THE EFFECT OF ZEOLITE AND BENTONITE ON SOME SOIL CHEMICAL AND MICROBIOLOGICAL CHARACTERISTICS AND ON THE BIOMASS OF THE TEST PLANT

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Abstract

In a pot experiment, we have studied the effect of zeolite and bentonite in different dosages in comparison to the control treatment on acidic (pH_{H2O}=5.93) humus sandy soil. The experiment was set up in 2007 and 2008 in the greenhouse of the UD CASE Department of Agrochemistry and Soil Science. As a test plant, perennial ryegrass (Lolium perenne L.) was used.

In laboratory examinations, $pH_{(H2O)}$, $pH_{(KCl)}$, hidrolytic acidity, nitrate-N content, nitrate-exploration of soil, readily available phosphorus and potassium content were determined. From among soil microbial parameters, the total number of bacteria, and microscopic fungi, the carbon-dioxide production of soil were measured. In the experiment the biomass of the test plant was determined.

The effect of zeolite and bentonite in different dosages on the studied chemical and microbial soil parameters and on the plant biomass can be summarized as follows:

- *The pH increased under the effect of low dosages. The pH increased in major extent under the effect of bentonite, than under the zeolite. With the increasing of the pH the hidrolytic acidity - at the bentonite treatments significantly – decreased.*
- *Regarding the readily available nutrient content of the soil, low and medium dosages proved to be effective. High dosages of zeolite treatments reduced the nitrate-N content, high dosage of bentonite treatments reduced the nitrate-N content, the readily available phosphorus, and potassium content of soil. The degree of the nitrate-exploration increased on the effect of low and medium dosages also, but in bentonite experiments the high dosages prevented the nitrate-exploration.*
- *Regarding the measured soil microbial parameters in both treatments low and medium dosages proved to be also effective, but the high dosages didn't cause decreasing at the total number of bacteria, and by zeolite treatments the soil-respiration. The high dosages decreased the number of microscopic fungi, and by bentonite treatments the soil respiration.*
- *Also the zeolite, and bentonite treatments enlarged the biomass of the test plant. We experienced significantly increasing by zeolite treatment 4., while in bentonite treatments the medium and high dosage caused significantly increasing in plant biomass. The largest dosages also didn't decrease the plant biomass significantly.*
- *We found some medium correlation between the studied parameters. Strong correlation was found between the hidrolytic acidity of soil and the biomass of the test plant (r=-0,806).*
- *In sum, it can be stated that both zeolite and bentonite treatments had a favourable effect on some studied chemical and microbial parameters of acidic sandy soil, and on the biomass of the test plant. Regarding nutrient stock of the soil zeolite treatments were more stimulating. For microbial activity, the zeolite treatment proved to be advantageous for amount of the total number of bacteria, and carbon-dioxide production of the soil, while the bentonite treatments had a better effect on the microscopic fungi. The bentonite treatments were more effective regarding the plant biomass.*

Keywords: sandy soil, bentonite, zeolite, nutrient content, soil microbiology, plant biomass

INTRODUCTION

An essential tool for increasing agricultural production and for successful crop production is the protection of soils, the preservation of their fertility. The maintenance and enhancement of soil fertility can only be solved by enlarging the range of materials with a more complex effect for soil amelioration and yield enhancement. Up-to-date agrotechniques become profitable only where the necessary conditions are provided, that is on soils with appropriate fertility (Balogh, 1999).

Nowadays, the notion of ”sustainable agriculture” is widely used worldwide, the cornerstone of which is the sound utilization of our most important natural resource, the soils, their protection and the maintenance of their diverse functions (Várallyay, 2005). With a view to these requirements, the use of natural materials in soil amelioration such as alginite (Solti, 1987; Kátai, 1994), zeolite (Kazó, 1981; Köhler, 2000), or bentonite (Márton & Szabóné 2002; Makádi et al. 2003; Tállai, 2007; Szeder et al. 2008) is increasing.

Zeolite is an aluminium-silicate, which generally forms in the caves of basic vulcanic rocks (basalts), but it can appear as an accompanying mineral in hydrotermal streaks of ore.

It is used for multiple purposes both by the industry and agriculture. As a fertilizer, it has an advantageous effect on soil pH (reduces acidity) and the management of rare elements (Simon, 2001; Muhlbachova & Simon, 2003). It enhances water uptake by plants and the water management of soils. A major utilization form of it in agriculture is as a feed additive in animal husbandry (Željko et al., 2007; Šperanda et al. 2008), it prevents deficiency diseases by supplying rare elements.

Bentonite is a rock consisting mainly of montmorillonite (Fekete & Stefanovits, 2002), but it also contains caolin, quartz, mica, feldspar, illyte, crystobalite and lime (Pártay et al., 2006). It is considered a promising amelioration material, as literature data support that it has a favourable effect on the physical, chemical and biological characteristics of soils with unfavourable parameters.

Bentonite contains three-layered clay minerals and due to the isomorph replacement of central ions, it has a high cation adsorption capacity. By mixing these materials into the soil, it increases the nutrient content via preventing them from leaching (Noble et al., 2000).

In an incubation experiment, Usman et al. (2005) studied the effect of different clay minerals (Ca-bentonite, Na-bentonite, zeolite) on the heavy metal pollution and microbial characteristics of soils treated with sewage sludge. According to their results, the metal concentration of the soil decreased, while soil respiration, soil microbial biomass-C content and inorganic N content increased as a result of clay mineral treatments (especially in Na-bentonite and Ca-bentonite treatments). Summing up, their results proved that clay minerals have an advantageous effect on soil microbial activity.

MATERIALS AND METHODS

The pot experiment was set up at the greenhouse of the UD CASE Department of Agrochemistry and Soil Science on humus sandy soil ($pH_{(H2O)}$ 5.93) in 2007 and 2008. In the treatments, the same dosages of zeolite and bentonite were applied *(Table 1.)*. As a test plant, perennial ryegrass *(Lolium perenne L.)* was used. Samples were collected in fourth and eight weeks of the season. The laboratory examinations were performed at the soil chemistry and soil microbiology laboratory of the Department. As a basic treatment, 100 mg P_2O_5 and 100 mg K_2O was applied to each pot as a common solution of potassium-dihydrogen-phosphate and potassium-sulphate. We measured the $pH_{(H2O)}$, $pH_{(KCl)}$, hidrolytic acidity (Filep,1995), nitrate-N content of soil, and the degree of nitrate-exploration (Felföldy, 1987). The readily available phosphorus and potassium content were also determined (Gerei, 1970). From among the microbial parameters, the total number of bacteria, and microscopic fungi were determined by plate dilution from soil-water suspension (on Bouillon soup, and peptone-glucose agar) (Szegi, 1979). We also measured the amount of carbon-dioxide released from the soil in 10 days (Witkamp, 1966 cit. Szegi, 1979). Twice in each one season the biomass of the test plant were determined. The results were evaluated statistically, the means of samplings, deviation and significant differences were calculated and correlation analysis was applied for revealing the relationships between the studied parameters. We used for calculate the statical analysis the SPSS 13.0 for Windows program.

Table 1.

The applied zeolite and bentonite treatments

Treatments number	Treatments	
	ZEOLITE	BENTONITE
1.	control	control
2.	5g kg^{-1}	5g kg^{-1}
3.	10g kg^{-1}	10g kg^{-1}
4.	15g kg^{-1}	15g kg^{-1}
5.	20g kg^{-1}	20g kg^{-1}

RESULTS AND CONCLUSIONS

The change of soil pH are presented based on the averages of the repetitions at the two sampling dates. We measured the pH in aqueous medium and in KCl solution. According to our results in case of zeolite treatments $pH_{(H2O)}$ ranged between 5.5 and 6.09 *(Figure1.)*. The second treatment increased the soil pH, though for larger dosages we experienced decrease. By bentonite the results were similar, the pH varied between 5.7 and 6.07, as a result of low dosage the soil pH increased significantly.

The pH values measured in KCl solutions ranged between 4.37 and 5.03 *(Figure 1.)* In case of both treatments the smallest dosage caused significant increment. For bentonite treatment the twofold dosage increased the pH also significantly. High dosages of zeolite decreased the soil pH significantly.

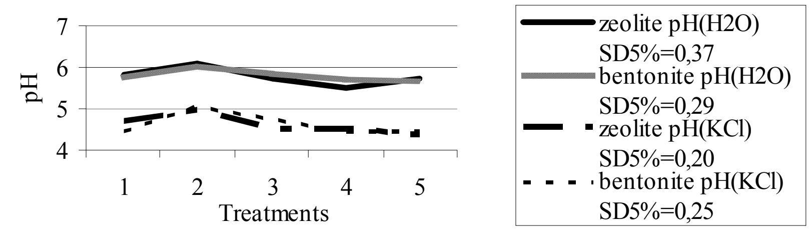

Figure 1: The effect of zeolite and bentonite treatments on the $pH_{(H2O)}$ and $pH_{(KCl)}$ of the soil (averages of samplings in 2007-2008)

In connection with soil pH we measured the values of hidrolytic acidity *(Figure 2.)*, that ranged between 11.14 and 14.11 in case of the two treatment methods.

The y_1 values reduced as a result of treatments, the decrease was significant for all bentonite dosages.

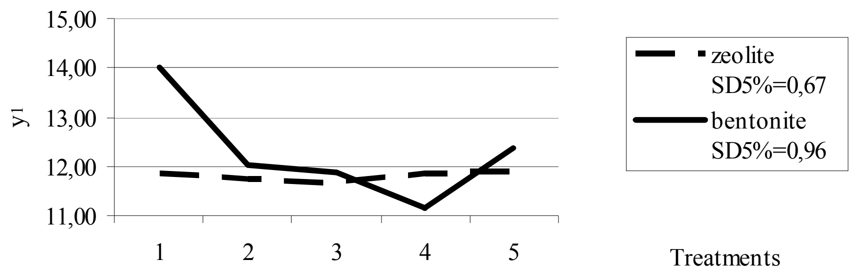

Figure 2: The effect of zeolite and bentonite treatments on the hidrolytic acidity of soil (averages of samplings in 2007-2008)

Relating to the soil nutrient content *(Table 2.)* we measured the soil nitrate-N content. In 2007 the zeolite treatments had no significant effect on nitrate-N content of soil. Larger nitrate-N content was caused by onefold dosage. In case of bentonite treatments small and medium dosage (treatments 2. and 3.) increased the nitrat-N content of soil significantly, although the two largest dosages caused depression (treatment 4. and 5.)
Nitrate-exploration was enhanced by small and medium dosages (treatments 2. and 3.) in case of both treatments, by bentonite treatment the threefold dosage has a significant positive effect on nitrate-exploration.

Easily available phosphorous and potassium content increased significantly by both treatments. Low and medium dosages proved to be effective. High dosage (5. treatment) caused also significant increment in phosphorus content by zeolite treatment. Potassium content increased also for the fourfold dosage, but the treatment did not prove to be significant. In case of bentonite treatments phosphorous content increased as an effect of medium dosage. Although the two highest dosages decrease its value.
The highest value for AL-soluble potassium was measured at small dosage (treatment 2.), but treatment 3. and 4. increased its quantity also significantly. The highest dosage caused non significant increment.

Considering the experimental results of 2008 similarly to our former results nitrate-N content of soil did not change significantly for the treatments by zeolite. In bentonite treatments small increment was resulted by treatments 4, while for bentonite small and medium dosages proved to be stimulating.

Nitrate-exploration increased significantly as an effect of zeolite, and bentonite treatments 2., and 3. The threefold dosage by zeolite increased significantly its value, too. The highest dosage by bentonite decrease its value.

Easily available phosphorous and potassium content increased as an effect of onefold dosage for both treatment methods, and medium dosage (treatment 3.) increased their value also. In case of zeolite treatments except for potassium content the highest dosages reduced their value.

Table 2

The effect of treatments on the readily available nutrient content and nitrate-exploration of soil (averages of samplings in 2007-2008)

	zeolite				bentonite			
	2007.							
Treatments number	Nitrate-N (mg 100 g^{-1})	Nitrate-exploration (mg 100 g^{-1})	P_2O_5 (mg 100 g^{-1})	K_2O (mg 100 g^{-1})	Nitrate-N (mg 100 g^{-1})	Nitrate-exploration (mg 100 g^{-1})	P_2O_5 (mg 100 g^{-1})	K_2O (mg 100 g^{-1})
1.	4.58	5.25	100.67	220.00	3.53	5.19	94.50	246.67
2.	5.91	6.99	131.67	276.67	4.66	8.19	99.66	283.33
3.	5.52	7.78	106.33	273.33	4.80	7.66	111.66	280.00
4.	4.66	6.61	154.33	263.33	3.10	8.87	88.86	270.00
5.	3.05	5.00	130.33	246.67	2.63	4.70	90.03	253.33
$SD_{5\%}$	1.56	1.54	15.07	31.60	1.07	1.07	5.81	18.19
	2008.							
1.	3.44	6.01	104.00	212.17	4.11	5.86	90.43	254.17
2.	3.23	9.25	112.83	260.83	5.55	7.63	96.83	312.50
3.	3.04	8.60	109.00	236.67	5.62	6.96	112.00	271.33
4.	3.70	8.50	97.57	274.50	4.30	6.31	87.58	259.17
5.	3.61	7.07	100.67	295.00	3.85	4.85	85.53	244.17
$SD_{5\%}$	0.52	2.08	8.34	24.31	1.00	1.06	9.00	25.07

Among microbiological soil properties we investigated the total number of bacteria for both treatment methods *(Table 3.)*. In 2007 small and medium dosages proved to be effective for both bentonite and zeolite treatments. For zeolite treatment the treatment 2, while in case of bentonite treatments 3. and 4. influenced the total number of bacteria positively. Fourfold dosages had reducing effect.

The number of microscopic fungi were increased also by treatment 2. and 3., in case of bentonite threefold dosage increased its value also significantly. Fourfold dosages resulted reduce.

Soil CO_2-production was increased significantly by onefold and secondfold dosages of bentonite. The largest dosage significantly decreased the soil carbon-dioxide production in both cases.

In 2008 the total number of bacteria was increased by both treatments, in case of low and medium dosage (treatment 2., 3., by bentonite 4.,also) the increment was significant. High dosages decreased their quantities.

The number of microscopic fungi increased as an effect of low and medium dosages of zeolite (treatment 2. and 3.) while significant reduction was measured for the greatest dosage. In case of bentonite their number increased, too, significantly on effect of one-, two-, and threefold dosages.

Soil respiration intensified for both treatment methods, treatment 3. and 4. proved to be stimulating, in case of zeolite treatment the soil CO_2-production was increased significantly by low dosage (treatment 2.).

Table 3

The effect of treatments on total number of bacteria, and fungi and on the CO_2-production of soil (averages of samplings in 2007-2008)

	zeolite			bentonite		
	2007.					
Treatments number	Total number of bacteria ($*10^6$ g^{-1} soil)	Microscopic fungi ($*10^3$ g^{-1} soil)	CO_2-production (CO_2 mg $100g^{-1}$ 10 $days^{-1}$)	Total number of bacteria ($*10^6$ g^{-1} soil)	Microscopic fungi ($*10^3$ g^{-1} soil)	CO_2-production (CO_2 mg $100g^{-1}$ $10days^{-1}$)
1.	2.12	67.33	4.05	2.27	55.33	4.60
2.	3.30	74.00	4.48	2.95	86.33	5.88
3.	2.35	67.67	6.98	4.92	80.67	5.43
4.	1.85	67.33	4.63	3.73	80.00	4.25
5.	1.93	62.33	3.55	2.25	52.33	3.25
$SD_{5\%}$	0.56	6.56	0.47	1.23	9.10	0.39
	2008.					
1.	2.27	59.67	4.03	2.50	57.83	4.15
2.	4.87	71.83	5.17	4.62	68.50	4.22
3.	6.95	61.33	6.35	4.47	69.17	5.83
4.	3.23	53.83	5.20	4.00	68.50	5.70
5.	2.50	51.50	4.67	3.43	49.17	4.93
$SD_{5\%}$	1.33	6.13	0.69	1.49	8.77	0.92

During soil sampling the quantity of plant-biomass was measured *(Figure 3.)* in both season. Its value changed in zeolite treatments between 2.85-3.25g $seasons^{-1}$, in bentonite treatments between 2.80-3.26g $seasons^{-1}$. Our results show that both zeolite and bentonite treatments increase the plant production, in case of zeolite, treatment 4., while for bentonite treatment 3. and 4. caused significant increment. The largest dosage (fourfold) didn't diminishe significantly the dry matter production of plant.

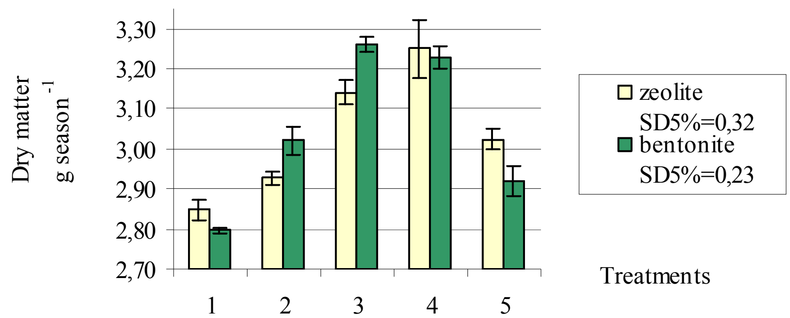

Figure 3. The effect of treatments on the biomass of the test plant, rye-grass *(Lolium perenne L.)* (average values of 2007-2008)

The results of the two experimental years (2007-2008) were evaluated by correlation analysis *(Table 4.)*. In case of zeolite treatment medium correlation was found between the pH measured in KCl solution and the nitrate-N content of the soil (r=0.579), the total number of bacteria (r=0.793), plant biomass (r=0.618). Medium correlation was also between the hidrolytic acidity and the nitrate-N content of the soil (r=-0.620), the total number of bacteria (r=-0.701). Further between the AL-phosphorus content of soil and the soil respiration (r=0.587), and between the nitrate-N content of the soil, and the plant biomass (r=0.567). Strong correlation was between the y_1 and the biomass of the testplant (r=-0.806).

For bentonite treatments medium correlation was found between the $pH_{(H2O)}$ and CO_2-production (r=0.512), the $pH_{(KCl)}$, and easily soluble phosphorous content of soil (r=0.641), total number of bacteria (r=0.521). Further medium correlation was between the AL-potassium content and soil respiration (r=0.679).

Table 4:

Correlation analysis (r) (average values of 2007-2008)

Studied parameters		r
zeolite		
$pH_{(KCl)}$	Hidrolytic acidity (y_1)	-0.655
	Nitrate-N content	0.579
	Total number of bacteria	0.793
	Plant biomass	0.618
Hidrolytic acidity (y_1)	Nitrate-N content	-0.620
	Total number of bacteria	-0.701
	Plant biomass	-0.806
AL-phosphorus	CO_2 - production	0.587
Nitrate-N content	Plant biomass	0.567
bentonite		
$pH_{(H2O)}$	CO_2 - production	0.512
$pH_{(KCl)}$	AL-phosphorus	0.641
	Total number of bacteria	0.521
AL-potassium	CO_2 - production	0.679

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