MEASUREMENT OF PROPERTIES RELATED TO PLANT GROWTH OF MARTIAN SOIL SIMULANT FOR LARGE SCALE FIELD EXPERIMENTS. V.Yu. Makovchuk [1], E.A. Grishakina [1], Z.S. Ezhelev [2], V.S. Cheptsov [2,3], A.A. Belov [2], J.L. Vázquez-Poletti [4], I.M. Llorente [4], M. Ruiz-Ramos [5], A. Sanz-Cobena [5], A. Rodríguez [5,6]. [1] Vernadsky Institute of Geochemistry and Analytical Chemistry, RAS, Moscow, Russian Federation. [2] Lomonosov Moscow State University, Moscow, Russian Federation. [3] Space Research Institute, RAS, Moscow, Russian Federation.[4] Universidad Complutense de Madrid (UCM), Spain.[5] Universidad Politécnica de Madrid (UPM), Spain. [6] Universidad de Castilla La Mancha (UCLM), Spain.

Keywords

Mars; Martian soil simulant; crop simulation; physical and mechanical soil properties; hydrophysical and microbiological soil characteristics.

Introduction: In this study we tested the hydrophysical and microbiological properties of Martian soil analogue for the ExoMars mission [1], imitating the main physical and mechanical properties of the Martian soil in the surface layer that determine its aptitude for growing crops like corn, wheat or potatoes in different climatic conditions and supporting missions to explore Mars.

Material and Methods: Laboratory experiments

In this work, we continue the laboratory studies of the Martian soil analogue, originally created for the drop tests of the ExoMars landing module. For the analogue soil, the components that were cheap and available in a volume of several tons were selected: crushed quartz sand 0.5-1.2 mm - 25%, rounded quartz sand 0.19-0.23 mm 15%, fly-ash - 30%, ash-slag waste - 30%. After mixing the components in the required proportions, a soil-analogue was obtained, according to the grain composition, referring to silty sand, having a density of 1.30 g/cm3 in loose composition and 1.55 g/cm3 in dense composition, with a moisture content of less than 1% and a value of cohesion within the first ten kilopascals (Tables 1a, 1b). Mechanical properties of soil analogue were obtained in triaxial and direct shear tests.

Table 1a. Grain-size distribution in Martian soil simulant in weight %

	Grain-size (mm)	Percentage (%)
Cobble	>10	0.0
Pebble	10-5	0.0
	5-2	0.2
Sand	2-1	7.4
	1-0.5	21.2
	0.5-0.25	4.6
	0.25-0.1	16.9
	0.1-0.05	12.5
Dust	0.05-0.01	35.1
	0.01-0.005	1.0
	0.005-0.002	1.0
	<0.002	0.0

Table 1b. Physical and mechanical properties of Martian soil simulant

Property		Symbol	Value
Moisture content, %		W	0.4
Particle density, g/cm^3		ρ_s	2.48
Dry bulk density, g/cm^3	Compact	$\rho_{d\ max}$	1.55
	Loose	$\rho_{d\ min}$	1.30
Cohesion, MPa		c	0.007
Angle of internal friction, degree		φ	25
Stiffness modulus (in stress range 0.1-0.2 MPa), MPa		E	5.6
Elastic modulus, MPa		E_y	57.3
Bearing capacity, MPa		E_{bc}	0.332
Dynamicelastic modulus, MPa		E_d	248.9
Frictional coefficient		tgφ	0.458
Dynamic modulus, MPa		v	55.3

Based on the similarity of the analogue soil to the Martian soil on the physical and mechanical properties [1], we conducted a series of laboratory tests of the analogue soil to determine the hydrophysical (coefficient of filtration, water retention curve, liquid limit) and microbiological properties (total number of prokaryotic cells in situ, number of culturable bacteria multisubstrate testing of the microbial community as described in [2]).

Results

Conducted experiments of hydrophysical parameters show coefficient of filtration of our Martian soil analogue in range of 25-28.6 cm/day (med 25.7 cm/day), which corresponds to average level of filtration [3].

In the course of microbiological analyzes, the total number of prokaryotic cells was found at a level of 1.14±0.35×107 per gram of model soil, and about 2×103 colony forming units per gram were found on rich nutrient media. Cultivated bacteria are predominantly Gram-positive and belong to the genera Arthrobacter, Bacillus, Micrococcus, Staphylococcus and Streptomyces. During multisubstrate testing, potential metabolic activity was found close to the sensitivity limit of the method: out of 47 substrates studied, only peptone consumption is recorded.

Thus, analogue soil is characterized by a low number and variety of prokaryotes, as well as low functional diversity and potential metabolic activity.

Discussion and further work

In further vegetative experiments, we are planning to add plant growth-promotion bacteria, various functional groups of bacteria to provide mineral nutrition of plants, as well as natural microbial communities of extreme ecosystems, characterized by conditions similar to those of the Martian regolith. The low biological activity of analogue soil necessitates the introduction of microorganisms, and at the same time, the native microflora of analog soil will not hinder the development of introduced microorganisms.

To refine hydrophysical growth conditions of plants, we are planning to determine water retention curve of our analogue (saturation, field capacity and wilting point) as well as liquid limit, plastic limit and plasticity index of soil (according to ASTM D 4318 standart). Some of these features are required inputs for crop model simulations. Crop modelling will allow to extend the scope of the experimental set-up and testing a wide variety of genetic x management x environmental (G x M x E) interactions. Therefore, in future, data obtained during this and future research on this topic will be used crop model simulation on a Martian soil.

References:

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