Acta Agrophysica, 2001, 52, 117-123

EFFECT OF DIFFERENTIATED PHOSPHORUS-POTASSIUM FERTILIZATION ON CROP YIELD UNDER SULPHUR IMMISSION (MODEL TESTS)

J. Kiepul

Institute of Soil Science and Plant Cultivation, Experimental Station in Jelcz-Laskowice
Łąkowa 1, 55-230 Jelcz-Laskowice, Poland

A b s t r a c t. The effect of differentiated phosphorus-potassium fertilization on crop yields under simulated immission of sulphur and preventive liming was tested in a five-year pot experiment. The tests were carried out on two kinds of soil: brown (heavy loamy sand) and black earth (medium silty loam).

An increased phosphorus-potassium fertilization applied under conditions of a considerable drop in the brown soil reaction brought about by sulphur immission, was found to attenuate depression in the crop yields. Now, at the prolonged sulphur application with a parallel treatment to maintain soil reaction at the level optimum for plants, interaction between sulphur doses and phosphorus-potassium fertilization was found positive. The above process began when the first negative symptoms of the sulphur impact on plants were noticed. In the case of brown soil, it took place in the second, and of black earth only in the last year of the experiment.

K e y w o r d s: sulphur, liming, phosphorus-potassium fertilization, crop yield.

INTRODUCTION

Harmful action of excessive SO_2 immission on the soil medium, and through the soil on the crops, has been proved by many researchers. Its final effect is depression of yield, depending mainly on the degree of soil degradation and the plant species [6,8,10]. That negative effect of sulphur on plants can be attenuated by protecting them and improving the conditions of their vegetation. In such cases fairly good effects were obtained with soil liming [5,6,9,10]. In the above range, nitrogen fertilization may play a certain role, as literature reports a possible, positive interaction of nitrogen and sulphur for the crop yield [7,10,11]. Not much, however, is known about the part played by phosphorus-potassium fertilization in such conditions. It seems that fertilization can attenuate the negative effects of acidic precipitations on the crop yield particularly in the case when the available phosphorus and potassium forms in the soil have been reduced, as reported by some authors [5,6,8,10].

This research has aimed at determining the effect of differentiated phosphorus-potassium fertilization on crop yields in the conditions of a simulated sulphur immission and preventive liming.

METHODS

The research was based upon a five-year pot experiment carried out in a plant house with Wagner-type pots. Two kinds of soils were used in the experiment: brown (heavy loamy sand, pH_{KCl}=5.5, content of available forms P-6.6, K-13,5 mg/100 g soil) and black earth (medium silty loam, pH_{KCl}-7.5, content of available forms P-21.1, K-43.2 mg/100 g soil). In the experiment carried out in four replications, four doses of sulphur: S_0, S_1-150 kg/ha (i.e. 0.83 ml conc. H_2SO_4/pot), S_2-300 kg/ha (1.66 ml H_2SO_4/pot), S_3-600 kg/ha (3.32 ml H_2SO_4/pot), and two levels of liming: Ca_0-no liming, Ca_1 - lime treatments with $CaCO_3$ were applied. Two doses of nitrogen (1N, 2N) and phosphorus-potassium (1PK, 2PK) fertilization in different combinations were applied against that background. The essential fertilization when converted to a pot (of 7 kg soil volume) was: 1N-0.6 g (as NH_4NO_3), P-0.5 g (KH_2PO_4 and KCl) together with a full set of microelements. The basis for determining the maximum dose of sulphur was the real quantity of immission in some regions of the south-west and west part of Poland [6,8]. Like other authors, that kind of contamination was simulated by introducing an aqueous solution of sulphuric acid into the soil [5,6]. It was applied twice a year (by 0.5 dose): in spring together with fertilization and liming and in autumn after the harvest of crops following some earlier methods [6]. The black earth was limed during the whole experimental period, while the brown soil only in the first year, acc. to 1 Hh. From the second year onwards, liming of brown soil was modified so that lime doses in each treatment were composed of two parts: one resulting from the liming according to 0.5 Hh, and the other necessary for the neutralization of the yearly sulphur dose from that treatment. The test plants were as follows: spring wheat, sugar beets, spring barley, maize for green and again spring wheat. The plants were harvested at the stage of full ripenes (wheat and barley) or technical maturity (beets and maize).

The yields obtained were statistically assessed following the method of variance analysis with the Tukey's confidence half-interval test (programme AWAR).

RESULTS AND DISCUSSION

Interaction between sulphur doses and liming on the soil reaction and crop yield crops was typical [5,6,8-10]. The soils tested in the present experiment were systematically acidified by the application of sulphur (after five years at the highest dose: brown soil to pH_{KCl}=3.3, black earth to pH_{KCl}=5.3), while liming maintained the soil reaction at a level close to the initial one [7]. From the second year of the experiment on the brown soil, a negative effect of sulphur on crop yield was observed. The process was intensified with increasing sulphur doses and duration of the experiment (Table 1). That negative sulphur action doses was evidently reduced by liming. In many cases it even raised the crop yield significantly (Table 2). In the present experiment sulphur positively influenced the yields of all crops grown on black earth except for beets (Tables 3 and 4). The mechanisms of the above processes have been already discussed in literature [5,6,8,10].

Table 1. Yields of plants (in g/pot) on the brown soil (unlimed objects) as affected by sulphur rates, nitrogen and phosphorus-potassium fertilization

Objects		Sugar beets[a]		Spring barley[b]		Maize[a]	Winter wheat[b]	
		roots	leaves	grain	straw		grain	straw
0S	1PK	113	210	22.5	25.9	561	14.1	35.2
	2PK	136	247	25.4	30.4	572	13.2	36.1
1S	1PK	129	191	10.2	15.7	550	9.9	25.4
	2PK	141	233	14.0	21.8	532	9.7	29.9
2S	1PK	26	56	0	0	156	0	0
	2PK	43	117	0	0	181	0	0
3S	1PK	0	0	0	0	0	0	0
	2PK	0	0	0	0	0	0	0
Mean	1PK	67	114	8.2	10.4	317	6,0	15.1
	2PK	80	149	9.8	13.1	321	5.7	16.5
Mean	1N	70	109	9.1	11.5	329	7.0	17.9
	2N	77	154	8.9	11.9	309	4.7	13.8
$LSD_{0.05}$								
Sulphur rates (I)		5.5	7.9	0.60	0.60	13.6	0.86	1.39
Fertilization N (II)		2.9	4.2	n.s.	0.32	7.3	0.46	0.74
PK (III)		2.9	4.2	0.31	0.32	n.s.	n.s.	0.74
Interactions IxII		***	***	***	***	***	***	***
IxIII		***	***	***	***	**	n.s.	***
IIxIII		***	***	**	n.s.	*	***	***

[a]fresh matter; [b]dry matter; n.s. - not significant; * $p \le 0.05$; ** $p \le 0.01$; *** $p \le 0.001$.

Table 2. Yields of plants (in g/pot) on the brown soil (limed objects) as affected by sulphur rates, nitrogen and phosphorus-potassium fertilization

Objects		Sugar beets[a]		Spring barley[b]		Maize[a]	Winter wheat[b]	
		roots	leaves	grain	straw		grain	straw
0S	1PK	148	234	29.1	32.1	434	18.8	37.2
	2PK	169	254	28.6	33.9	459	18.1	39.3
1S	1PK	180	237	29.0	33.2	484	20.5	41.3
	2PK	260	295	29.7	37.1	522	23.6	42.9
2S	1PK	152	259	20.6	35.9	536	21.5	40.3
	2PK	229	313	28.0	40.8	711	24.7	42.9
3S	1PK	119	240	10.5	29.4	487	21.1	40.3
	2PK	162	359	15.3	34.4	533	24.6	42.6
Mean	1PK	150	242	22.3	32.6	486	20.5	39.5
	2PK	205	305	25.4	36.5	556	22.7	41.5
Mean	1N	175	190	23.5	33.6	402	22.5	40.1
	2N	180	358	24.1	35.5	639	20.7	40.9
$LSD_{0.05}$								
Sulphur rates (I)		9.4	15.4	0.93	1.16	20.3	1.11	1.71
Fertilization N (II)		n.s.	8.2	0.50	0.62	10.9	0.60	n.s.
PK (III)		5.0	8.2	0.50	0.62	10.9	0.60	0.92
Interactions IxII		***	***	***	***	***	n.s.	n.s.
IxIII		***	***	**	**	***	**	*
IIxIII		***	***	n.s.	n.s.	***	***	**

Explanations as in Table 1.

Increased doses of phosphorus-potassium fertilization applied against such a background did not significantly affect the wheat yield in the first year only. Therefore, these results were omitted in our presentations. In the following years, the reaction of brown soil dropped considerably. Higher doses of phosphorus-potassium fertilization evidently attenuated the decrease in yields in the successive crops (Table 1). When the soil reaction was optimum for plants (limed treatments), fertilization with increased doses of phosphorus and potassium positively influenced plant yield. Most often this increase was significant compared with the essential PK fertilization (Table 2). A similar action of phosphorus-potassium fertilization on the black earth was manifested evidently only in the last year of the tests (Tables 3 and 4). That positive process started with the first symptoms of the negative effects of sulphur immission on plants. In the case of brown soil, it was observed in the second, and of black earth only in the last year of the experiment. However, only the beetroot, barley and wheat yields depended mainly on the level

Table 3. Yields of plants (in g/pot) on the black earth (unlimed objects) as affected by sulphur rates, nitrogen and phosphorus-potassium fertilization

Objects		Sugar beets[a]		Spring barley[b]		Maize[a]	Winter wheat[b]	
		roots	leaves	grain	straw		grain	straw
0S	1PK	293	299	24.9	25.8	563	13.6	31.5
	2PK	287	288	25.3	26.8	603	14.2	33.1
1S	1PK	267	283	26.1	26.9	603	13.5	31.2
	2PK	268	274	26.3	27.1	641	15.2	36.2
2S	1PK	228	280	27.8	26.7	665	13.8	30.2
	2PK	233	279	29.2	28.2	686	17.8	37.8
3S	1PK	240	304	32.2	31.3	641	13.3	33.3
	2PK	234	297	32.1	31.9	682	19.7	43.3
Mean	1PK	257	291	27.7	27.7	618	13.5	31.6
	2PK	255	284	28.2	28.5	653	16.7	37.6
Mean	1N	191	211	25.0	25.5	556	14.4	33.7
	2N	321	364	30.9	30.6	715	15.8	35.4
$LSD_{0.05}$								
Sulphur rates (I)		17.5	13.5	1.13	0.93	18.4	0.64	1.44
Fertilization N (II)		9.4	7.3	0.61	0.50	9.8	0.34	0.77
PK (III)		n.s.	n.s.	n.s.	0.50	9.8	0.34	0.77
Interactions IxII		***	***	***	***	***	*	n.s.
IxIII		n.s.	n.s.	n.s.	n.s.	n.s.	***	***
IIxIII		n.s.	n.s.	n.s.	n.s.	n.s.	**	n.s.

Explanations as in Table 1.

of phosphorus and potassium fertilization. Yields of beet leaves and maize were more related to nitrogen fertilization doses. The effects of nitrogen fertilization on the soils affected with sulphur immission was discussed in an earlier paper [7].

Literature showed that nitrogen exerts the greatest effect on the yield quantity of beet leaves [12] and maize [3,11], while phosphorus on wheat and barley [1,2] and phosphorus-potassium on beetroots [4]. However, the yield-creating effect of phosphorus is highly dependent on the content of its available forms in the soil [1,4]. Lower phosphorus content in the soil is conductive to better reaction of plants to this component. Relatively little influence of phosphorus and potassium on crop yield in the first four years on black earth resulted probably from the very high initial abundance of these components in the soil. Thus the reaction of the experimental plants to phosphorus-potassium fertilization was in line with literature data.

Systematic application of higher sulphur doses leads to the impoverishment of the available forms of phosphorus and potassium in the soil [5,6,8,10]. That negative process is not counteracted by the preventive soil liming [6,10]. Hence, fertilization

Table 4. Yields of plants (in g/pot) on the black earth (limed objects) as affected by sulphur rates, nitrogen and phosphorus-potassium fertilization

Objects		Sugar beets[a]		Spring barley[b]		Maize[a]	Winter wheat[b]	
		roots	leaves	grain	straw		grain	straw
0S	1PK	250	313	27.0	26.3	609	14.8	30.5
	2PK	242	292	25.9	26.6	622	15.0	33.7
1S	1PK	232	365	27.0	26.6	646	16.0	30.5
	2PK	238	343	26.9	26.9	663	16.6	34.9
2S	1PK	240	297	28.3	27.5	683	17.6	31.5
	2PK	238	290	29.1	29.0	683	22.1	38.9
3S	1PK	209	294	31.0	30.3	665	15.8	32.3
	2PK	218	278	31.0	31.8	681	22.2	40.3
Mean	1PK	232	317	28.3	27.6	645	16.0	31.2
	2PK	234	301	28.2	28.6	662	19.0	36.9
Mean	1N	193	219	25.7	25.9	550	17.7	32.5
	2N	274	399	30.9	30.3	758	17.3	35.7
$LSD_{0.05}$								
Sulphur rates (I)		14.4	13.8	0.90	0.96	16.3	0.81	1.48
Fertilization N (II)		7.7	7.4	0.48	0.51	8.7	0.43	0.79
PK (III)		n.s.	7.4	n.s.	0.51	8.7	0.43	0.79
Interactions IxII		***	***	**	***	***	n.s.	**
IxIII		n.s.	n.s.	n.s.	n.s.	n.s.	***	***
IIxIII		n.s.	**	n.s.	n.s.	n.s.	n.s.	***

Explanations as in Table 1.

with higher doses of phosphorus and potassium can stamp out the deficit of these components in the soil and thus improves the conditions for plant vegetation [10]. One of the possible effects of that process may be advantageous interaction of sulphur doses and phosphorus-potassium fertilization proved in the experiment (Tables 2, 3, and 4). The results obtained point out that, except for beets and barley grown on the brown soil in the treatments with the highest doses of sulphur, the positive action of fertilization on crop yield was intensified with increasing doses of sulphur and duration of its application.

CONCLUSIONS

1. In the case of a marked decrease in the brown soil reaction brought about by sulphur immission an increased phosphorus-potassium fertilization attenuated depression of the crop yields.

2. Application of sulphur with a simultaneous stability of the soil reaction at a level optimum for plants makes interaction of sulphur doses and phosphorus-potassium fertilization advantageous. The above process, positive to crop yielding, started with the first symptoms of the negative effects of sulphur immission on plants. In the case of brown soil, it took place in the second, and of black earth only in the last year of the experiment.

REFERENCES

1. **Adamus M., Boratyński K., Kozlowska H.:** Reaction of cereals to the gradually increasing doses of nitrogen, phosphorus and potassium on different agricultural soil complexes of our country in the experiments of agricultural schools. Pam. Puł., 55, 109-125, 1972.
2. **Bednarek W., Lipiński W.:** Influence of mineral fertilization and liming on physico-chemical properties of light soil, crop yield and some features of spring barley. Roczn. Glebozn., 47, 3-4, 109-115, 1996.
3. **Fotyma E.:** The response of field crops to nitrogen fertilization in maize. Fragm. Agronomica, 44, 20-35, 1994.
4. **Jaszczolt E.:** Influence of high superphosphate rates on the yield of sugar beet roots and sugar as well as on sorption of the fertilizer phosphorus. Roczn. Nauk Roln., A, 107, 4, 91-104, 1990.
5. **Kaczor A.:** The after-effect of simulated acid rains and dolomite on the yield of ordinary cockfoot and on the content of available phosphorus, potassium and magnesium in the soil. Roczn. Glebozn., 47, 3-4, 223-229, 1996.
6. **Kiepul J.:** Effects of sulphur used as sulphuric acid on crop yields and soil properties. IUNG, Puławy, R(289), 1991.
7. **Kiepul J.:** Effect of nitrogen fertilization on crop yields under conditions of different contamination of soil with sulphur used as sulphuric acid (a model study). Zesz. Probl. Post. Nauk Roln., 418, 629-635, 1995.
8. **Motowicka-Terelak T., Dutka S.:** Chemical degradation of soils polluted with sulfur and the influence of soil degradation on field crops. IUNG, Puławy, R(284), 1991.
9. **Motowicka-Terelak T., Terelak H.:** The need and the efficiency of liming of sulphur polluted soils. Zesz. Probl. Post. Nauk Roln., 418, 665-669, 1995.
10. **Siuta J., Rejman-Czajkowska M.:** Siarka w biosferze. PWRiL, Warszawa, 1980.
11. **Uziak Z., Szymańska M.:** Interaction of nitrogen, phosphorus and sulphur in the absorption of macroelements by horse-bean and maize. Pam. Puł., 71, 39-51, 1979.
12. **Wójcik S.:** Variability of biometric traits, yielding and technologic quality of sugar beet under conditions of different nitrogen fertilization. Rocz. Nauk Roln., 107, 4, 79-90, 1990.