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Physicochemical Properties and Enzymatic Activity of Sulfur-Acidified Horticultural Soil

J. Wyszkowska*, J. Kucharski*, Z. Benedycka

* Chair of Microbiology,
Chair of Agricultural Chemistry and Environmental Protection,
University of Warmia and Mazury, Plac Lodzki 3; 10-727 Olsztyn, Poland

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Abstract

This experiment was performed under laboratory conditions in three replications. Three types of horticultural soil were put in plastic pots using 200 dm^3 per pot. Prior to filling the pots, the soils were carefully mixed with dusty elementary sulfur at 0.0,1.0, 2.0, 3.0, 4.0 and 5.0 g • dm^{-3} and incubated for three months at 18-20°C, maintaining moisture at 60% of capillary water holding capacity. After 90 days the samples were taken for the determination of active acidity in H_2O, hydrolytic acidity (H) and total of bases (S). Based on the results of the assay, the total exchange capacity (T) and degree of base saturation (V) were computed from the formulas: $T = S + H$ and $V = S \cdot T^{-1} \cdot 100$. In addition, the activity of dehydrogenases, urease and acid and alkaline phosphatase was determined.

Elementary sulfur was found to have an effect on physicochemical and biochemical properties of horticultural soil. The highest rate of sulfur reduced pH (in H_2O) from 6.7 to 3.9, the total of exchange bases by 3-fold, the total exchange capacity by 1.2-fold and the degree of base saturation by 2.4-fold. It also depressed the activity of dehydrogenases by 12.6-fold, urease by 74.1-fold, acid phosphatase by 1.8-fold and alkaline phosphatase by 4.1-fold. Sulfur applied at 5 g • dm^{-3} increased hydrolytic acidity by 9-fold.

Keywords: sulfur, hydrolytic acidity, dehydrogenases, urease, acid and alkaline phosphatase, horticultural soil

Introduction

Precisely designed fertilization treatments are required for the purpose of intensive horticultural production, involving application of optimum doses and dates of crop protection chemicals and growth regulators, irrigation and selection of suitable natural or artificial substrate, whic2h is of special importance in cases of greenhouse crops [1, 2, 3]. Temperature is another significant factor, owing to the effect it has on physiological characteristics of plants [1], which become manifest in the yield [4, 5].

Nutritional requirements of horticultural crops are varied and depend on species and variety [6]. However, even if the right quantities of nutrients are available in the soil, plants will not develop properly unless soil pH is maintained at the optimum. For some plant species the bed must be acid, in which case soil is acidified using elementary sulfur (S°), oxidized to sulfuric acid by sulfuric bacteria [7]. A change in the soil reaction has some effect on physicochemical [8] and biochemical properties [9] of soils used for cultivation of agricultural crops. The results of research in agriculture available to date encouraged the authors to trace the effect of acidification of horticultural soils with sulfur on physicochemical and biochemical properties of soils. The aim of this experiment was to investigate on the impact of sulfur doses on acidity and enzymatic activity of growing media.

Correspondence to: Prof. J. Kucharski

Methods

The tests were performed under laboratory conditions in three replications. Three types of horticultural soil were put into plastic pots, using 200 dm^3 of soil per pot (Table 1). Prior to filling the pots, the soils were carefully mixed with powdery elementary sulfur at the following rates: 0.0,1.0, 2.0, 3.0, 4.0 and 5.0 g • dm^{-3} and incubated for three months at 18-20°C, with the moisture kept at 60% capillary water holding capacity. Doses of sulfur were similar to those which are used in horticultural practice. After 90 days of the experiment, samples were collected for determination of active acidity in H_2O, hydrolytic acidity (H) and total of bases (S) according to the method of Kappen [10]. Based on the values obtained, total exchange capacity (T) and degree of base saturation (V) were computed from the formulae:

$$T = S + H$$

$$V = S \cdot T^{-1} \cdot 100$$

Table 1. Some physical and chemical properties of horticultural soils.

Characteristics	Units	Horticultural soil		
		A	B	C
Volume density	kg·dm^{-3}	0.63	0.41	0.58
Water holding capacity	kg·dm^{-3}	0.67	0.75	0.69
C contents	g·dm^{-3}	62.85	63.74	69.84
N contents	g·dm^{-3}	5.10	4.67	5.63
C : N relation		12.32	13.64	12.38

Activity of dehydrogenases by Lenhard's method modified by Casidy et al. [11], urease using the method of Gorin and Chine Chang [12] and acid and alkaline phosphatase according to Tabatabai and Bremner [13] were also determined.

Results and Discussion

Application of sulfur for the purpose of acidification of horticultural soil turned out to be very effective. Even the lowest rate of S° (1.0 g • dm^{-3}) increased active acidity by one unit (Table 2), while the highest rate (5.0 g • dm^{-3}) reduced soil pH (in H_2O) by 1.7-fold. It is hardly surprising then that pH was highly negatively correlated with the rate of sulfur. The correlation coefficients ranged from -0.95 and -0.98. Just as high a correlation, although positive (r = 0.99), was observed for hydrolytic acidity, which, under the effect of the highest rate of sulfur, increased by 6.6 to 14.5-fold depending on the type of horticultural soil. On average, hydrolytic activity rose nearly 9 times. Consequently, a change in the total of exchange bases, total exchange capacity and degree of base saturation was unavoidable. All three properties were negatively correlated with the rate of sulfur. The correlation coefficients for the total of exchange bases ranged from -0.99 to -1.00, for total exchange capacity from -0.52 to 0.96 and for degree of base saturation -0.99 in all three soils. The lowest value (30% to 40%) of the latter index was determined for the objects treated with 5.0 g • dm^{-3} of sulfur. At this rate of sulfur the degree of base saturation declined by 2.3 to 3.1-fold. The smallest changes caused by the application of sulfur were recorded for the total exchange capacity of the soils, which, although negatively correlated with the rate of sulfur, did not decrease as drastically as the increase in acidification expressed by hydrolytic acidity and degree of base saturation rose. This observation is particularly relevant in the case of soils A and C. Apart from changing physicochemical properties of soil, application of sulfur to horticultural soils was responsible for disturbances in enzymatic activity.

The higher the rates of sulfur applied, the greater the reduction in the activity of dehydrogenases in horticultural soils (Table 3). In extreme cases, the activity of these enzymes was reduced 16.5-fold in soil A, 14.4-fold in soil B and 8.5-fold in soil C. The activity of urease was affected even more profoundly, declining at higher rates of sulfur. Under the influence of sulfur applied

Table 2. Some physical properties of horticultural soils.

Sulfur (S) dose (g dm^{-3} of soil)	pH [in H_2O]			Hydrolytic acidity (H) [cmol (+) dm^{-3}]			Total of bases (S) [cmol (+) dm^{-3}]		
	Horticultural soil								
	A	B	C	A	B	C	A	B	C
0	7.0	6.2	6.9	1.65	1.21	0.87	22.62	17.18	23.49
1	6.0	5.1	6.1	2.36	1.67	2.18	19.97	14.47	21.52
2	5.2	4.6	5.6	4.49	3.01	3.92	16.82	10.62	20.36
3	4.5	4.3	4.8	7.09	5.25	6.53	14.05	8.32	15.72
4	4.0	4.1	4.3	10.40	6.41	10.01	12.85	5.62	12.70
5	3.8	3.7	4.1	12.76	7.99	12.62	8.51	3.40	9.34
$\bar{x}$	5.1	4.7	5.3	6.46	4.25	6.02	15.80	9.94	17.19
r	-0.98	-0.95	-0.99	0.99	0.99	0.99	-0.99	-1.00	-0.99

r – correlation coefficients

Table 3. Horticultural soil enzyme activity.

Sulfur (S) dose ($g\ dm^{-3}$ of soil)	Dehydrogenases ($cm^3\ H_2 \cdot dm^3 \cdot d^{-1}$)			Urease ($mg\ N\text{-}NH_4 \cdot dm^{-3} \cdot h^{-1}$)			Alkaline phosphatase ($mmol\ PNP \cdot dm^{-3} \cdot h^{-1}$)			Acid phosphatase ($mmol\ PNP \cdot dm^{-3} \cdot h^{-1}$)		
	Horticultural soil											
	A	B	C	A	B	C	A	B	C	A	B	C
0	6.75	2.30	4.16	67.73	16.45	91.53	3.65	1.90	4.85	4.02	2.52	3.97
1	3.33	0.59	1.29	32.11	4.99	27.46	3.22	0.99	3.00	3.43	2.48	3.70
2	1.19	0.24	0.95	11.81	1.48	18.50	1.63	0.89	1.80	3.00	2.43	3.03
3	0.83	0.24	0.60	6.63	1.21	5.72	1.13	0.89	1.22	2.29	2.19	2.69
4	0.66	0.19	0.53	1.66	1.21	0.76	0.85	0.82	1.04	2.21	1.86	2.56
5	0.41	0.16	0.49	1.45	0.54	0.38	0.69	0.80	1.02	2.14	1.62	2.06
$\bar{x}$	2.19	0.62	1.34	20.23	4.31	24.06	1.86	1.05	2.16	2.85	2.18	3.00
r	-0.87	-0.76	- 0.79	-0.88	-0.79	-0.84	-0.94	-0.76	-0.90	-0.96	-0.95	-0.99
LSD	a – 0.13; b – 0.10; axb – 0.26			a – 0.50; b – 0.27; axb – 0.66			a – 0.17; b – 0.09; axb – 0.22			a – 0.11; b – 0.10; axb – 0.25		

a - sulfur dose; b - kind of horticultural soil; a x b - interaction; r - correlation coefficients

at 5.0 g • dm^{-3} the activity of urease in soil A dropped 47-fold, in soil B 31-fold and in soil C 241-fold. Soil acidification with sulfur also had a negative effect on the activity of alkaline phosphatase. Even the activity of acid phosphatase was inhibited by products of sulfur oxidation, although to a lesser extent compared to the other enzymes. The acidifying effect produced by sulfur, which is a result of sulfur being oxidized by bacteria to sulfates [7], shapes the physicochemical properties of soil and horticultural soil. Modified physicochemical soil properties, including soil acidity, influence chemical and biochemical properties by enhancing or depressing availability of nutrients [14] for plants and microorganisms. Soil reaction, therefore, can affect the development of microorganisms not only directly, but also indirectly by modifying the availability of nutrients. This in turn has an indirect effect on enzymatic activity [15, 16], which is also modified directly by the pH of the environment [17]. Many enzymes are active in a slightly acid or inert environment. Sulfur produced a strongly acid environment, which was unfavorable to dehydrogenases, urease alkaline phosphatase and even acid phosphatase. Acosta-Martinez and Tabatabai [9] reported that for the pH between 4.9 and 6.9, the activity of acid phosphatase in soil under agricultural crops was correlated negatively and the activity of other enzymes (glucosidase, galactosidase, amidase, urease, glutaminase, asparaginase, alkaline phosphatase and phosphadieterase) positively with the value of pH. This pattern of correlation is confirmed by the authors' own studies as regards dehydrogenases, urease and alkaline phosphatase. Had the horticultural soils been sown with plants, the activity of acid phosphatase might have been different, since this enzyme showed the weakest response to soil acidification caused by sulfur oxidation.

Conclusions

1. Elementary sulfur applied in the form of dust at rates from 1.0 to 5.0 g • dm^{-3} had an effect on physicochemical and biochemical properties of horticul tural soils.
2. The highest rate of sulfur reduced pH (in H_2O) from 6.7 to 3.9; the total of exchange bases by 3-fold; the total exchange capacity - 1.2-fold and the degree of base saturation - 2.4. At the same time, it increased hydrolytic acidity by 9-fold.
3. Acidification of horticultural soil through sulfur oxidation to sulfates reduced the activity of dehyd rogenases (by 12.6-fold), urease (74.1-fold), acid phos phatase (1.8-fold) and alkaline phosphatase (94.1-fold).

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