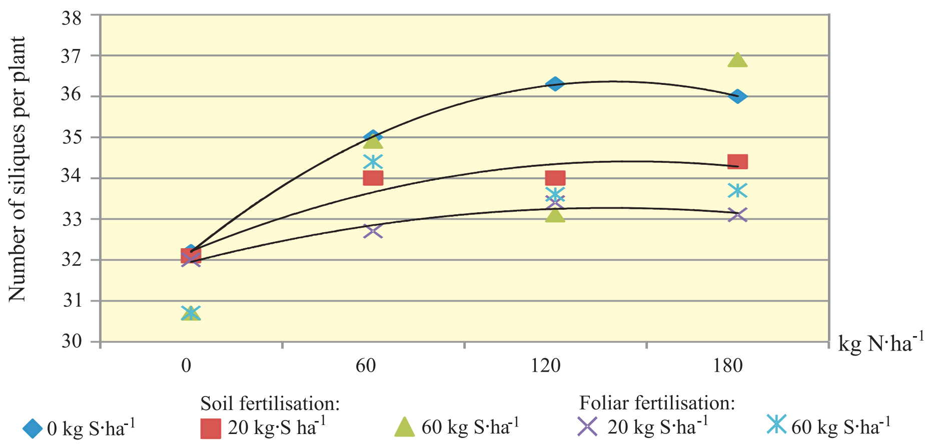
Study results were evaluated with analysis of variance, proper for split-block design. Significance of differences between the average plot values was estimated on the basis of border range of the Tukey's test at the significance level of P = 0.05.

RESULTS AND DISCUSSION

Spring rapeseed belongs to plant species with high phenotypic plasticity, which demonstrates itself with the changeability of yield components under the effect of growth and development conditions. The size of seed yield of the species is formed first of all by the number of siliques and seeds per silique, and also by the mass of 1000 grains [Wielebski 2006].

Silique number per spring rapeseed plant

In every study year, significant effect of nitrogen on the number of siliques per spring rapeseed plant was noted (Table 3). Plants fertilised only with nitrogen (without sulphur) at the doses of 60, 120, and 180 kg·ha^{-1}, on average per study year, formed in comparison with plants unfertilised with this element, more siliques by 8.7%, 12.8%, and 11.8%, respectively. Regression analysis demonstrated that the discussed characteristic was strongly associated with nitrogen fertilisation, particularly in plants not fertilised with sulphur (R = 1.00) and fertilised with the dose of 20 kg S·ha^{-1}, in-soil (R = 0.97) and foliar (R = 0.99) (Fig. 1). It results from the analysis of regression equations that the highest values of a given characteristic was reached only after the application of 175 kg N·ha^{-1} or joint application of 20 kg S·ha^{-1} and 150 kg N·ha^{-1} (in-soil variant) and 200 kg N·ha^{-1} (foliar variant). For the dose of 60 kg S·ha^{-1}, regardless of sulphur application method and date, relations between the discussed characteristic and nitrogen doses may not be described by the model of second degree multiple regression.



Function equations:
– for the dose of 0 kg S·ha^{-1}: $y = -0.0002x^2 + 0.07x + 31.9$, R = 1.00
– for the dose of 20 kg S·ha^{-1}, in-soil application: $y = -0.0001x^2 + 0.03x + 32.3$, R = 0.97
– for the dose of 20 kg S·ha^{-1}, foliar application: $y = -0.0002x^2 + 0.04x + 30.7$, R = 0.99
– for the remaining doses function equations were not statistically significant

Fig. 1. Relation between the number of siliques per spring rapeseed plant and in-soil and foliar sulphur fertilisation against nitrogen fertilisation; average values for three study years

Positive effect of nitrogen fertilisation within the range of 0-160 kg N·ha^{-1} on the number of formed siliques of spring rapeseed cultivar Star was also confirmed by the studies of Budzyński and Jankowski [2003], and for the range of 0-120 kg N·ha^{-1} of Kotecki *et al.* [2001]. In the quoted research, in addition to nitrogen fertilisation, weather conditions and application of chemical protection means affected the number of siliques.

Table 3. Silique number per spring rapeseed plant, silique·plant^{-1}

kg N·ha^{-1} (A)	Study year												Mean for years			
	I year				II year				III year							
	kg S·ha^{-1} (B)			Mean	kg S·ha^{-1} (B)			mean	kg S·ha^{-1} (B)			mean	kg S·ha^{-1} (B)			mean
	0	20	60		0	20	60		0	20	60		0	20	60	
In-soil sulphur fertiliser																
0	36.2	36.0	31.2	34.5	28.0	29.2	29.2	28.8	32.5	31.2	31.7	31.8	32.2	32.1	30.7	31.7
60	37.0	37.0	37.2	37.1	32.0	32.0	32.0	32.0	36.0	33.0	35.5	34.8	35.0	34.0	34.9	34.6
120	39.2	40.0	36.2	38.5	34.0	28.7	31.7	31.5	35.7	33.2	31.5	33.5	36.3	34.0	33.1	34.5
180	36.0	38.2	40.5	38.2	36.2	31.7	35.2	34.4	35.7	32.7	35.0	34.5	36.0	34.2	36.9	35.7
mean	37.1	37.8	36.3	37.1	32.6	30.4	32.1	31.7	35.0	32.5	33.4	33.6	34.9	33.6	33.9	34.1
$LSD_{0.05}$		A 1.0 A × B 2.6	B 1.4 B × A 2.1			A 1.1 A × B 4.0	B ns B × A 2.9			A 2.6 A × B ns	B ns B × A ns			A ns A × B ns	B ns B × A ns	
Foliar sulphur fertiliser																
0	36.2	36.0	36.0	36.1	28.0	29.2	26.0	27.6	32.5	30.7	30.2	31.1	32.2	32.0	30.7	31.6
60	37.0	35.0	38.2	36.7	32.0	30.0	32.2	31.4	36.0	33.2	32.7	34.0	35.0	32.7	34.4	34.0
120	39.2	35.0	37.0	37.1	34.0	32.0	32.2	32.7	35.7	33.2	31.5	33.5	36.3	33.4	33.6	34.4
180	36.0	34.0	37.2	35.7	36.2	32.5	29.0	32.6	35.7	32.7	35.0	34.5	36.0	33.1	33.7	34.3
mean	37.1	35.0	37.1	36.4	32.6	30.9	29.9	31.1	35.0	32.5	32.4	33.3	34.9	32.8	33.1	33.6
$LSD_{0.05}$		A 0.4 A × B 2.1	B 1.3 B × A 1.6			A 2.3 A × B 4.2	B 2.9 B × A 3.4			A 2.3 A × B ns	B 3.7 B × A ns			A ns A × B ns	B 2.4 B × A ns	

ns – non-significant differences

Exclusive application of sulphur at the dose of 60 kg S·ha^{-1} usually caused a decrease in the number of siliques per spring rapeseed plant in comparison with the control plot. Regardless of the application method of this element (in-soil, foliar), on average in the study years, the difference amounted to 1.4 silique, that is 4.3%. Sulphur application date had no statistically confirmed effect. Only in the first two study years, significant interaction between the studied fertilisation elements occurred.

Number of seeds per spring rapeseed silique

Number of grains per spring rapeseed silique was diversified depending on the growth season (Table 4). The highest number of seeds was found in the humid first study year (from 21.5 to 27.5 seeds per silique), and the lowest number in the dry third year, in which the number did not exceed 22 seeds per silique for any fertilisation combination. In all the study years, nitrogen application was the factor that significantly formed the discussed characteristic, but its highest effectiveness was demonstrated in the first year. The difference between the plants fertilised exclusively with 180 kg N·ha^{-1} and the control plot (with no sulphur or nitrogen) amounted to 25.6% (5.5 seeds per silique). Using only sulphur for spring rapeseed fertilisation also caused an increase in the number of seeds per silique. Higher effectiveness of this element applied at the dose of 20 kg S·ha^{-1} was found as a result of foliar application (average difference in relation to the control plot was 18.0%) than of in-soil fertilisation (difference amounted to 13.2%). There were usually no significant differences between plants fertilised with the doses of 20 and 60 kg S·ha^{-1}.

Favourable effect of sulphur on the number of seeds per silique was also observed in the conditions of increasing nitrogen doses, although in none of the study years significant interaction between those elements in the formation of the discussed characteristic was demonstrated.

As demonstrated by regression analysis, for the in-soil dose of 20 kg S·ha^{-1}, the function of seed number per silique depending on the nitrogen doses was linear, and for the same foliar dose, the function reached its maximum for about 100 kg N·ha^{-1} (Fig. 2).

Mass of 1000 grains

The highest mass of 1000 grains of spring rapeseed was noted in the first study year (Table 5), which was characterized by advantageous temperatures and abundant precipitation with favourable distribution (Table 2). Difference between the average values of the mass of 1000 grains for the first study year and of the driest of the study years – the third year – amounted to 21.7%. Both studied factors significantly formed the analyzed characteristic but its value was determined first of all by nitrogen fertilisation. Application of nitrogen at the doses of 60, 120, and 180 kg N·ha^{-1} without sulphur fertilisation caused, on average for the three study years, an increased mass of 1000 grains in comparison with the control group by 16.2%, 18.4%, and 21.6%. Respective differences for the doses of 20 and 60 kg S·ha^{-1} applied without nitrogen depending on the sulphur application date amounted to 10.5% and 2.9% (in-soil application) and 8.3% and 9.0% (foliar application). The highest effectiveness of both fertilising elements, especially nitrogen, was demonstrated in the first study year.

It ought to be underscored that positive effect of nitrogen fertilisation on the mass of 1000 grains was demonstrated by numerous authors in their studies also on other plant species [Szulc *et al*. 2008, Szulc 2010].

Table 4. Seed number per spring rapeseed silique, seed·silique^{-1}

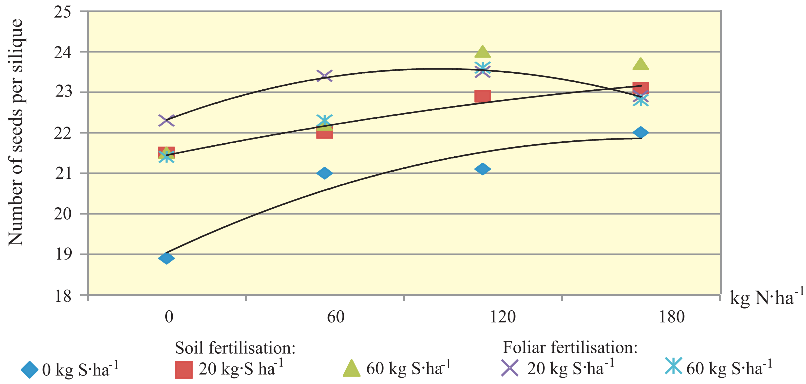
kg N·ha^{-1} (A)	Study year												Mean for years			
	I year				II year				III year							
	kg S·ha^{-1} (B)			mean	kg S·ha^{-1} (B)			mean	kg S·ha^{-1} (B)			mean	kg S·ha^{-1} (B)			mean
	0	20	60		0	20	60		0	20	60		0	20	60	
In-soil sulphur fertiliser																
0	21.5	24.7	24.5	23.6	18.2	20.5	21.0	19.9	17.0	19.2	19.0	18.4	18.9	21.5	21.5	20.6
60	24.7	25.7	25.0	25.1	20.0	21.2	23.2	21.5	18.2	19.0	18.5	18.6	21.0	22.0	22.2	21.7
120	24.5	24.7	27.5	25.6	20.0	23.7	23.2	22.3	18.7	20.2	21.2	20.0	21.1	22.9	24.0	22.7
180	27.0	26.0	26.0	26.3	20.0	23.2	24.0	22.4	19.0	20.0	21.0	20.0	22.0	23.1	23.7	22.9
mean	24.4	25.3	25.7	25.2	19.6	22.2	22.9	21.6	18.2	19.6	19.9	19.3	20.8	22.4	22.9	22.0
$LSD_{0.05}$		A 2.2 A × B ns	B 1.3 B × A ns			A 2.3 A × B ns	B 1.6 B × A ns			A 2.0 A × B ns	B 1.1 B × A ns			A 0.9 A × B ns	B 2.4 B × A ns	
Foliar sulphur fertiliser																
0	21.5	25.5	26.0	24.3	18.2	22.2	21.0	20.5	17.0	19.2	17.2	17.8	18.9	22.3	21.4	20.9
60	24.7	27.5	26.7	26.3	20.0	22.7	21.7	21.5	18.2	20.0	18.5	18.9	21.0	23.4	22.3	22.2
120	24.5	25.7	27.0	25.7	20.0	24.7	22.7	22.5	18.7	20.2	21.3	20.1	21.1	23.5	23.6	22.7
180	27.0	26.5	26.5	26.7	20.0	22.2	21.0	21.1	19.0	20.1	21.0	20.0	22.0	22.9	22.8	22.6
mean	24.4	26.3	26.6	25.8	19.6	23.0	21.6	21.4	18.2	19.9	19.5	19.2	20.8	23.0	22.5	22.1
$LSD_{0.05}$		A 0.4 A × B ns	B 1.3 B × A ns			A 2.3 A × B ns	B 1.7 B × A ns			A 0.9 A × B ns	B 1.1 B × A ns			A 1.0 A × B ns	B 1.9 B × A ns	

ns – non-significant differences

Table 5. Mass of 1000 grains of spring rapeseed, g

kg N·ha^{-1} (A)	Study year												Mean for years			
	I year				II year				III year							
	kg S·ha^{-1} (B)			mean	kg S·ha^{-1} (B)			mean	kg S·ha^{-1} (B)			mean	kg S·ha^{-1} (B)			mean
	0	20	60		0	20	60		0	20	60		0	20	60	
In-soil sulphur fertiliser																
0	2.52	3.18	2.59	2.76	3.11	3.20	3.18	3.16	2.67	2.79	2.79	2.75	2.77	3.06	2.85	2.89
60	3.57	3.59	3.59	3.58	3.29	3.55	3.41	3.42	2.79	2.82	2.60	2.74	3.22	3.32	3.20	3.25
120	3.68	3.85	3.85	3.79	3.33	3.61	3.47	3.47	2.82	2.85	3.40	3.02	3.28	3.44	3.57	3.43
180	3.78	3.81	3.84	3.81	3.51	3.63	3.62	3.59	2.82	2.85	2.84	2.84	3.37	3.43	3.43	3.41
mean	3.39	3.61	3.47	3.49	3.31	3.50	3.42	3.41	2.77	2.83	2.91	2.84	3.16	3.31	3.26	3.25
$LSD_{0.05}$		A 0.42 A × B 0.34	B 0.11 B × A 0.38			A 0.22 A × B 0.29	B 0.05 B × A 0.28			A 0.01 A × B 0.04	B 0.04 B × A 0.05			A ns A × B ns	B ns B × A ns	
Foliar sulphur fertiliser																
0	2.52	3.04	3.17	2.91	3.10	3.20	3.19	3.16	2.67	2.76	2.72	2.72	2.77	3.00	3.02	2.93
60	3.57	3.60	3.60	3.59	3.30	3.55	3.40	3.42	2.79	2.87	2.80	2.82	3.22	3.34	3.27	3.28
120	3.68	3.81	3.85	3.78	3.32	3.63	3.47	3.49	2.82	3.42	2.84	3.03	3.28	3.61	3.39	3.43
180	3.78	3.81	3.83	3.81	3.50	3.64	3.63	3.59	2.82	3.40	3.15	3.12	3.37	3.61	3.53	3.50
mean	3.39	3.56	3.61	3.52	3.30	3.51	3.43	3.41	2.77	3.12	2.88	2.92	3.16	3.39	3.30	3.29
$LSD_{0.05}$		A 0.14 A × B 0.14	B 0.11 B × A 0.18			A 0.06 A × B 0.08	B 0.06 B × A 0.09			A 0.04 A × B 0.05	B 0.05 B × A 0.06			A 0.4 A × B ns	B 0.2 B × A ns	

ns – non-significant differences

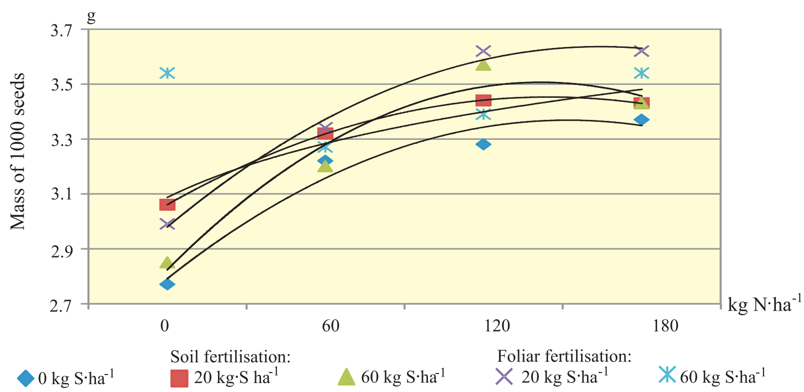


Function equations:
– for the dose of 0 kg S·ha^{-1}: $y = -0.0008x^2 + 0.03x + 19.0$, $R = 0.96$
– for the dose of 20 kg S·ha^{-1}, in-soil application: $y = 0.01x + 21.5$, $R = 0.98$
– for the dose of 20 kg S·ha^{-1}, foliar application: $y = -0.0001x^2 + 0.03x + 22.3$, $R = 1.00$
– for the remaining doses function equations were not statistically significant

Fig. 2. Relation between the number of seeds per spring rapeseed siliques and in-soil and foliar sulphur fertilisation against nitrogen fertilisation; average values for three study years

Nitrogen effectiveness in the formation of the mass of 1000 grains increased as a result of sulphur application. The greatest interactive effect of both studied elements was obtained through nitrogen fertilisation, with simultaneous foliar application of 20 kg S·ha^{-1} (Fig. 3).

On the basis of regression analysis, it ought to be assumed that for in-soil application of 20 kg S·ha^{-1}, the highest effectiveness may be reached for nitrogen dose nearing 150 kg·ha^{-1}, and for foliar application of the above dose for 130 kg N·ha^{-1}.



Function equations:
– for the dose of 0 kg S·ha^{-1}: $y = -0.00003x^2 + 0.08x + 2.78$, $R = 0.98$
– for the dose of 20 kg S·ha^{-1}, in-soil application: $y = -0.0002x^2 + 0.06x + 3.01$, $R = 0.99$
– for the dose of 60 kg S·ha^{-1}, in-soil application: $y = -0.0003x^2 + 0.08x + 2.82$, $R = 0.99$
– for the dose of 20 kg S·ha^{-1}, foliar application: $y = -0.0002x^2 + 0.03x + 2.99$, $R = 0.99$
– for the dose of 60 kg S·ha^{-1}, foliar application: $y = 0.003x + 3.06$, $R = 0.99$

Fig. 3. Relation between the mass of 1000 grains of spring rapeseed and in-soil and foliar sulphur fertilisation against nitrogen fertilisation; average values for three study years

CONCLUSIONS

1. It was demonstrated that in each of the study years, exclusive fertilisation with nitrogen affects significantly and favourably the values of all the studied yield components of spring rapeseed. The highest effectiveness of this element was found in the first study year, distinguished in comparison with the remaining years by advantageous temperatures and abundant precipitation with favourable distribution.

2. Exclusive fertilisation with sulphur usually increased the number of grains per rapeseed silique and the mass of 1000 grains, at the same time causing a decrease in the number of siliques per plant.

3. Only the number of seeds per silique was not significantly formed by the interaction between nitrogen and sulphur. In the case of the other characteristics, including sulphur in nitrogen fertilisation usually caused an increase in their values.

4. Research conducted on soil with low richness in sulphur indicates a clear effect of its application as a sole fertiliser element, and also in interaction with nitrogen, on the formation of spring rapeseed yield components.

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SIARKA JAKO CZYNNIK KSZTAŁTUJĄCY EFEKTYWNOŚĆ AZOTU W AGROTECHNICE RZEPAKU JAREGO. CZĘŚĆ I. WYBRANE ELEMENTY PLONOWANIA

Streszczenie. Podstawą badań było trzyletnie ścisłe doświadczenie polowe przeprowadzone na czarnej ziemi zdegradowanej, klasy bonitacyjnej IIIb, o obojętnym odczynie, wysokiej zasobności w fosfor i potas oraz niskiej w siarkę. Doświadczenie realizowano w układzie równoważnych bloków z dwoma czynnikami, w czterech powtórzeniach. Celem badań była ocena wpływu zróżnicowanych dawek azotu (0, 60, 120 i 180 $kg \cdot ha^{-1}$) i siarki (0, 20 i 60 $kg \cdot ha^{-1}$), z uwzględnieniem różnych sposobów jej aplikacji (doglebowo i dolistnie), na elementy plonowania rzepaku jarego odmiany Star. Wyłączne nawożenie azotem istotnie zwiększało wartości wszystkich badanych elementów, wyłączne nawożenie siarką – tylko liczbę nasion w łuszczynach oraz wartość MTN. Tylko liczba nasion w łuszczynach w żadnym z lat badań nie była istotnie kształtowana przez interakcję azotu i siarki. W przypadku pozostałych cech uwzględnienie w nawożeniu siarki obok azotu powodowało na ogół istotny wpływ na kształtowanie ich wartości w porównaniu z kontrolą.

Słowa kluczowe: azot, komponenty plonowania, nawożenie, rzepak jary, siarka

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