THE EFFECT OF ZEOLITE AND BENTONITE ON SOME SOIL CHARACTERISTICS ON ACIDIC SANDY SOIL

János Kátai – Rita Kremper - Magdolna Tállai
University of Debrecen, Centre for Agricultural Sciences and Engineering, Faculty of Agriculture,
Department of Agrochemistry and Soil Science, Debrecen
katai@agr.unideb.hu

SUMMARY

In a pot experiment, we have studied the effect of zeolite and bentonite in different dosages [control-5 (1x)-10 (2x)-15 (3x)-20 (4x) g kg^{-1}] in comparison to the control treatment on acidic (pH_{H2O}=5.58) humus sandy soil. The experiment was set up in 2007 in the greenhouse of the UD CASE Department of Agrochemistry and Soil Science. As a test plant, perennial ryegrass *(Lolium perenne L.)* was used. The samples were collected four and eight weeks after sowing.

In laboratory examinations, nitrate-N content, readily available phosphorus and potassium content were determined. From among soil microbial parameters, the total number of bacteria, the amount of cellulose-decomposing bacteria, the carbon-dioxide production of soil and saccharase activity were measured.

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

- Regarding the readily available nutrient content of the soil, low and medium dosages proved to be effective, high dosages of both treatments reduced the nitrate-N content. A high dosage of zeolite significantly increased the readily available phosphorus content of the soil, it also increased (not significantly) the AL-soluble potassium content. A high dosage of bentonite reduced (not significantly) the AL-soluble phosphorus content of the soil and increased the readily available potassium content.
- Among the soil microbial parameters, the total number of bacteria was measured and it was increased by both treatments. The low (1x) and medium (2x, 3x) dosages resulted in a significant increment for zeolite and bentonite treatments, respectively. The bentonite treatments resulted in a larger increment than the zeolite treatments.
- The twofold dosages of both treatments tripled the number of cellulose-decomposing bacteria. The number of bacteria increased significantly as a result of the medium-dosage bentonite treatment. The highest dosage of both treatments reduced the number of bacteria below that of the control.
- The CO_2-production of the soil was significantly increased by the two- and threefold dosages of zeolite and by the low and medium dosages of bentonite. Based on our results, the zeolite treatments proved to be more effectibe as regards soil respiration.
- Saccharase activity was significantly increased by the basic dosage (1x). Medium dosages resulted in a significant and non-significant increase in enzyme activity in the case of bentonite and zeolite treatments, respectively. The largest dosage of both treatments reduced the enzyme activity.
- In the correlation analysis, we found a tight positive correlation between the soil nitrate-N content and the saccharase activity (r=0.880). In the case of the bentonite treatments, we also found a tight positive correlation between the changes in the total number of bacteria and saccharase activity (r=0.869). We found medium correlations between numerous other soil parameters.

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 soils. The zeolite treatments were more effective regarding the nutrient stock of the soil. For microbial activity, the zeolite treatment proved to be advantageous for the carbon dioxide production of the soil, while the bentonite treatments had a better effect on the total number of bacteria, the amount of cellulose-decomposing bacteria and the saccharase activity.

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 kaolin, quartz, mica, feldspar, illite, 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).

The primary effect of bentonite is the increase of the available water content of the soil. Thereby, it contributes to the inducement of biological activity as the wate potential of the soil is one of the most important factors for the microbes. There is a tight correlation between the moisture content of the soil and the amount of soil algae (Shitina & Bolyshev, 1963; Shimmel & Darley, 1985).

According to Lazányi & Karucka (2003), bentonite decreases the water permeability of sandy soils. The results support that the macropores determine the speed of water movement in soils almost saturated with water. As a result of a bentonite treatment, the amount of water permeating through the soil profile is reduced depending upon the dosage and the depth of mixing it into soil. The reduction is greater if the whole amount of bentonite is applied to the 0-20 cm soil layer. As an effect of bentonite mixed into the soil column, the amount of withheld water increased. The increase was not significant, but it could be detected well at the 6 kg/m^2 dosage.

In the experiment of the University of München, where bentonite was mixed to the soil of salad seedlings, the 3% dosage had a favourable effect on the fresh weight of seedlings, but a higher dosage had a depressing effect on plants (Schnitzler et al., 1994).

According to Kátai et al., (2007), manure composted with bentonite significantly increased the total number of bacteria, the total number of fungi, the amount of cellulose-decomposing bacteria and the biomass-C content of soils.

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.

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

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 ($pH_{(H2O)}$ 5.65) in 2007. In the treatments, the same dosages of zeolite and bentonite were applied. The different treatments are presented in Table 1. The experiment was performed in three repetitions with 1 kg soil per pot. The moisture content of soils was set to 70% of maximum water capacity, then they were irrigated daily to a constant mass. As a test plant, perennial ryegrass *(Lolium perenne L.)* was used. Samples were collected in fourth and eighth weeks of the season. After thorough homogenization, the laboratory examinations were performed at the soil chemistry and soil microbiology lab 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 nitrate-N content (Felföldy, 1987) and the readily available phosphorus and potassium content (Gerei, 1970). From among the microbial parameters, the total number of bacteria were determined by plate dilution from soil-water suspension (on Bouillon soup agar) (Szegi, 1979). The number of cellulose-decomposing bacteria was determined by most probable number of germs method of Pochon & Tardieux, (1962). We also measured the amount of carbon-dioxide released from the soil in 10 days (Witkamp cit. Szegi, 1979) and the activity of the saccharase enzyme (Bertrand cit. Szegi, 1979).

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. Statistical evaluation was done using the SPSS 13.0 programme.

Treatment No.	Dosages	Treatments	
		ZEOLITE	**BENTONITE**
1.	-	control	control
2.	5 $g\ kg^{-1}$	1x	1x
3.	10 $g\ kg^{-1}$	2x	2x
4.	15 $g\ kg^{-1}$	3x	3x
5.	20 $g\ kg^{-1}$	4x	4x

Table 1. The applied zeolite and bentonite treatments

RESULTS AND CONCLUSIONS

The results presented in the study are the averages of the repetitions at the two sampling dates. In our examinations, we measured the readily available nutrient content of soils.

As an effect of the zeolite treatments, the nitrate-N content of the soil (Figure 1) ranged between 3.05 and 5.91 mg kg^{-1}. The treatments did not have a significant effect. A higher nitrate-N content was measured for the 1x dosage. The highest dosage of treatment 5 reduced (non-significantly) the nitrate-N content of the soil.

In the bentonite treatments, the nitrate-N content of the soil varied between 3.53 and 4.80 mg kg^{-1}. As a result of the low and medium dosages (treatments 2 and 3), the soil nitrate-N content increased significantly, while the nitrate-N values at the two highest dosages (treatments 4 and 5) were lower than that of the control.

Bentonite $SD_{5\%}$=1.07
Zeolite $SD_{5\%}$=1.56

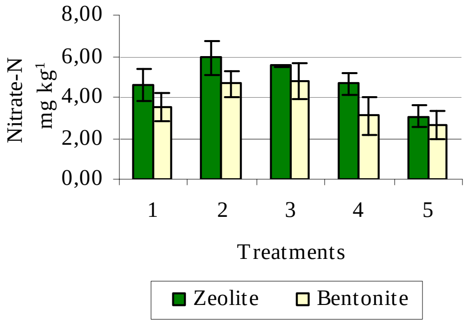
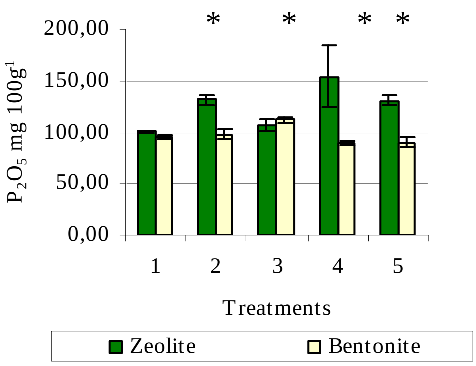


Figure 1: The effect of zeolite and bentonite treatments on the nitrate-N content of the soil (averages of samplings in 2007)

Regarding the readily available phosphorus and potassium content (Figure 2), the soil was in the medium- (100.66; 94.5 P_2O_5 mg kg^{-1}), and well-supplied categories (220.00; 246.67 K_2O mg kg^{-1}). In the zeolite treatments, both phosphorus and potassium contents increased significantly, phosphorus content increased significantly also as a result of the high dosage (treatment 5) (130.33 P_2O_5 mg kg^{-1}). Potassium content also increased (but not significantly) as a result of the fourfold dosage (246.67 K_2O mg kg^{-1}). In the case of bentonite treatments, the low and medium dosages (treatments 2 and 3) proved to be effective, phosphorus content increased significantly as a result of the medium dosage (111.66 mg kg^{-1}). The two highest dosages reduced phosphorus content, though not significantly. The highest value of AL-soluble potassium (283.33 mg kg^{-1}) was measured at the low dosage (treatment 2), but it increased significantly also in treatments 3 and 4. The highest dosage resulted in a non-significant increment.

2a.

Zeolite AL-phosphorus *$SD_{5\%}$=15.07
Bentonite AL-phosphorus *$SD_{5\%}$=5.81



2b.

Zeolite AL-potassium *$SD_{5\%}$=31,63

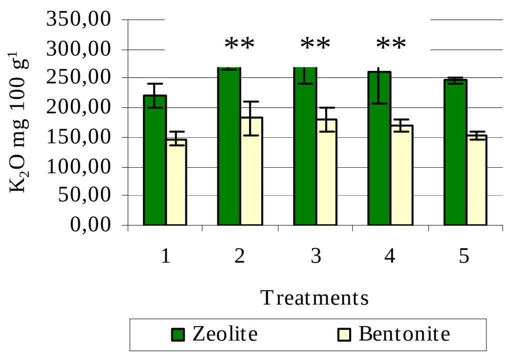


Figure 2: The effect of zeolite and bentonite treatments on the readily available phosphorus (2a) and potassium content (2b) of the soil (averages of samplings in 2007)

Among the soil microbial parameters, the total number of bacteria was measured in both treatment types. Regarding the zeolite treatments *(Table 2)* it can be stated that the low- and medium-dosage treatments proved to be effective, that is treatments 2 and 3 increased the total number of bacteria significantly and non-significantly, respectively. The three- and fourfold dosages resulted in a non-significant reduction.

The number of cellulose-decomposing bacteria were increased also by the low and medium dosages, treatment 3 significantly increased (tripled) their number. Treatments 4 and 5 reduced their number, though not significantly, the highest dosage reduced it to the level of the control.

The CO_2-production of the soil was increased non-significantly by the 1x dosage and significantly by the two- and threefold dosages. The highest dosage significantly reduced the carbon-dioxid production of the soil.

The activity of the saccharase enzyme increased in treatments 2, 3 and 4, the 1x dosage resulted in a significant increase. Treatment 5 non-significantly reduced the activity of saccharase.

Treatment No.	Zeolite treatments	Total number of bacteria ($*10^6$ g^{-1} soil)	Cellulose-decomposing bacteria ($*10^3$ g^{-1} soil)	CO_2-production (CO_2 mg $100g^{-1}$ 10 nap^{-1})	Saccharase (Glucose mg $100g^{-1}$)
1.	control	2.12	1.55	4.05	4.38
2.	1x	*3.30	2.40	4.48	*7.13
3.	2x	2.35	*4.65	*6.98	6.93
4.	3x	1.85	2.35	*4.63	5.21
5.	4x	1.93	1.50	*3.55	3.44
$*SD_{5\%}$		0.56	1.29	0.47	2.74

Table 2.: The effect of zeolite treatments on some soil microbial characteristics (avarage of the samples in 2007.)
Number of treatments; Zeolite treatments; Total number of bacteria ($*10^6$ g^{-1} soil); Cellulose-decomposing bacteria ($*10^3$ g^{-1} soil); CO_2-production (CO_2 mg $100g^{-1}$ 10 $days^{-1}$), Saccharase enzyme (glucose mg 100^{-1})

Regarding the bentonite treatments (*Table 3)*, it can be stated that the total number of bacteria increased (non-significantly) already as a result of the lowest dosage (treatment 2). The two medium dosages (treatments 3 and 4) significantly increased its value, the more effective was treatment 3. The highest dosage reduced the total number of bacteria to the level of the control.

The highest number of cellulose-decomposing bacteria (four times higher than that of the control) was also measured in treatment 3 (medium dosage), but their number was already significantly increased by treatment 2. As a result of treatment 4, a somewhat higher number of bacteria was measured, but the value was close to that of the control. The highest dosage resulted in a non-significant reduction.

The CO_2-production of the soil increased significantly as a result of the low and medium dosages (treatments 2 and 3), the largest CO_2-production was measured in treatment 2 (lowest dosage). Treatments 4 and 5 reduced soil respiration, the highest dosage resulted in a significant reduction.

The activity of saccharase was significantly increased to almost 250% by small and medium dosages (treatments 2 and 3). Treatment 4 also increased (non-significantly) enzyme activity, while the highest dosage reduced the enzyme activity under that of the control.

Treatment No.	Bentonite treatments	Total number of bacteria ($*10^6$ g^{-1} soil)	Cellulose-decomposing bacteria ($*10^3$ g^{-1} soil)	CO_2-production (CO_2 mg $100g^{-1}$ 10 day^{-1})	Saccharase (Glucose mg $100g^{-1}$)
1.	control	2.27	2.45	4.60	4.62
2.	1x	2.95	*8.65	*5.88	*10.03
3.	2x	*4.92	*8.80	*5.43	*11.21
4.	3x	*3.73	2.90	4.25	5.65
5.	4x	2.25	1.49	*3.25	3.75
$*SD_{5\%}$		1.23	2.36	0.39	2.81

Table 3.: The effect of bentonite treatments on some soil microbial characteristics (avarage of the samples in 2007.)
Number of treatments; Bentonite treatments; Total number of bacteria ($*10^6$ g^{-1} soil); Cellulose-decomposing bacteria ($*10^3$ g^{-1} soil); CO_2-production (CO_2 mg $100g^{-1}$ 10 $days^{-1}$), Saccharase enzyme (glucose mg 100^{-1})

The results were evaluated by correlation analysis to determine the relationship between the changes in the soil nutrient content and the studied microbial parameters separately for the zeolite and bentonite treatments.

In the zeolite treatments *(Table 4)* a medium positive correlation was found between the nitrate-N content of the soils and the readily available phosphorus content (r=0.622). A medium correlation was also found between the nitrate-N content (r=0.709), the readily available phosphorus content (r=0.627) and the total number of bacteria. Further medium correlations were found between AL-soluble phosphorus and saccharase activity (r=0.765), and the total number of bacteria and saccharase activity (r=0.788). There was a tight correlation between the changes in the nitrate-N content of the soil and the activity of the saccharase enzyme (r=0.880).

Measured soil characteristics	Nitrate-N	AL-P_2O_5	AL-K_2O	Total number of bacteria	Cellulose-decomposing bacteria	CO_2-production	Saccharase enzyme
Nitrate-N	**1**						
AL-P_2O_5	.622*	**1**					
AL-K_2O	.298	.455	**1**				
Total number of bacteria	.709*	.627*	.316	**1**			
Cellulose-decomposing bacteria	.352	.121	.113	.487	**1**		
CO_2-production	.286	.452	.308	.392	-.123	**1**	
Saccharase enzyme	.880**	.765*	.339	.788*	.348	.304	**1**

Table 4: Correlation analysis (r) (Zeolite)
Measured soil characteristics; Nitrate-N; AL-phosphorus; AL-potassium; Total number of bacteria; Cellulose-decomposing bacteria; CO_2-production; Saccharase enzyme

In the bentonite treatments (*Table 5)* a medium positive correlation was found between the changes in the soil nitrate-N content and the readily availanle potassium content (r=0.679), and between the readily available potassium and phosphorus contents (r=0.526). The change in the soil nitrate-N content had a positive effect on the total number of bacteria, a medium correlation was found between them (r=0.544). The changes in the soil nitrate-N content and the saccharase enzyme activity also showed a medium positive correlation (r=0.667). There was a medium positive correlation between the amount of cellulose-decomposing bacteria and the CO_2-production of the soil (r=0.773). There was a tight positive correlation between the total number of bacteria and the changes in the saccharase activity (r=0.869).

Measures soil characteristics	Nitrate-N	AL-P_2O_5	AL-K_2O	Total number of bacteria	Cellulose-decomposing bacteria	CO_2-production	Saccharase enzyme
Nitrate-N	**1**						
AL-P_2O_5	.117	**1**					
AL-K_2O	.679*	.526*	**1**				
Total number of bacteria	.544*	.174	.301	**1**			
Cellulose-decomposing bacteria	.018	.161	-.086	.351	**1**		
CO_2-production	-.152	.151	-.016	-.147	.773*	**1**	
Saccharase enzyme	.667*	.092	.225	.869**	.167	-.240	**1**

Table 5: Correlation analysis (r) (Bentonite)
Measured soil characteristics; Nitrate-N; AL-phosphorus; AL-potassium; Total number of bacteria; Cellulose-decomposing bacteria; CO_2-production; Saccharase enzyme

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