Improvement of physical and chemical properties of Hungarian sandy soils by adding organic and inorganic amendments

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Abstract
The main purpose of the study was to investigate and compare the single and precomposted combined effects of different amount of organic (liquid manure, sewage sludge) and inorganic (bentonite, montmorillonite, $CaCO_3$) treatments on soil physical, chemical properties of sandy soils from Nyírség geographical area. Laboratory and field experiments were carried out for the study. The laboratory samples included sandy soil treated with increased amount of montmorillonite and bentonite; liquid manure; beet potash and the precomposted combinations of those. Sewage sludge compost was applied on the field. Rheological methods were applied to detect the changes in physical properties of soil samples.

Key Words
Organic and inorganic amendments, sandy soils, Rheology.

Introduction
One quarter of the total area of Hungary is covered by light textured soils, of which 16% is sandy, 9.5% is sandy loam. These soils occur in most of the genetic soil types (Várallyay 1984). Sandy soils are lacking organic and inorganic colloids. These are the reasons, why the fertility and the properties of these soils is determined by high water infiltration and weak water storage capacity, low available water and natural nutrient capacity, sensitivity for aridity and wind erosion (Várallyay 1984). Various and important experiments were carried out to improve sandy soils all over the world. The role of different soil constituents were explained by several authors (Volk and Hensel 1969; Troeh and Thompson 1993; Singh and Uehara 2000; Kay and Angers 2002).

Methods
Materials
Different compositions of organic and inorganic compounds were prepared for the laboratory investigations. The soil was classified as “Haplic Arenosol, Dystric” (WRB 2006). Different amounts of refuse bentonite, montmorillonite, beet potash and diary liquid manure were applied. In case of field samples 20 t/ha compost was applied. The compost contained: 40% fermented sewage sludge, 25% riolite, 15% bentonite, 10% lime and 10% straw. The soil was a “Lammelic Arenosol, Dystric” (WRB 2006).

Methods
Beside rheological measurements in soil suspension, the following soil chemical and physical investigations were carried out: Cation exchange capacity of the samples by modified Mehlich procedure (Buzás 1988), hygroscopic coefficient of the samples by Sík (hy1), simplified water retention capacity of the samples, simplified determination of 0.02 mm size particles in water and Na-pyrophosphate, micro-aggregate stability (dispersity factor according to Kacsinszkij and structural factor by Vageler) (www.soil-index.com).

Results
During the rheological measurements the initial maximum of the flow curves,τ_{inimax} (Pa) and the Bingham yield values were determined. The initial maximum is the maximum of the flow curves determined in the direction of the increasing velocity, and provides information on the structure of the soil, and the bonding forces at present. The Bingham yield value (B) is the value of the linear part of the curves projected to zero shearing stress, and provides information on potential aggregation in the decreasing velocity gradient range following the discontinuation of the shear stress.

Initial maximum of the flow curves
On increasing the bentonite content of the sand samples, the initial maximum of their flow curves increased. There was a strong linear correlation between the two parameters, with a Pearson's coefficient of 0.923. The relation was even stronger in case of samples containing beet potash and increasing amounts of bentonite. In this case Pearson's coefficient was 0.936.

At the same time, due to organic matter, Pearson's correlation coefficient was 0.847 when the samples contain two inorganic components besides the liquid manure (Figure 1). The explanation in this case could be that bentonite – organic matter – Ca agglomerates were formed that link sand particles together. The reason for the fact that the highest initial maximum values were not obtained from the samples containing both organic and inorganic additives could be that their organic component, due to its complicated structure, was very sensitive to external effects, such as shearing stress.

In case of field samples, the one from 2004, treated with compost could tolerate the highest shear stress. As an effect of the compost treatment, the strength of the bonds between the particles became stronger, due to the organic and inorganic additives within the compost. However, the treated samples from 2006 have produced similar results to those of the untreated samples, which suggest that as a result of the treatment the sample showed aggregation, but it was not present two years later at the second sampling. This was probably due to the repeated yearly disturbance, or the downward movement of organo-mineral complexes.

Bingham yield values
The rebuilding of the aggregates in the suspension was only observed in the case of samples with organic matter content, and not with samples containing only mineral materials (Figure 2). The reason for this was that the organic material, due to its great charges, could relatively quickly form organic matter – bentonite – Ca bridges after the disturbance, and that because of the presence of organic matter, microbial activity should also be considered. The fulvic acids formed during the microbial decomposition of unrecompensed dead organic residues and the Ca^{2+} ions in the system connected with the negative charges of the clay minerals.

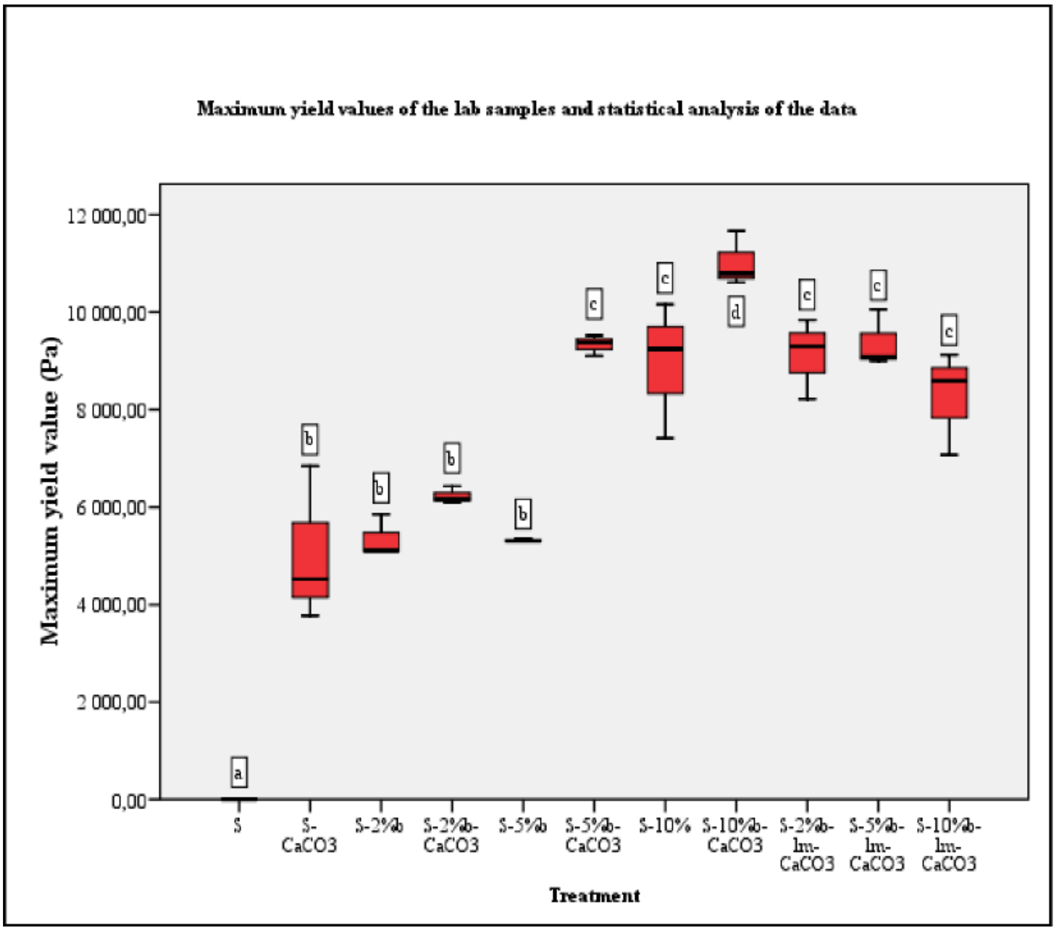

Figure 1. Maximum yield values of the flow curves of laboratory samples (significant differences are indicated with the lower case letters of the alphabet, with a confidence interval of 95%).

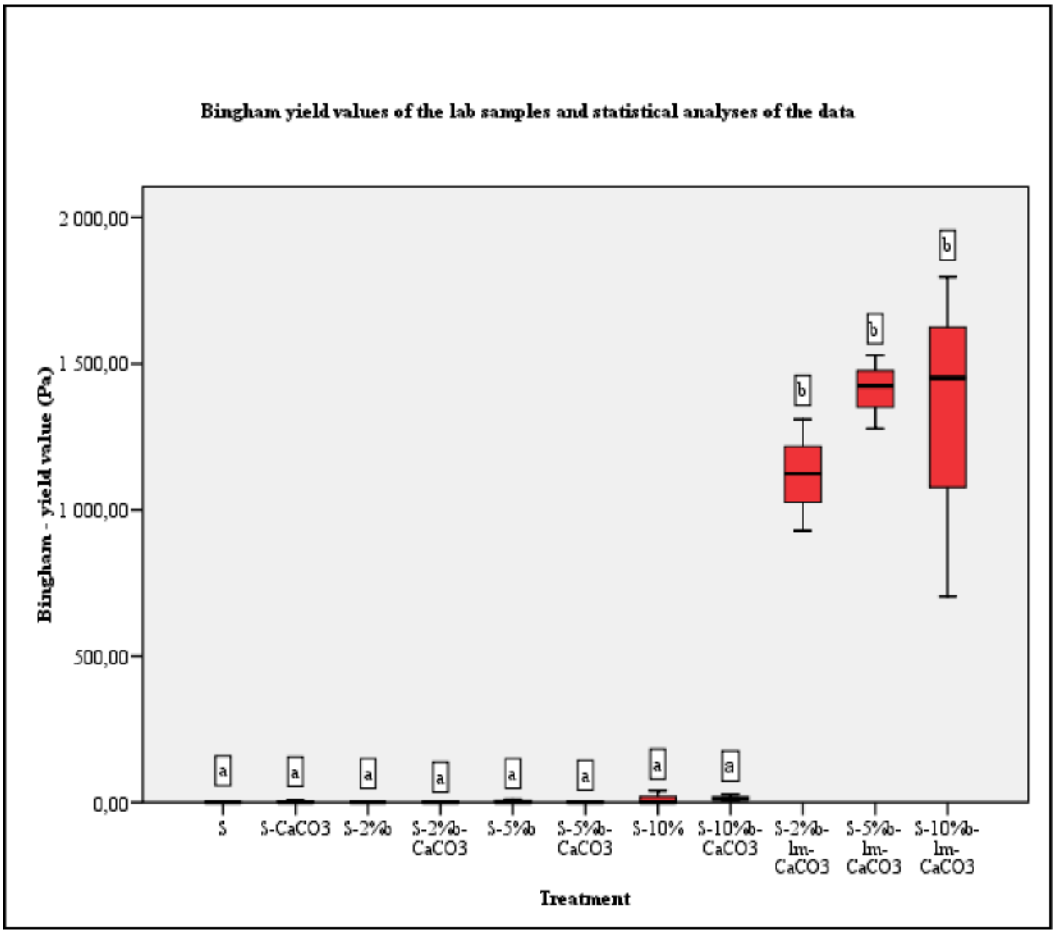

Figure 2. Bingham –yield values of the flow curves of laboratory samples, significant differences are indicated with the lower case letters of the ABC, with a confidence interval of 95%.

In the case of field samples, the one from 2004 treated with compost had the highest Bingham yield value, which means that as a result of the compost treatment, due to the organic and inorganic additives applied to the soil, the structure of the soil suspension showed re-aggregation after disturbance, on account of the increased number of bonding points. This effect could not be observed in the second sampling season, which could be because the organo-mineral complexes have either ceased to exist or moved to the lower layers.

The statistical comparison of the results of rheological measurements and results of traditional methods

Table 1 shows the correlation comparison of the results from Rheology and the applied measurements indicated by the Pearson's correlation coefficient.

Based on the results it can be concluded that a linear relationship could be observed between the initial maximum of the flow curves (τ inimax), the results of hy1 and cation-exchange capacity. That was, on the application of organic and inorganic additives, if we increase the colloid content (and charge) of the soil, it also increased the maximum shear stress it could tolerate. The Bingham – yield values showed strong correlation with the results of the water retention measurements. This means that if the soil's water-holding capacity increases, so does its ability to re-aggregate in? suspension after the end of the stress it was exposed to. The Bingham – yield values showed a strong medium connection with dispersed particles content in water, and a weak medium connection can be observed with the dispersed particles content in Na - pyrophosphate.

Table 1. The statistical comparison of the results of rheological measurements and results of traditional methods; *: correlation is significant at 0.05 level, **: correlation is significant at 0.01 level; n.c.: no correlation.

	Water retention	Dispersed particles in water	Dispersed particles in Na-pyrophosphate	Vageler structure factor	Kacsinszkij dispersion factor	hy1	CEC
τ inimax	0.444^{*}	0.391^{*}	n.c.	n.c.	n.c.	0.788^{**}	0.820^{**}
Bingham yield value	0.985^{**}	0.666^{**}	0.497^{**}	n.c.	n.c.	n. c.	n. c.

Conclusion

Clay minerals, rocks containing clay minerals and also materials containing $CaCO_3$ have a significant effect on soil properties. Due to their colloid and adhesive properties, they increase the strength of bonds between soil particles. Both physical and chemical measurements properties showed better improvement when the organic and inorganic components were precomposted before application. The addition of beet potash resulted in further favorable effects on the results of water retention capacity and rheological measurements. Rheology proved to be a suitable method to track changes in soils resulting from the addition of different mineral and organo-mineral materials. It provides quantitative measures of the forces linking together the soil particles (maximum yield value, Bingham – yield value). The results of rheological measurements can be compared and do show a certain level of similarity with other methods for measuring different soil chemical and physical parameters. In soils it is primarily the „newly added" organic material content that takes part in the re-aggregation of the suspension structure after disturbance, as opposed to the mineral components.

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