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EFFECT OF SULPHUR AND POTASSIUM FERTILIZATION ON YIELD AND CONTENT OF VARIOUS FORMS OF NITROGEN IN SPRING RAPE

WPŁYW NAWOŻENIA SIARKĄ I POTASEM NA PLONOWANIE I ZAWARTOŚĆ RÓŻNYCH FORM AZOTU W RZEPAKU JARYM

Abstract: This study analyzed the effect of sulphur and potassium fertilization on yield and on total N, protein N, N-NO_3^- and N-NH_4^+ content in spring rape harvested during the bloom period and at full maturity. The study was based on plant material obtained from a pot experiment. The results obtained indicate that fertilization with sulphur and potassium significantly increased the yield of rape harvested during the bloom period and at full maturity. Only the effect of potassium on seed yield was not found to be significant. The highest yields were noted in the objects fertilized with the higher doses of sulphur and potassium. The effectiveness of potassium fertilization depended on the plants' supply of sulphur. Potassium influenced the effectiveness of sulphur fertilization, but to a lesser degree. Supplying the test plant with sulphur and potassium had a beneficial effect on nitrogen metabolism. This was manifested as an increased proportion of protein nitrogen in the total nitrogen and a decrease in mineral forms of this nutrient in the plants fertilized with sulphur and potassium.

Keywords: rape yield, content of various forms of nitrogen, sulphur and potassium fertilization

One of the essential conditions for obtaining optimal plant yield, in terms of both quantity and quality, is a suitable soil environment with proper proportions of nutrients [1–3]. One of the factors limiting agricultural production in Poland in the last 10–15 years has been insufficient amounts of assimilable forms of potassium and sulphur in soils. The reduction in assimilable forms of these nutrients in soils is mainly due to decreased use of mineral, natural and organic fertilizers. An additional cause of sulphur deficiency has been the significant reduction in SO_2 emissions into the atmosphere, and thus into the soil [4–7].

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Potassium and sulphur have many important functions in plants, including a strong influence on nitrogen metabolism [8–10]. Studies thus far conducted in this area have mainly concerned the effect of nitrogen or nitrogen and sulphur [11–13], while there is a lack of research on the combined effect of potassium and sulphur on the metabolism of nitrogen compounds in plants. Hence the aim of this study was to determine the scope of the influence of sulphur and potassium fertilization on yield and content of various forms of nitrogen in spring rape.

Materials and methods

The study was based on results obtained from a two-year pot experiment conducted on soil material taken from the arable layer of brown soil with a loamy silt granulometric composition. Before the study, the soil had neutral pH and was low in available phosphorus, potassium and magnesium, as well as in sulphate sulphur. The experiment was set up with a completely randomized design. It had two variables (the dose of sulphur and dose of potassium) on three levels in eight repetitions. Fertilization with elemental sulphur and potassium in the form of KCl was applied each year before sowing, as follows:

1. S_0K_0
2. S_0K_1
3. S_0K_2
4. S_1K_0
5. S_1K_1
6. S_1K_2
7. S_2K_0
8. S_2K_1
9. S_2K_2

where:

S_0 – no sulphur fertilization;
S_1 – fertilization with elemental sulphur in the amount of 0.012 g S · kg^{-1} of soil for spring barley and 0.024 g S · kg^{-1} of soil for spring rape;
S_2 – fertilization with elemental sulphur in the amount of 0.024 g S · kg^{-1} of soil for spring barley and 0.048 g S · kg^{-1} of soil for spring rape;
K_0 – no potassium fertilization;
K_1 – potassium fertilization in the form of KCl in the amount of 0.05 g K · kg^{-1} of soil for spring barley and 0.1 g K · kg^{-1} of soil for spring rape;
K_2 – potassium fertilization in the form of KCl in the amount of 0.1 g K · kg^{-1} of soil for spring barley and 0.2 g K · kg^{-1} of soil for spring rape.

The test plant in the first year of the study was the Atol variety of spring barley, and in the second year it was the Sponsor variety of spring rape. These plants were chosen for the experiment because of their differing requirements for sulphur and potassium. The plants were cultivated in pots with capacity 3 dm^3, each filled with 3 kg of soil. In all of the experimental objects the same level of fertilization with nitrogen, phosphorus and magnesium, as well as microelements, was applied each year in amounts appropriate to the requirements of these plants. Sulphur and potassium was applied in solid form and the other nutrients – in the liquid form. The plants were harvested during the bloom period and at full maturity. Plants from four repetitions were harvested each time.

This paper presents a part of the study and concerns the effect of the experimental factors on yield and on content of various forms of nitrogen in spring rape. After the rape was harvested during the bloom period and at full maturity (seeds and straw), the following forms of nitrogen were determined in the plant material: total nitrogen by the Kjeldahl method, after mineralization of the plant material in concentrated H_2SO_4 with H_2O_2; protein nitrogen by distillation after hot extraction with trichloroacetic acid; ammonia nitrogen colorimetrically by the Nessler method in trichloroacetic acid extract; and nitrate(V) nitrogen colorimetrically using sodium salicylate [14]. Mineral forms of nitrogen were determined only in the rape harvested during the bloom period. The plant material was analyzed in two repetitions in average object samples. Average values can be found in the tables. The effect of the experimental factors on rape yield was calculated by means of variance analysis for factorial experiments using Tukey confidence half-intervals.

Discussion of results

Sulphur fertilization significantly differentiated spring rape yield during the developmental stages investigated (Table 1).

Table 1

The effect of sulphur and potassium fertilization on the yelding of spring rape

Object	Phase of flowering	Full maturity	
		Seeds	Straw
	[g d.m. · pot^{-1}]		
S_0K_0	6.65	×	3.87
S_0K_1	6.67	×	4.21
S_0K_2	6.69	×	4.44
S_1K_0	12.64	8.00	25.54
S_1K_1	13.45	6.29	35.66
S_1K_2	14.89	5.59	41.27
S_2K_0	15.59	11.87	27.39
S_2K_1	20.56	13.78	38.69
S_2K_2	22.32	14.93	43.74
LSD (p = 0.01)			
S	0.64	0.37	0.73
K	0.64	n.s.	0.73
S × K	1.45	0.85	1.64

× – the plants did not develop seeds.

In the case of potassium, significant differentiation of yield occurred only in the plants harvested during the bloom period and in the straw. The interaction between sulphur and potassium was also found to be significant in all cases. It is clear from the data obtained that in both development stages the lowest yields were in the series

without sulphur fertilization (S_0). Due to the lack of sulphur in the environment the rape did not enter the generative stage and thus did not produce seeds. The results obtained confirm the fact [2, 6, 13] that rape is a plant with very high sulphur requirements. In this experiment the effectiveness of sulphur fertilization depended on the degree of potassium supply to the plants, and the effectiveness of potassium fertilization depended on the amount of sulphur applied. This dependency was more marked in the case of potassium. When sulphur was lacking in the soil (S_0), the rape harvested during the bloom period did not respond to potassium fertilization with increased yield. In the case of the seeds, lack of response to potassium fertilization was noted in the series with the lower dose of sulphur (S_1).

The highest yields for the test plant were obtained in the objects fertilized with the higher doses of sulphur and potassium (S_2K_2). This confirms that the effectiveness of sulphur fertilization is highest in conditions where high doses of nitrogen, phosphorus and potassium are applied [15].

The experimental factors also had a marked influence on the content in the spring rape of the forms of nitrogen determined in the study (Table 2). Depending on the experimental object, the total nitrogen content in the plants cut during the bloom period was between 26.21 and 59.41 g N · kg^{-1}. The range of values for total N in the seeds was from 32.68 to 45.77 g N · kg^{-1}, while in the straw it was 4.01 to 47.37 g N · kg^{-1}. Fertilization with sulphur and potassium caused a noticeable decrease in total nitrogen content in the plants. This is probably due to the increase in yield produced by these elements and to the phenomenon of nitrogen dilution [1, 16].

The highest protein nitrogen content was noted in the rape seeds, and the lowest in straw. In most cases the experimental factors caused a decrease in protein nitrogen in the spring rape. The beneficial effect of sulphur and potassium on nitrogen metabolism in the plants is demonstrated by the fact that as the amount of these nutrients applied to the rape was increased, the amount of nitrogen incorporated into protein increased. This was particularly clear in the case of the plants harvested during the bloom period and in the straw. In the seeds, the highest degree of conversion of nitrogen into protein was noted in the plants fertilized with the lower dose of sulphur (S_1). The results obtained confirm the essential role of sulphur in the process by which plants convert nitrogen compounds into protein [1, 9, 10, 17]. They also indicate that in plants insufficiently supplied with potassium the ratio of protein nitrogen to non-protein nitrogen undergoes a shift in favour of non-protein nitrogen.

Nitrate nitrogen (N-NO_3^-) and ammonium nitrogen (N-NH_4^+) content in the plants harvested during the bloom period confirm that fertilizing rape with sulphur and potassium has a beneficial effect on nitrogen metabolism (Table 2). In general it can be concluded that the lowest amounts of the mineral forms of nitrogen determined were noted in the rape that was fertilized with the higher dose of sulphur and potassium (S_2K_2), while the highest content of these forms of nitrogen occurred in the plants that were not fertilized with sulphur (S_0). Studies by other authors [17, 18] have also demonstrated that sulphur deficiency in the environment contributes to accumulation of non-protein forms of nitrogen in plants. The effect of potassium is similar, but as the data obtained indicate, it is more effective when plants are well-supplied with sulphur.

Tabela 2

The effect of sulphur and potassium fertilization on the content of various forms of nitrogen in spring rape

Object	Flowering					Seeds			Straw		
	Tot. N	Prot. N	Prot. N / Tot. N	$N\text{-}NO_3$	$N\text{-}NH_4$	Tot. N	Prot. N	Prot. N / Tot. N	Tot. N	Prot. N	Prot. N / Tot. N
	[g N · kg^{-1}]		[%]	[mg N · kg^{-1}]		[g N · kg^{-1}]		[%]	[g N · kg^{-1}]		[%]
S_0K_0	59.41	12.34	20.77	2645.71	413.58	×	×	×	46.66	10.61	22.74
S_0K_1	56.27	11.12	19.76	2911.04	456.29	×	×	×	47.37	11.37	24.00
S_0K_2	56.95	11.59	20.35	2404.63	437.64	×	×	×	41.69	11.24	26.96
S_1K_0	39.41	10.95	27.78	1854.93	377.87	45.25	34.09	75.34	9.43	5.25	55.67
S_1K_1	34.74	10.33	29.73	1170.17	344.79	45.77	34.63	75.66	6.50	3.71	57.08
S_1K_2	33.91	8.79	25.92	1322.01	328.14	44.06	32.44	73.63	6.80	4.02	59.12
S_2K_0	36.12	10.95	30.31	866.70	365.39	35.12	25.30	72.04	6.78	4.31	63.57
S_2K_1	28.25	9.31	32.95	285.88	314.39	33.43	23.48	70.24	4.62	2.77	59.96
S_2K_2	26.21	10.48	39.98	270.46	309.56	32.68	23.47	71.82	4.01	3.08	76.81

× – no determination (calculation) due to the lack of material.

Conclusions

1. Sulphur fertilization significantly increased the yield of spring rape harvested during the bloom period and at full maturity. Significant increase in rape yield as a result of potassium fertilization only occurred in plants harvested during the bloom period and in straw.

2. The effectiveness of fertilizing rape with potassium was strongly dependent on the plants' supply of sulphur. Potassium also enhanced the effectiveness of sulphur fertilization, but to a lesser extent.

3. Increasing the supply of sulphur and potassium in spring rape had a beneficial effect on nitrogen metabolism. This was manifested as increased utilization of this nutrient for protein synthesis and a reduction in mineral nitrogen content ($N\text{-}NO_3^-$, $N\text{-}NH_4^+$).

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Abstrakt: W pracy przeanalizowano wpływ nawożenia siarką i potasem na plonowanie i zawartość N og., N białk., $N\text{-}NO_3^-$ i $N\text{-}NH_4^+$ w rzepaku jarym zbieranym w okresie kwitnienia i pełnej dojrzałości. Podstawę badań stanowił materiał roślinny uzyskany z doświadczenia wazonowego. Uzyskane wyniki wskazują, że nawożenie siarką i potasem istotnie zwiększyło plony rzepaku zbieranego w okresie kwitnienia i pełnej dojrzałości. Brak istotności wystąpił tylko w oddziaływaniu potasu na plon nasion. Najwyższe plony roślin odnotowano w obiektach nawożonych większymi dawkami siarki i potasu. Efektywność nawożenia potasem zależała od zaopatrzenia roślin w siarkę. Potas na efektywność nawożenia siarką wpływał, ale w mniejszym stopniu.

Zaopatrzenie rośliny testowej w siarkę i potas korzystnie wpłynęło na przemiany metaboliczne azotu. Ten korzystny wpływ wyraził się zwiększeniem udziału azotu białkowego w azocie ogólnym i zmniejszeniem mineralnych form tego składnika w roślinach nawożonych siarką i potasem.

Słowa kluczowe: plonowanie rzepaku, zawartość różnych form azotu, nawożenie siarką i potasem