PhD thesis

EFFECT OF BENTONITE AND ZEOLITE ON CHARACTERISTICS AND CHANGE OF MICROBIAL ACTIVITY OF ACIDIC HUMIC SANDY SOIL

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1. INTRODUCTION

Nowadays, the term of "sustainable agriculture" is widely used in worldwide, which is keystone of the rational utilization of soils as one of our most important natural resources. It is the important aims of "sustainable agriculture" to protect and maintain of the multi functions of soils *(Várallyay, 2005)*.

For preservation and sustainability the productivity of soil we have to take special regard to the sandy soils having unfavourable properties. These soils have very low colloid contents, their water management is extreme due to the weak structure with only transmission pores, and the nutrient management is also poor. Sandy soils having such characteristics are known to have a considerable territory in Hungary (more than 1,2 million ha).

An increased expectation can be the environmentally sound and maintainable farming, in our homeland opposite with the modern cultivation and agricultural activities. Introduction of those methods is a requirement without the application of the agrochemical products - or with its great reduction – in face of the soil fertility *(Zsuposné, 2007)*.

There are many opportunities of the integrated plant production systems, in which may repair the fertility of soils by using natural substances. According to *Lazányi, (2003)* there are three categories of natural soil amelioration materials:

1. the group of the green manures and other organic matters, which can be produced on the field,
2. which are byproducts of the animal husbandry as livestock manures and composts,
3. the mined soil conditioning substances, like alginate, bentonite, or zeolite.

The aim is to avoid the environmental loads of pollutants and to keep in mind the sustainability. There is a great necessity nowadays for applications of natural substances like the bentonite and zeolite in the agriculture as soil preserving natural materials, which can be mined and found in a suitable quantity in our country.

The University of Debrecen, Centre for Agricultural and Applied Economic Sciences (UD CASE), Institute of Agrochemistry and Soil Science joined to a sandy soil amelioration experiment, in which the bentonite – like perspective sandy texture soil conditioner - was studied between 2003 and 2005 and its influence on the different physical, chemical and microbiological characteristics of soil.

The examination was conducted in a greenhouse of UD CASE Institute of Agrochemistry and Soil Science in a small-pot experiment. It was set up on sandy soil type, and between 2007 and 2010 the effect of increased dose of bentonite and zeolite on some chemical properties, on the microbial dynamics and enzymological properties of an acidic humic sandy soil and on the biomass of a test plant was studied in controlled conditions. The test plant was perennial ryegrass *(Lolium perenne L.)*.

2. AIM AND SCOPE

Effects of different doses of natural substances - the **bentonite** and the **zeolite** – were studied the following physical, chemical and microbiological characteristics of an acidified sandy soil:

- moisture content of soil,
- water holding- and fixing of soil,
- conditions of acidity,
- easily available soil nutrient content (nitrate-N content, AL-soluble phosphorus and potassium content),
- the total number of bacteria, and microscopic fungi,
- amount of nitrifying bacteria, and the nitrate-exploration capacity,
- the amount of cellulose decomposing bacteria, and the CO_2-production of soil,
- the soil microbial biomass carbon and nitrogen,
- some soil enzymes' activity (phosphatase, saccharase, urease),
- in pot experiment the dry matter of plant biomass.

3. MATERIAL AND METHODS

3.1. Some characteristics in the experiment applied bentonite and zeolite

Bentonite is known as clay, and colloid-rich material, which mainly consists of montmorillonite. The colour is yellowish brown or gray, the feeling is greasy. Softened in water, fold-soaking, their swelling-capacity can reach their volume of 15-20 times.

Zeolites are Na-, Ca-aluminium silicates. Their known minerals of the groups are the natrolite, the chabazite, the mordenite and the clinoptilolite. Their colour is white or greyish white. Main characteristics are that in the grid gaps with some cations may be exchanged with other metal ions and their water content can be removed by heating and then later it can be re-watered.

The texture of the applied bentonite and zeolit is clay. Their salinity is very low. Among the chemical properties their pH is slightly alkaline ($pH_{(H2O)}$=7.3; 7.9). Their organic C and N content is low, according to the easily soluble nutrient content the betonies is medium-supplied in phosphorus, and high-supplied in potassium. The zeolite is good in phosphorus content, and very high-supplied in easily soluble potassium content *(Table 1.)*.

Table 1: Main physical and chemical properties of bentonite and zeolite used in the experiment

Examined parameters	***Bentonite***	***Zeolite***
Silt and clay fraction (Li %)	38	38
Arany-type of plasticity index (K_A)	39	41
Salinity (%)	0.03	0.08
$pH_{(H2O)}$	7.3	7.9
$pH_{(KCl)}$	6.4	7.0
Humus content (Hu %)	0.05	0.02
Organic-C (mg %)	29	14
Total-N (mg %)	6.7	4
Nitrate-N (mg/1000g)	11.2	6.9
AL-soluble P_2O_5 (mg/1000g)	159	171
AL-soluble K_2O (mg/1000g)	570	1010

3.2. Soils characteristics in experiments applied

The experiments were set up on sandy texture soil - based on silt and clay %; hygroscopic characteristics according to Kuron, plasticity index according to Arany – and their pH were acidic. Some major parameters of the applied soils are summarised in *Table 2*.

In the field of the bentonite experiment the examined soil type was brown forest soil with thin layers of clay substances, the "kovárvány", while soil type of the pot-experiment was humus sandy soil of Pallag.

Soil densities were above the average value. The minimal water holding capacity was 24 m/m%, which is considered low. The pH of the cultivated layers was acidic (pH_{H2O} 5.3; 5.6). Both of the soil types were low in humus. The examined soil types were low in nitrogen, their easily soluble phosphorus content proved to be medium-supplied, while the easily soluble potassium content was good in the brown forest soil, and well-supplied on the humic sandy soil.

Table 2: Soil characteristics in the experiments applied

Examined parameters	***Brown forest soil with kovárvány***	***Humus sandy soil***
Silt and clay fraction (Li %)	10	10
Hygroscopicity (hy)	0.8	0.7
Arany-type of plasticity index (K_A)	<30	30
Soil texture	Sand	Sand
Soil density (g/cm^3)	1.5	1.6
Porosity (%)	43	39
Minimal water holding capacity (VK_{min})	24	24
Acidity pH $_{(d.water)}$	5.3	5.6
$pH_{(KCl)}$	4.3	4.6
y_1	11.9	12.1
Humus content (Hu %)	1.11	0.71
Organic-C (mg %)	645	413
Total-N (mg %)	86	70
Nitrate-N (mg/1000g)	6.5	3.8
AL-soluble P_2O_5 (mg/1000g)	149	89
AL-soluble K_2O (mg/1000g)	251	211

3.3. The experimental conditions

The field experiment with bentonite, the pot experiment with bentonite and zeolite were set up.

3.3.1. The field experiment

A sandy soil amelioration experiment was carried out by the Research Settlement of UD CASE Research Institute of Nyíregyháza in 2002 with the different dose of bentonite. In this experiment the cultivated plants were: green pea (*Pisum sativum* L.), sweet corn *(Zea mays var. Saccharata* L.*)*, buckwheat (*Fagopyrum esculentum* Moench), mustard (*Sinapis alba* L.), rye (*Secale cereale* L.) (Makádi, 2010).

The setting up of experiment on 10 x 10 m experimental parcels in a block arrangement, in four repetitions was happened. The spillage of bentonite with shovel, and the outwork in soil in 0-25 cm level with tillage was happened. Granulate fraction of bentonite was among 0-5 mm, it was applied at spring 2002. Soil samples were collected from control plot and from plots treated by increasing doses of bentonite (5, 10, 15, 20 t/ha). Different treatments are shown in the *Table 3*.

Table 3: Treatments and their doses
(Nyíregyháza, 2003-2005)

Notations of samples and the treatments		
Notations	***Bentonite***	***Doses (t/ha)***
B0	Control	0
B1	1x	5
B2	2x	10
B3	3x	15
B4	4x	20

3.3.2. The small-pot experiment

Small-pot experiment was set up in the greenhouse of the Institute. The effect of bentonite and zeolite doses was studied on soil on the physical, chemical and microbiological properties as well as the quantity of plant biomass of Pallag. As test plant the rye-grass (*Lolium perenne* L.) was used. At the bentonite and zeolite treatments in the experimental pots were watered on the same determined weight, therefore we could not establish differences in soil moisture content. In order to get information about the water management the water-holding and lifting capacity were studied among laboratory conditions. The pot experiment was set up in greenhouse of UD CASE Institute of Agrochemistry and Soil Science. The experiment duration: 2007-2010. Bentonite and zeolite treatments were the same, which are shown in the *Table 4*.

Table 4: The treatments and the applied doses of the small-pot experiment (Debrecen, 2007-2010)

Number of treatments		Treatments	**BENTONITE**	**ZEOLITE**	Doses ($g\ kg^{-1}$)
B0	Z0	Control	-	-	0
B1	Z1	Small-dose	*1x	*1x	5
B2	Z2	Middle-dose	2x	2x	10
B3	Z3	Middle-large dose	3x	3x	15
B4	Z4	Large dose	4x	4x	20
* three-fold dose of the field dose (5t ha^{-1})					

The bentonite and zeolite treatments were set up in every year in six kg, bottom perforated pots. During the four examination years the same soil was recycled. The experiments of 2007 three replications were set, and after-effects of treatments were studied in the following years. With five treatments and three replicates, a total thirty pots were used, by using a random arrangement. Water content of treatments was kept on the same level, which is 70% of the maximum water-holding capacity. The pots were watered in every day to the same weigh. Test plant was the perennial rye-grass *(Lolium perenne L.).* The throw happened in each year in the spring, at the end of March. Each pot has got six g seeds, with a hand-made incorporation. Germination of seeds – during 8-10 days – the pot surfaces was covered by dark foil. After seed germination eight week of growing-season was calculated. Laboratory examinations were done after sampling. Soil samplings were done at the fourth and eighth weeks of growing season. There were three- sampling points from at each pot. The laboratory examinations of homogenized soils were made after the sampling times in the Institute of soil chemical and microbiological laboratory. At sampling the plant biomass was also harvested, and averaged samples were cut, minced, homogenized, and dried, the biomass production were determined.

Basic treatments 6*100 mg nitrogen – as $Ca(NO_3)_2$ solution – and 6*100 mg P_2O_5 and 100 mg K_2O as potassium dihydrogen orthophosphate and potassium sulphate solution were given to every pot.

3.4. Soil characterization

Among the soil **physical parameters** the soil moisture content was measured according to Klimes-Szmik, (1962). The silt and clay % content, the Arany-type of plasticity index was determined from control soil. Soil texture (type of soil physics) as well as the real density of soil was determined (Filep, 1995).

Among the **chemical parameters** of soil the pH of soil in suspension of distilled water and M KCl [$pH_{(H2O)}$; $pH_{(KCl)}$] and the hydrolytic acidity were measured (Filep, 1995). The humus content of soil was determined (Székely, 1960. cit. Buzás, 1988), in which the organic carbon content of soil was concluded (Hargitai, 1988 cit. Filep, 1995). In the control soils the total calcium carbonate content was determined by Scheibler's calcimeter (Buzás et al. 1988). To concern to the soil nutrient content the nitrate nitrogen content and the level of nitrate mobilization (Felföldy, 1987), further the ammonium lactate-acetate soluble phosphate and potassium content of soil was determined (Egner et al. 1960).

Among the **microbiological parameters** the total countable numbers of bacteria (in meat soup agar), the number of microscopic fungi (in peptone glucose agar) was determined by plate dilution method according to Szegi, (1979). The number of aerobic cellulose decomposing and nitrifying bacteria was determined by Pochon & Tardieux, (1962) with the MPN (Most Probable Number) method in liquid culture media. Further parameters were the soil respiration (Witkamp, 1966. cit. Szegi, 1979), the microbial biomass C (MBC) and the microbial biomass N (MBN) (Jenkinson & Powlson, 1976), the activities of phosphatase (Krámer-Erdei, 1959), saccharase enzyme (Bertrand cit. Szegi, 1979), and urease enzyme (Kempers cit. Filep, 1995) were determined.

As **test plant** the perennial rye grass *(Lolium perenne L.)* was used, cutted in twice in a year. The cutting was happened two cm above the soil surface, with using scissors.

The wet weight of plant biomass was dried for two weeks in paper bags, and in drying-box. Plant biomass was given in g kg^{-1} dry weight basis.

3.5. Samplings and processing

The laboratory examinations of homogenized soils and the test plant samples were made after the sampling times in the soil chemical and microbiological laboratory of Institute of Agrochemistry and Soil Science.

3.5.1. Soil samples

In the field experiment four-four sampling were taken at random from each plot for all the three examination years between 2003 and 2005. Sampling occurred in spring (May) in every year. Soil samples were collected from the upper soil layer of 2-20 cm in disposable nylon bags. Average samples were obtained with homogenizing of part-samples. The moisture content of samples was measured immediately after sampling; samples for microbiological investigation were stored during the examined period on +5 °C, in a refrigerator.

In the small pot experiments (between 2007 and 2010) the soils were sampled in each growing season after the emergence of seeds at the fourth and the eighth weeks. The sowing-time of seeds was in every examination year at spring, at 2007. May 14., 2008. April 21., 2009. April 27. and 2010. May 11. Three sampling points were done in a pot, and then they were homogenized. When the experiments were finished – in the season after eight weeks - plants were harvested. The soil samples were stored in the refrigerator till the end of the microbiological examinations, preferably before the 1 month of storage.

3.5.2. Test-plant samples

The goal of the field experiment was to take fenology monitoring on there cultivated plants primarily. We joined to this soil amelioration experiment, and we examined some soil physical, chemical and microbiological characteristics in this experiment. The cultivated plants were: green pea (*Pisum sativum* L.), sweet corn *(Zea mays var.*

Saccharata L.*)*, buckwheat (*Fagopyrum esculentum* Moench), mustard (*Sinapis alba* L.), rye (*Secale cereale* L.) (Makádi, 2010).

In a pot experiment as test plants the perennial rye grass *(Lolium perenne L.)* was used, cut in twice in a year. The cutting was happened two cm above the soil surface, with using scissors. The wet weight of plant biomass was dried for two weeks in paper bags, and in drying-box, at 40°C for one week. Plant biomass was given in g kg^{-1} dry weight basis.

3.5.3. Statistical analysis

Results were evaluated by statistical analysis. Average of samples and the standard deviations were calculated. F-test analysis of variance was performed, and significant difference was calculated at p=5% level generally accepted in the agriculture practice (I, Szűcs, 2002). We compared the effects of the treatments to controls, and the differences among the treatments were examined, to prove the significant differences on the 95% probability level. The dissertation contains also the error limits at 1% probability level *(Szűcs, 2002)*.

Pearson's correlation, regression and factor analysis was performed in order to seek the relationships between each chemical and microbiological soil parameters. The examination of the effect of the treatments was done with Cohen-coefficient *(Pallant, 2005)*.

Statistical calculations by SPSS 13.0 for Windows and Microsoft Office Excel programs were carried out.

4. RESULTS AND DISCUSSION

4.1. Changes of the soil physical characteristics due to bentonite and zeolite treatments

The **moisture content** of the amended soil increased in the three field-experimental years compared to the control parcels. The different doses of bentonite significantly increased the moisture content of the soil compared to the control, but among the treatments statistical differences couldn't be proved *(Figure 1.)*.

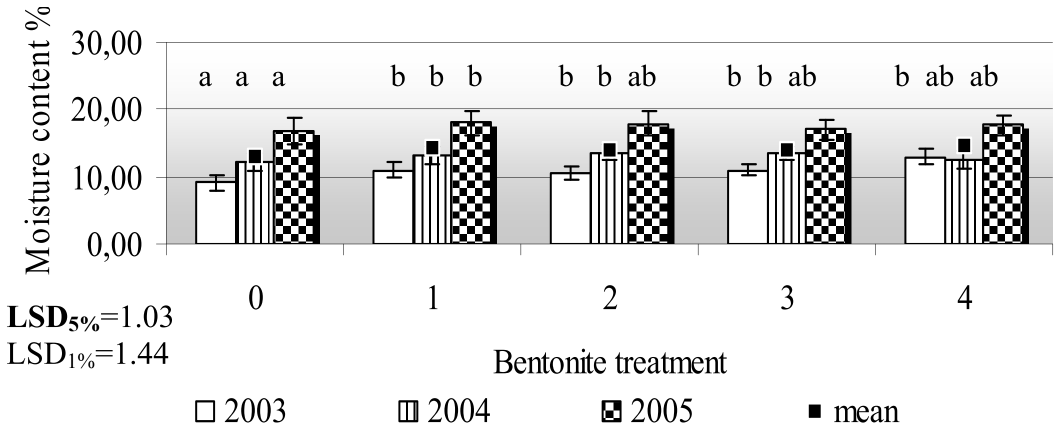

Figure 1: Effect of the increasing doses of bentonite on the moisture content of the sandy soil
(Nyíregyháza, field experiment, 2003-2005)

The bentonite and zeolite have good adsorption properties and large water holding capacity, so these amendments has increased the **water fixing-** and **water holding-capacity** of the sandy soil. The water fixing capacity was the least in large-dose by both of natural amendments, but there was no significant difference in the effect of these treatments. The bentonite held more water by 10% – compared to water holding capacity of a sandy soil - than the zeolite *(Table 5)*.

Table 5: The water fixing- and the water-holding capacity of the bentonite and zeolite and their effect on sandy soil

Number of treatments	Dosage ($g\ 100g^{-1}$)		Water fixing capacity (mm) $5h^{-1}$		Water-holding capacity ($ml\ h^{-1}\ 100g^{-1}$)	
	Control		**Bentonite**	**Zeolite**	**Bentonite**	**Zeolite**
	Bentonite	Zeolite	**430**	**340**	**62.50**	**58.5**
0.	Control sandy soil		468 a	468 a	38.5 a	38.5 a
1.	0.5		468 a	455 a	38.5 a	38.0 a
2.	1		465 a	448 a	40.0 a	39.5 a
3.	1.5		460 a	440 a	***42.5 b***	40.5 ab
4.	2		455 a	**438** ab	***43.5 b***	***41.5** ab*
$LSD_{5\%}$			29		2.2	
$LSD_{1\%}$			39		3.0	

4.2. Changes of the soil chemical characteristics due to bentonite and zeolite treatments

Among the soil chemical properties the **pH** and **hydrolytic acidity** was measured. By the effect of bentonite the soil pH both in distilled water and both in M KCl increased, parallel with it, the hydrolytic acidity decreased. The significantly bigger pH value was measured by the medium dose (10 t ha^{-1}) treatments. Among the doses of bentonite and zeolite on soil acidity significant differences couldn't be estimated *(Figure 2.)*.

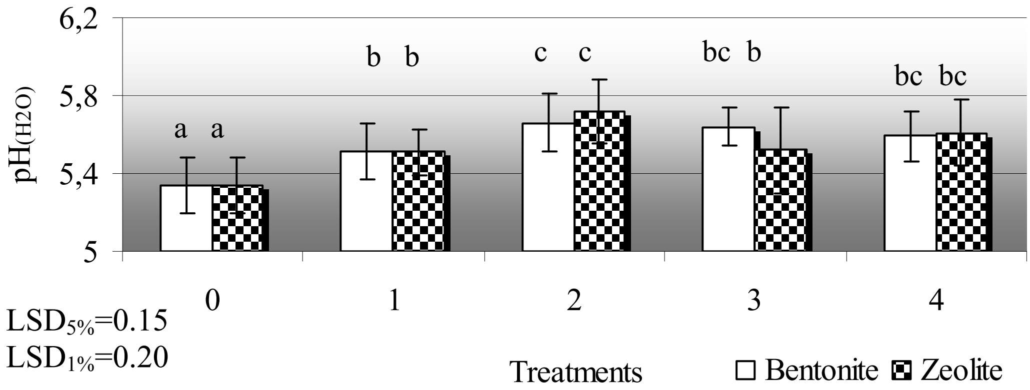

Figure 2: Effect of the increasing doses of bentonite and zeolite treatments on the soil pH measured in distilled water
(Debrecen, small-pot experiment, average values of 2007-2010)

The quantity of the **available nutrients** differed in the field and small-pot experiments, that explicable with the different needs of the experimental plants. From among N, P and K, the nitrate-N content changed less during the years only, and only we small change was established in the phosphorus content of soil. The available potassium content increased mainly with the application of the zeolite. Regarding the bentonite treatments the medium dose (10 t ha^{-1}), while at the zeolite treatments the large dose (20 t ha^{-1}) proved to be effective on the available nutrient content of soil *(Table 6)*.

Table 6: Effect of increasing doses of bentonite and zeolite on the easily available nutrient content of the soil
(Debrecen, small-pot experiment, average values of years of 2007-2010)

Dosage	Nitrate-N (mg $1000g^{-1}$)	AL-P_2O_5 (mg $1000g^{-1}$)	AL-K_2O (mg $1000g^{-1}$)
Bentonite			
0.	3.69 a	89.33 a	229.75 a
1.	4.42 a	98.25 a	**270.83** b
2.	4.56 a	**104.75** ab	**275.54** b
3.	3.86 a	90.76 a	**258.33** b
4.	3.60 a	90.34 a	243.75 ab
Zeolite			
0.	3.69 a	89.33 a	229.75 a
1.	4.20 a	**104.70** ab	**255.42** ab
2.	4.36 a	99.30 a	**291.46** bc
3.	4.00 a	**109.96** b	**313.00** bcd
4.	3.64 a	**109.85** b	**342.50** e
$LSD_{5\%}$	1.07	10.28	24.49
$LSD_{1\%}$	1.41	13.55	32.30

4.3. Changes of the soil microbial characteristics due to bentonite and zeolite treatments

Among the measured eleven soil **microbiological properties** seven parameters in field experiment and ten parameters in small-pot experiment was increased by bentonite significantly. The zeolite increased all the eleven examined soil microbial parameters. Regarding the microbiological characteristics of the soil the zeolite proved to be more stimulating – but not significantly - because it increased in seven cases from the eleven examined microbial parameters in a bigger scale, than the bentonite. All in the field experiment, and the small-pot experiment the middle-dose of bentonite (10 t ha^{-1}), and the small and middle doses of zeolite (5-10 t ha^{-1}) proved to be efficient.

From the microbiological parameters for most sensitive ones were by treatments in an order the number of nitrifying and the total number of bacteria, the nitrate-exploration, the saccharase enzyme activity, and the microbial biomass-N content.

4.4. Relationships among the studied soil physical, chemical and microbiological parameters (Correlation and Factor analysis)

Correlation analysis was made to seek relations among the different parameters on the bases of the soil physical, chemical, and microbiological results. In all the two treatment-forms there was positive medium correlation between the nutrient-forms between the AL-soluble potassium content and the soil respiration (bentonite experiment: r=0.681; zeolite experiment: r=0.538). Negative medium relationship was found between the hydrolytic acidity and the AL-soluble potassium content (bentonite experiment: r=-0.522; zeolite experiment: r=-0.504) as well as the phosphatase enzyme activity (bentonite experiment: r=-0.563; zeolite experiment: r=-0.759).

In case of bentonite treatments tight correlation was proved between the microbial biomass-N content of soil and the urease enzyme activity (r=0.847), in zeolit treatments between the number of nitrifying bacteria and the CO_2-production of soil (r=0.875).

The *factor analysis* proved that soil processes were mainly influenced by the changing of acidity and nutrient content of soil, especially the nitrate-N content, and the nitrate-exploration of soil.

4.5. Effect of bentonite and zeolite on the dry biomass production of the perennial rye-grass (*Lolium perenne* L.)

The **biomass production of the test plant's** – in a four-year period and in a small-pot experiment- was significantly increased by the medium dose of zeolite (10 t ha^{-1}). All the bentonite, and zeolite treatments increased the quantity of the plant biomass in a small-scale only, the average increase was 16% in the biomass dry matter *(Figure 3.)*.

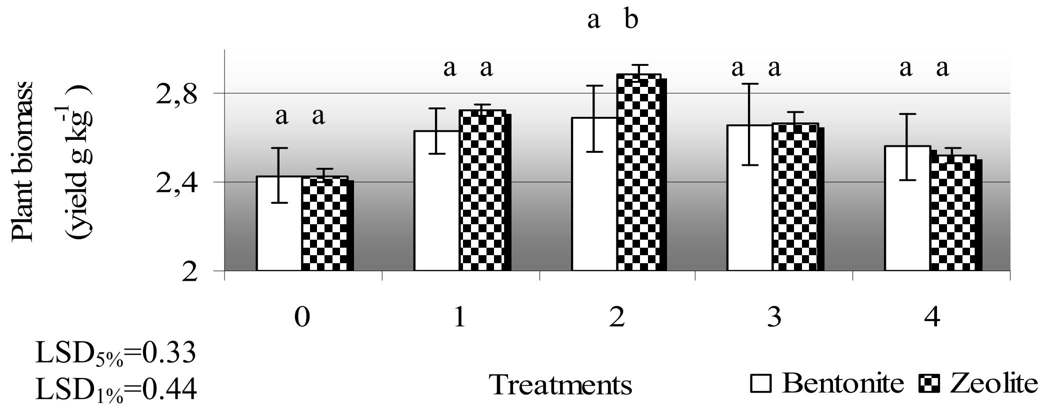

Figure 3: Effect of the increasing doses of bentonite and zeolite on the production of test plant's dry biomass
(Debrecen, small-pot experiment, average values of years of 2007-2010)

In the field experiment the effect of 10-15 t ha^{-1} bentonite doses increased the examined field production by 10% *(Makádi, 2010)*.

In the course of *correlation analysis* all in the both experiment tight relationship was between the microbial biomass-C and plant's biomass (bentonite experiment: r=0.848; zeolite experiment: r=0.832). The increased pH relations influenced positively the quantity of plant biomass (bentonite experiment: r=0.680; zeolite experiment:r=0.578).

4.6. Dosage-depending effect of bentonite and zeolite

The medium doses of bentonite (10 t ha^{-1}), and the large dose of zeolite (20 t ha^{-1}) proved to be more favourable on the soil physical and chemical characteristics. In all the field and small-pot experiment the medium dose of bentonite (10 t ha^{-1}), and the small, medium dose of zeolite (5-10 t ha^{-1}) stimulated the examined microbial soil parameters. The test plant biomass was increased by 10-15 t ha^{-1} doses significantly.

4.7. Evaluation the short-range and permanent effects of the amendments

On the bases of the experimental results, the after-effect of treatments were studied of the function of time and regarding the bentonite in the 50%-of the cases the stimulating effect was experienced in the first two years. In the third and fourth years the stimulating effect of this amendment on the soil properties reduced by 50%. The stimulating effect of zeolite was found to be the most intensive in the first year. The effect of duration of the zeolite proved to be longer during the examination years, than the bentonite.

5. CONCLUSION, PROPOSALS

Many kind of mining and industrial products, as well as different amendments are used to examine the effects of these materials on the enrichment of the organic and inorganic colloid content, and improvement of the water and nutrient management of the sandy soils.

In course of our experiments the effects of **bentonite** and **zeolite** on some physical, chemical and microbiological characteristics of the sandy soil, and on the amount of the test plant' biomass was investigated.

5.1. New and novel scientific results

On the bases of the scientific results the following new and novel scientific result and conclusion can be summarised:

1. Both the bentonite and both the zeolite increased the **water fixing-** and **water holding**-**capacity** of the sandy soil. The moisture content of the soil has already increased by 10% by the effect of the small-dose of bentonite. The zeolite treatments increased the pH of the soil in a larger scale, than the bentonite, the results were not significant.
2. In the small-pot experiment the quantity of the available nutrients was increased by all the two natural amendments. The quantity of the **nitrate-N content**, the **AL-soluble phosphorus and potassium content** of the soil has increased significantly. The phosphorus content increased by 4%, the potassium near 30% by the effect of the large dose of zeolite (20 t ha^{-1}) application. The zeolite was more effective on **plant' biomass**, the increase was more by 6,5% than in case of the bentonite.
3. The easily uptakable nutrient of the soil increased in case of the **bentonite** by **10 t ha^{-1}**, and the **zeolite** by **20 t ha^{-1}** doses. The quantity of the **plant' biomass** was increased by the **10 t ha^{-1}** dose significantly.
4. The effect of bentonite was favourable on seven **microbiological parameters** in the field experiment and ten parameters in pot-experiment. Regarding the zeolite, all of examined eleven parameters increased, and in seven occasions the effect of the zeolite was higher than it was in the bentonite application.
5. The **most sensitive microbiological properties** – independent from the experimental circumstances and doses of amendments - were the **total number of bacteria**, and **number of nitrifying bacteria** referring to the critical nutrient content of the sandy soil.

5.2. Results for practical utilization

Summarising the new scientific results for practical utilization:

- Both the ***bentonite*** and both the ***zeolite*** suited for ***increasing the pH***, ***improvement*** of ***the water and nutrient management*** and indirectly the ***stimulation of the microbiological activity*** of an acidic sandy texture soil.
- Both natural amendments increased the quantity of the **plant' biomass.** For the field application the **10-20 t ha^{-1} doses could be suggested.**
- Both amendments have good after-effect, which are confirmed by the experimental results. The after-effect of the bentonite is shorter than the zeolite' effect and steadily decrease for longer period.

- **Investigation the connection between the variables it was certified, that the realised positive effects across the pH, acidity relations, water and nutrient management of the sandy soil, the soil fertility was increased.**

PUBLICATION IN THE FIELD

Scientific periodicals in foreign language:

Tállai, M. – Balláné, K. A. – Nagy, P. T. – Kátai, J. (2008): The effect of bentonite on soil characteristics and on biomass of the small-pot experiment. Cereal Research Communications. Vol. 36. Part. II. 1179-1182.

Kátai, J. – Kremper, R. – **Tállai, M.** (2008): The effect of zeolite and bentonite on some soil characteristics on acidic sandy soil. Journal of Agricultural Sciences. Acta Agraria Debreceniensis. 117-122.

Kátai, J. – **Tállai, M.** – Sándor, Zs. – Zsuposné, O. Á. (2010): Effect of Bentonite and Zeolite on some characteristics of acidic sandy soil and on the biomass of a testplant. Agrokémia és Talajtan. 59./ 1. Akadémiai Kiadó. 165-174.

Tállai, M. – Jakab, A. – Kátai, J. (2011): Application of bentonite on acidic humic sandy soil. Fascicula: Protecţia Mediului Anul 16. Kiadó: Universty of Oradea. 479-484.

Scientific periodicals in Hungarian language:

Tállai M. (2007): Bentonit hatása a talajmikrobák mennyiségi előfordulására, a CO_2-képződésére, valamint a szacharáz enzim aktivitására. Agrártudományi Közlemények 26. Acta Agraria Debreceniensis. 287-293.

Kátai J. - **Tállai M.** (2008): Bentonit hatása a talaj felvehető tápanyagtartalmára és néhány mikrobiológiai tulajdonságára humuszos homok talajon. Environmental protection and food safety in crop production. Hungarian – Slovakian Intergovermental S & T Cooperation. (Szerk: Dr. Pepó P.) ISBN 978-963-9732-34-6. 99-104.

Tállai M. - Sándor Zs. - Kátai J. (2008): Bentonit hatása humuszos homok talaj tápanyagtartalmára és néhány mikrobiológiai tulajdonságára. Talajtani Vándorgyűlés, Nyíregyháza, 2008. május 28-29. Talajvédelem (Különszám). (Szerk: Simon L.) Talajvédelmi Alapítvány Bessenyei György Könyvkiadó. ISBN 978-963-9909-03-8. 527-534.

Tállai M. (2009): Bentonit és zeolit alkalmazása a talajjavításban savanyú homoktalajon. Agrártudományi Közlemények. 36. Acta Agraria Debreceniensis.131-137.

Kátai J. – Jakab A. – Sándor Zs. – Zsuposné O. Á. – **Tállai M.** (2011): Bentonit és zeolit vizsgálata tenyészedény-kísérletben. Agrokémia és Talajtan. 60/1. 203-218.

Papers in Scientific Conference Issues in foreign language:

Kátai, J. – **Tállai, M.** – Lazányi, J. – Lukácsné, V. E. – Sándor, Zs. (2007): The effect of bentonite on specific soil parameters and microbial characteristics of the carbon cycle, Joint International Conference on Long-term Experiments, Agricultural Research and Natural Resources, Debrecen-Nyírlugos, (Szerk: I. Láng, J. Lazányi, N. Csép) ISBN 978-963-473-054-5. 247-254.

Kátai, J. – Kremper, R. – **Tállai, M.** (2008): The effect of zeolite and bentonite on some soil chemical and microbiological characteristics and on the biomass of the test plant. “Risk Factors for Environment and Food Safety” International Symposium, Románia, Nagyvárad, november 14-15. Vol. XIII., Anul. 13. 71-79.

Kátai, J. – **Tállai, M.** (2009): The effect of nutrition supply on some soil chemical characteristics of humus sandy soil and some elements of the nitrogen-cycle. “Natural resources and sustainable development” 7. Fascicula: Protecția Mediului Anul 14. Oradea. 174-183.

Papers in Scientific Conference Issues in Hungarian language:

Kátai J. – Sándor Zs. – Zsuposné O. Á. – **Tállai M.** (2009): A tápanyagutánpótlás hatása a talaj néhány tulajdonságára és egy tesztnövény biomasszájának mennyiségére. Erdei Ferenc V. Tudományos Konferencia Kecskemét. 2009. szeptember 3-4. 1253-1257.

Tállai M. (2011): Bentonit hatása humuszos homoktalaj néhány tulajdonságára és egy tesztnövény biomassza mennyiségére. Pannon Egyetem, Georgikon Kar. XVII. Ifjúsági Tudományos Fórum, 2011. április 21. Keszthely. CD-ROM. ISBN 978-963-9639-42-3. 1-6. p.

Conference-proceeding (Abstracts):

Tállai M. (2007): Bentonit hatása a talaj nedvességtartalmára és kémhatására, valamint mikrobiológiai aktivitására. XXVIII. Országos Tudományos Diákköri Konferencia Agrártudományi Szekció. Előadáskivonatok. DE AMTC, Debrecen, 2007. április 16-18. (Szerk: Tikász I. E., Girhiny I., Antal Zs.) ISBN 978-963-9732-12-4. 282.

Conference presentation:

Kátai J. – Zsuposné O. Á. - **Tállai M.** (2009): Bentonit és zeolit hatása a talaj tulajdonságaira. MÁFI. Budapest, XIV. Stefánia út. 14. Agyagok a Föld jelenében: mezőgazdasági jelentőségük. Tudományos ülés, 2009. június 8.

PUBLICATIONS NOT RELATED TO THE DISSERTATION

Scientific periodicals in foreign language:

Sándor, Zs. – Kátai, J. – **Tállai, M.** – Varga, A. – Balogh, E. (2007): The effect of herbicides applied in maize on the dynamics of some soil microbial groups and soil enzyme activity. Cereal Research Communications. Vol. 35. No. 2. 1025-1028.

Balláné, K. A. – Vágó, I. – Kremper, R. – Sipos, M. – **Tállai, M.** (2008): The influence of chemical and biofertilizers on the yield, nitrogen, phosphorus and potassium content of lettuce (Lactuca sativa L.) in a two-year greenhouse experiment. Journal of Agricultural Sciences. Acta Agraria Debreceniensis. Debrecen, 2008. október 3. 43-48.

Zsuposné, O. Á. – Lukácsné, V. E. – **Tállai, M.** (2008): The effect of plant culture on the soil biological actvity in an ecological farming. Cereal Research Communications. Vol. 36. Part II. 1167-1170.

Kátai, J. – Sándor, Zs. – **Tállai, M.** (2008): The effect of an artificial and a bacterium fertilizer on some soil characteristics and on the biomass of the rye-grass (Lolium perenne L.) Cereal Research Communications. Vol. 36. Part. II. 1171-1174.

Kátai, J. – Zsuposné, O. Á. – Sándor, Zs. – **Tállai, M.** (2009): Soil microbiological consequences of the stress effect of soil acidification in a long term experiment. Cereal Research Communications. Vol. 37. 403-406.

Jakab, A. – **Tállai, M.** – Kátai, J. (2011): Effect of bacterial preparations on the ryegrass (Lolium perenne, L.) biomass of calcareous chernozem soil. Fascicula: Protecția Mediului Anul 16. Kiadó: Universty of Oradea. 115-121.

Scientific periodicals in Hungarian language:

Kátai J. - Vágó I. - **Tállai M.** – Makádi M. (2008): A biogáz gyártás melléktermékének hatása a talaj néhány mikrobiológiai tulajdonságára. Talajtani Vándorgyűlés, Nyíregyháza, 2008. május 28.-29. Talajvédelem (Különszám). Talajvédelmi Alapítvány Bessenyei György Könyvkiadó.(Szerk: Simon L.) ISBN 978-963-9909-03-8. 417-422.

Tállai M. - Sándor Zs. - Vágó I. - Kátai J. (2008): A tápanyagutánpótlás különböző módjainak hatása a talaj néhány mikrobiológiai tulajdonságára. Agrártudományi Közlemények 32. Acta Agraria Debreceniensis.119-126.

Sándor Zs. – **Tállai M.** (2008): Kukoricához alkalmazott herbicidek hatása a talaj nitrogén-körforgalom néhány mikrobiológiai jellemzőjére. Agrártudományi Közlemények 32. Acta Agraria Debreceniensis. 93-100.

Tállai M. (2010): Műtrágya és baktériumtrágya összehasonlító vizsgálata humuszos homok talajon. Agrártudományi Közlemények. Acta Agraria Debreceniensis. 41. 111-117.

Jakab A. - Balláné K. A. - **Tállai M.** - Kátai J. (2011): Baktériumtrágyák hatása mészlepedékes csernozjom talaj tulajdonsáaira és az angolperje (Lolium perenne L.) biomasszájára. Agrokémia és Talajtan. 60/1. 219-232.

Sándor Zs. - Kátai J. - Nagy P. T. - **Tállai M.** - Sipos M. - Zsuposné O. Á. (2011): Herbicidek talajbiológiai hatásainak értékelése mikrokozmosz kísérletben. Talajvédelem. (Szerk: Simon L.) ISBN 978-963-9909-03-8. 237-244.

Papers in Scientific Conference Issues in Hungarian language:

Kátai J. - Vágó I. - Sándor Zs. - **Tállai M.** - Varga A. (2007): A talaj néhány tulajdonságának változása műtrágya és baktériumkészítmény (Bactofil A10) alkalmazásakor. Erdei Ferenc IV. Tud. Konferencia. Kecskemét. 2007. augusztus 27-28. (Szerk: Dr. habil Ferencz Árpád) ISBN 978-963-7294 63-1. 947-950.

Sándor Zs. – Kátai J. – Nagy P. T. – **Tállai M.** – Zsuposné O. Á. – Varga D. (2007): Különböző herbicidek összehasonlító értékelése a talaj szénkörforgalom mikrobiológiai jellemzői alapján. Erdei Ferenc IV. Tudományos Konferencia. II. kötet. Kecskemét. 2007. augusztus 27-28. (Szerk: Dr. habil Ferencz Árpád) ISBN 978-963-7294-63-1. 967-970.

Sándor Zs. – Kátai J. – **Tállai M.** (2009): A Merlin 480 SC és az Acenit A 880 EC herbicidek hatása néhány talajmikrobiológiai paraméterre. Erdei Ferenc V. Tudományos Konferencia. Kecskemét. 2009. szeptember 3-4. 379-383.

Conference-proceeding (Abstracts):

Kátai, J. – Vágó, I. – Sándor, Zs. – **Tállai, M.** – Zsuposné, O. Á. (2007): The effect of an artificial fertilizer and a bacterium preparation (Bactofil A10) on the properties of soils. Bulletin of university of agricultural sciences and veterinary medicine Cluj-Napoca. Agriculture, Vol. 63-64. 465.