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INFLUENCE OF MUSHROOM SUBSTRATE ON LITHIUM, BARIUM AND STRONTIUM CONTENTS AT ITALIAN RYEGRASS

ODDZIAŁYWANIE PODŁOŻA POPIECZARKOWEGO NA ZAWARTOŚĆ LITU, BARU I STRONTU W BIOMASIE ŻYCICY WIELOKWIATOWEJ

Abstract: The two-year pot experiment carried out in a green-house dealt with the influence of bed after mushroom production and complementary potassium, nitrogen, and potassium-nitrogen nutrition on lithium, barium, and strontium contents in a biomass of Italian ryegrass. Mean concentrations of studied elements in the tested grass biomass varied in particular experimental years and cuts forming the following sequence: Li > > Ba > Sr.

Keywords: mushroom substrate, lithium, barium, strontium

The economic and live activities of a man along with a gradual industry development force societies in 21st century to solve problems with still growing waste amounts. Continuously increasing number of new mushroom-producing facilities in Poland, namely Siedlce region, a specific production cycle, and new substrate preparation technologies make that more and more mushroom substrate – ie spent mushroom substrate SMS – or mushroom compost after processing, is disposed into the natural environment every year.

The mushroom substrate is a waste organic product containing large amounts of organic matter and some level of nutrients important for plants. Thus, this post--production biological waste should be managed in such a way to return it – in non-toxic manner – to ecosystems. Properly prepared and performed mushroom substrate should not contain pests, disease-forming fungi and weed seeds, instead it should be of a good consistence and tolerated ground-recalling smell. It may be used as organic fertilizer in orchard, vegetable, and crop-producing farms localized mainly (due to economic reasons) near mushroom-producing facility. It can be used after con-

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taminated soils remediation. It has rich and diverse populations of microorganisms (bacteria) as well as mushroom mycelium remains [1].

The study aimed at evaluating the influence of mushroom substrate and complementary mineral nutrition on lithium, barium, and strontium contents at Italian ryegrass during the two-year pot experiment.

Materials and methods

The two-year pot experiment was carried out in a green-house in completely randomized design. The soil material was collected from the humus layer of light loamy sand soil (according to PTG). The percentage of particular fractions was as follows: sand (2–0.1 mm) 63 %, dust (0.1–0.02 mm) 20 %, fine particles (< 0.02 mm) 17 %, including clay (< 0.002 mm) 7 %; pH_{H_2O} of the soil 6.12, pH_{KCl} 6.04; contents of studied elements [$mg \cdot kg^{-1}$ soil] were: Li – 1.7; Ba – 82.18; Sr – 29.06.

A substrate after mushroom production as well as fermented bovine manure (as a standard) was applied as an organic material in the experiment. Contents of studied elements in the mushroom substrate were [$mg \cdot kg^{-1}$ d.m.]: Li – 10.4; Ba – 52.5; Sr – 97.6; while in the bovine manure: Li – 18.3; Ba – 49.8; Sr – 73.5.

Pots were filled with 12 kg of the soil and such weights of mushroom substrate and manure were added to introduce 4 g $N \cdot pot^{-1}$. Mineral nutrition (NPK) was applied in reference to N:P:K ratio as in the manure (1:0.8:1.2). Following experimental objects were created: a – soil – control; b – soil + fermented bovine manure; c – soil + + mushroom substrate; d – soil + mushroom substrate + K_1; e – soil + mushroom substrate + K_2; f – soil + mushroom substrate + N_1; g – soil + mushroom substrate + N_2; h – soil + mushroom substrate + K_1N_1; i – soil + mushroom substrate + K_2N_2.

A complementary mineral nutrition with potassium in a form of K_2SO_4 and with nitrogen as NH_4NO_3 was applied in rates: K_1 – potassium at the level of 50 % of optimum rate; K_2 – potassium at optimum rate; N_1 – nitrogen at the level of 25 % of optimum rate; N_2 – nitrogen at the level of 50 % of optimum rate.

Italian ryegrass (*Lolium multiflorum* Lam) was tested plant species. The experiment was carried out in three replications. During the vegetation period, four cuts were harvested, which made up 8 for two experimental years. The plant samples were dried, ground, and total contents of Li, Ba, and Sr were determined. In order to determine selected elements concentrations, samples were combusted in a muffle furnace at 450 ^oC. Mineralized material were flooded in crucible (placed on a sand bath) with hydrochloric acid solution ($HCl:H_2O$ = 1:1, v/v) to decompose carbonates and separate silicates. Achieved chlorides were transferred using 10 % HCl into the measure flask of 100 cm^3 capacity separating the silicates on a filter paper. In such prepared solutions, contents of Li, Ba, and Sr were determined by means of emission atomic spectrometry with inductively-coupled plasma (ICP-EAS).

The difference significance related to studied elements contents was verified by applying variance analysis (Fisher-Snedecor's test), and LSD values were calculated using Tukey's test at the significance level of $p = 0.05$.

Results and discussion

The size of Italian ryegrass biomass yield [g · pot^{-1}] grown in the two-year pot experiment with organic fertilization in a form of mushroom substrate and varied mineral nutrition application, was given earlier [4].

Mean contents of studied elements in Italian ryegrass biomass varied depending on years and cuts. They might be lined up in a following sequence [mg · kg^{-1} d.m.): Li (30.2–62.1) > Ba (12.4–39.1) > Sr (14.0–30.5).

Average lithium content at Italian ryegrass for all cuts of the 1st and 2nd cultivation year varied due to applied fertilization (Table 1), which was confirmed by LSD values. More that element was found at ryegrass biomass in the II (50.2 mg · kg^{-1}), than I experimental year (43.1 mg · kg^{-1}). For both years, the largest lithium amounts (64.0 mg · kg^{-1}) were recorded in the biomass of grown grass harvested from the object fertilized with mushroom substrate with addition of mineral nitrogen at N_1 rate, while the smallest (36.7 mg · kg^{-1}) at plants from object treated with mushroom substrate with potassium at K_2 rate. Lithium content in ryegrass biomass harvested from object fertilized with only mushroom substrate was lower (41.1 mg · kg^{-1}) than that amended with bovine manure (49.2 mg · kg^{-1}). The two-year experiments revealed that mineral nitrogen and potassium-nitrogen (N_1, N_2, K_1N_1, K_2N_2) elevated the lithium concentration in tested grass biomass.

Barium concentration at Italian ryegrass biomass of the I, II, and IV cut of the second experimental year was significantly affected by varied organic-mineral fertilization, which was confirmed by LSD values (Table 2). Much higher average barium content in the biomass of tested species was found in the first year of study (23.1 mg · kg^{-1}) than in the second (14.2 mg · kg^{-1}). The largest amounts of that element (mean for two years) were recorded at the Italian ryegrass biomass on object fertilized with the mushroom substrate with addition of K_2N_2 (22.6 mg · kg^{-1}), while the smallest – at plants from the object treated with mushroom substrate plus K_1 (14.7 mg · kg^{-1}). Barium content at tested plant was lower on object fertilized with only mushroom substrate (17.6 mg · kg^{-1}) than bovine manure (18.9 mg · kg^{-1}). Complementary mineral nutrition at all tested rates (K_2, N_1, N_2, K_1N_1) influenced on the increase of barium concentration in Italian ryegrass biomass as compared to only mushroom substrate.

Strontium contents in biomass of plants harvested from all cuts in the first and second experimental years indicated significant differentiation depending on the fertilization applied, which was proved by LSD values (Table 3). Mean strontium concentration in Italian ryegrass biomass harvested in the 2nd year was higher (23.3 mg · kg^{-1}) than in the 1st year of study (16.0 mg · kg^{-1}). The highest amounts of the element (average for two years) were recorded at plant harvested from the object treated with mushroom substrate and mineral nitrogen at N_2 rate (27.1 mg · kg^{-1}), while the lowest from objects fertilized with mushroom substrate and potassium at K_1 and K_2 rates (15.8 and 15.3 mg · kg^{-1}, respectively). Strontium contents in tested grass fertilized with the mushroom substrate only and bovine manure were similar (17.1 and 17.6 mg · kg^{-1}, respectively). Complementary nitrogen and potassium-nitrogen fertilization

Table 1

The content of lithium [mg · kg^{-1} of d.m.] in the yield of *Lolium multiflorum* in I and II year of cultivation

Fertilizer objects	The content of lithium [mg · kg^{-1} of d.m.]										
	I year of cultivation (cuts)					II year of cultivation (cuts)					Mean from two years
	I	II	III	IV	Mean	I	II	III	IV	Mean	
a	54.5	59.5	19.1	32.9	41.5	58.4	105	35.8	18.2	54.5	49.8
b	46.5	66.0	28.4	64.1	50.5	48.4	86.6	41.5	12.8	44.5	47.5
c	33.9	59.4	18.9	13.6	31.3	74.2	79.3	27.8	22.6	50.9	41.1
d	73.3	58.5	24.0	19.3	41.3	59.7	54.8	18.3	30.9	38.4	39.6
e	43.7	60.4	14.1	15.2	18.3	57.9	42.6	34.2	25.2	39.9	29.1
f	50.7	58.6	35.2	27.5	43.0	55.1	99.6	96.3	88.6	85.1	64.0
g	42.0	79.6	42.6	54.5	54.6	66.9	34.4	46.8	24.3	43.1	48.8
h	35.5	52.2	30.7	22.6	35.2	69.4	46.2	41.8	33.8	47.8	41.5
i	50.6	64.5	74.1	22.4	52.9	66.7	31.6	36.2	36.6	39.9	46.4
Mean	47.6	62.1	31.9	30.2	43.1	61.8	64.4	42.1	32.5	49.4	46.5
$LSD_{0.05}$	14.0	7.58	5.47	9.27		8.72	11.8	10.9	10.5		

Explanations: a – soil – control; b – soil + fermented bovine manure; c – soil + mushroom substrate; d – soil + mushroom substrate + K_1; e – soil + mushroom substrate + K_2; f – soil + mushroom substrate + N_1; g – soil + mushroom substrate + N_2; h – soil + mushroom substrate + K_1N_1; i – soil + mushroom substrate + K_2N_2.

Table 2

The content of barium [mg · kg^{-1} of d.m.] in the yield of *Lolium multiflorum* in I and II year of cultivation

Fertilizer objects	The content of barium [mg · kg^{-1} of d.m.]										
	I year of cultivation (cuts)					II year of cultivation (cuts)					Mean from two years
	I	II	III	IV	Mean	I	II	III	IV	Mean	
a	12.3	20.6	7.90	33.8	15.6	19.5	11.4	10.2	8.34	12.3	13.9
b	9.72	34.2	8.42	40.7	23.2	19.5	17.7	10.8	10.7	14.6	18.9
c	11.3	37.3	7.96	40.0	42.0	15.4	10.6	10.6	7.94	11.1	21.5
d	10.7	15.9	7.87	40.5	18.7	17.0	11.3	7.65	6.78	10.7	14.6
e	10.9	30.5	8.29	42.0	23.0	18.2	20.4	7.65	7.88	14.8	18.9
f	13.1	17.6	8.24	41.0	20.1	18.1	13.8	12.4	15.7	16.2	18.1
g	16.6	44.4	10.5	39.4	23.9	20.9	15.8	17.4	14.9	18.3	21.1
h	13.7	40.4	8.29	28.3	22.6	20.3	12.6	21.2	13.9	15.7	19.1
i	13.6	48.4	10.2	45.7	29.5	19.8	10.9	16.3	16.4	16.2	17.5
Mean	12.4	32.1	8.63	39.1	23.1	18.7	13.8	12.7	11.4	14.2	18.6
$LSD_{0.05}$	4.86	5.88	n.i.	6.84		n.i.	4.25	2.73	3.84		

Table 3

The content of strontium [mg · kg^{-1} of d.m.] in the yield of *Lolium multiflorum* in I and II year of cultivation

Fertilizer objects	The content of strontium [mg · kg^{-1} of d.m.]										
	I year of cultivation (cuts)					II year of cultivation (cuts)					Mean from two years
	I	II	III	IV	Mean	I	II	III	IV	Mean	
a	17.5	14.8	17.6	23.2	18.3	21.9	19.7	19.1	21.1	20.4	19.3
b	12.7	13.6	11.2	16.4	13.5	25.2	19.7	21.1	20.8	21.7	17.6
c	13.5	12.9	15.4	17.9	14.9	19.4	15.3	19.2	23.4	19.4	17.1
d	12.9	11.2	16.4	16.1	14.1	19.2	17.3	14.5	19.4	17.6	15.8
e	12.7	11.3	12.4	15.8	13.1	20.2	18.7	19.6	15.8	18.6	15.3
f	14.4	15.6	14.7	15.4	15.0	23.3	21.1	27.3	49.6	30.3	22.6
g	19.3	19.1	16.2	27.5	20.2	25.3	26.8	29.9	54.0	34.0	27.1
h	13.5	12.3	15.8	24.6	16.5	23.3	19.3	18.9	35.5	24.2	20.3
i	15.5	15.7	14.6	27.4	18.3	24.1	16.2	20.4	35.0	23.3	20.8
Mean	14.7	14.0	14.9	20.5	16.0	22.4	19.3	21.1	30.5	23.3	19.7
$LSD_{0.05}$	4.05	3.83	2.13	3.49		1.87	2.68	4.17	5.03		

(N_1, N_2, K_1N_1, K_2N_2) affected the increase of the element concentration in tested grass as compared with objects fertilized with only mushroom substrate.

Lithium and barium levels at Italian ryegrass were higher, while strontium lower, when compared with earlier studies [2, 3], in which the influence of various mushroom substrate rates on trace elements contents at Italian ryegrass was examined. Higher lithium and barium concentrations at the grass might result from a slight soil acidifying due to mineral fertilization used, which might invoke the elevated intake of these elements by tested grass.

Conclusions

1. Less lithium, slightly more barium, and similar amounts of strontium were recorded in the biomass of Italian ryegrass grown in the two-year pot experiment on objects fertilized with only mushroom substrate as compared with those treated with bovine manure.

2. Complementary nitrogen and potassium-nitrogen nutrition at N_1, N_2, K_1N_1 and K_2N_2 rates affected the increase, while potassium (K_1, K_2) the decrease of barium, lithium, and strontium contents in tested grass yields in reference to treating with only the mushroom substrate.

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Abstrakt: W dwuletnim doświadczeniu wazonowym, przeprowadzonym w warunkach szklarni, badano wpływ podłoża po produkcji pieczarek i uzupełniającego nawożenia potasowego, azotowego i potasowo-azotowego na zawartość Li, Ba i Sr w biomasie życicy wielokwiatowej. Średnia zawartość badanych pierwiastków w biomasie testowanej trawy była zróżnicowana w poszczególnych latach i pokosach, układając się w następującym szeregu malejących wartości: Li > Ba > Sr.

Słowa kluczowe: podłoże popieczarkowe, lit, bor, stront