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SOIL PHYSICS

Agrophysical Assessment of Alluvial Calcareous Soils of the Çumra Region of Central Anatolia in Turkey

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Abstract—Some physical (density, coefficient of filtration, particle-size composition, etc.) and chemical (contents of carbonates, organic carbon, nitrogen, etc.) properties of an alluvial calcareous soil were studied in Central Anatolia (Konya province, Çumra region). These heavy-textured (medium clay) soils with a low content of organic carbon (less than 1%) have favorable agrophysical properties due to the stable structure of the pore space. The studies of the water regime of soils under drop irrigation confirm the favorable hydrological properties of these soils. The use of the known agrophysical estimates (after Medvedev, the index of the optimal water regime, etc.) has revealed the high dispersal of the data related to the low humus content in these heavy-textured soils. The favorable structure of the pore space is suggested to be stipulated by the active activity of the numerous and diverse representatives of soil biota. Four phyla predominate in the microbiological composition of the soils studied; among them, *Actinobacteria* is the dominant. The composition of this phylum is dominated by the elevated number of both higher (*Streptomyces*) and lower (three species of *Rhodococcus*) actinobacteria. The high biodiversity of bacteria against the background of their great total number and the developed trophic interactions in the microbial community promote the well-balanced production of specific metabolites, including gaseous ones (CO_2, H_2). This circumstance allows this clayey soil to function rather actively while protecting the pore space against compaction and maintaining the optimal density, porosity, and hydrological properties.

Keywords: soil physics, pore space, microbiological composition, agrophysics

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INTRODUCTION

Soils of Central Anatolia are actively used in agriculture due to their high heat resources, natural fertility, and the availability of water for their additional irrigation. However, many processes that determine the evolution and contribute to the scientifically substantiated and ecologically safe use of these soils remain poorly known. No scientific works on the optimization of the water and heat regimes of these soils have been carried out, although it is evident that such works are necessary to elaborate a strategy for the agricultural production and the rational use of the natural resources. Therefore, the agrophysical assessment of the soils in this region is very important.

This work is aimed at studying the physical properties, the elements of the water regime, and the soil microbiota of the alluvial calcareous soils in a special field experiment.

The tasks of this research are the following: (1) to investigate the fundamental physical properties of the alluvial calcareous soils, (2) to study the elements of the water regime of irrigated soils under the conditions of the agronomic field experiment, (3) to fulfill the agrophysical assessment of the soils studied using different criteria, and (4) to characterize the microbial community of the calcareous alluvial soils.

OBJECTS AND METHODS

The Çumra region studied (about 172 thousand ha) is located in the central part of Turkey (Central Anatolia, Konya province) between 37° and 38° E and 33° and 34° N at an altitude of 1013 m a.s.l. It is mainly a mountain–hilly territory; in its plain area, agriculture has been maintained for a long time.

The climate of the region has been formed under the influence of different factors, the main of which is its continentality: hot and dry summers and cold and dry winters. The mean annual temperature is 11.8°C; the minimal and maximal temperatures are –1.5 and +26.1°C, respectively. The mean annual precipitation is 306 mm. In the last years, the amount of precipitation has decreased (232.2 mm) as compared to that in the previous (1992–2007) years.

In the test area of the Agricultural Faculty of Selcuk University (Konya), 7 pits were made with a distance of 25–30 m between them. Drop irrigation was used over this area.

This paper presents detailed data for one of the irrigated plots (plot 1 with sugar beets, a traditional crop for this region) and the control one (without crops and irrigation). The distance between the drippers in the variant with drop watering was 20 cm. The watering (40 m^3 for each procedure) was carried out every 7 days. During the growing period of 2012, the test plot was irrigated 21 times (the total volume of the applied water was 840 m^3). Samples for the determination of the soil moisture were taken every 6 days.

The following horizons composed the profile of the alluvial soil (the description was made in the winter of 2011).

Ap, 0–38 cm—old arable, yellowish brown, (darker in the upper (0–10 cm) part), loamy-clay (clay–coarse silty, many loess–coarse silty particles), moist, friable. The transition is sharp by density and hardness (due to tillage).

B1, 38–62 cm—brown, compacted, weakly dry; efflorescence of secondary carbonates (1–2 mm) in the lower part. The transition is sharp by color, the presence of carbonates, and the size of their segregations.

Bca, 62–100 cm—lighter than the upper horizon, segregations of carbonates (up to 10 mm), very compact, single elongated prismatic peds.

The particle-size composition was determined using the laser-diffraction method and a FRITSCH Analysette 22 device with the preliminary treatment of the samples with ultrasound in pure water [19]. The soil bulk density was determined by the method of a cutting ring [10, 11]; it was 1.03–1.10 g/cm^3 in the upper plow layer and, from the depth of 40 cm, 1.35–1.50 g/cm^3. The contents of C and N were measured using a CNHS analyzer (Vario EL III Elementar) for solid samples. The obtained values of the C/N ratio were very low (table), thus testifying to the high N saturation of the organic matter. Usually [15, 16], in the well-humified organic matter, these ratios reach 12–13. The values of 5–7 in the calcareous alluvial soils were most likely related to the organic matter absorbed on the surface of the fine elementary mineral soil particles. This organic matter appears to be associated with the metabolic products of the soil biota.

The studies of 7 plots permitted us to perform the statistical analysis of the possible changes in the parameters (table) during the growing period. A comparative statistical analysis of the results using the Wilcoxon Matched Pairs Test showed that the contents of $CaCO_3$ and N, as well as the C/N ratios, significantly differed, unlike those of the organic carbon in the 0- to 40-cm soil layers. The significant decrease in the nitrogen content points to the necessity of monitoring its level based on its budget. The decrease in the concentration of carbonates seems to be related to their leaching from the soil, as well as to the high activity of the soil biota resulting in the higher amounts of CO_2 in the soil air and the higher soil acidity.

Contents of organic carbon (C_{org}, %), carbonates (C_{CaCO_3}, %), and nitrogen (N, %) in the alluvial soil at the beginning and at the end of the growing period. The data for June of 2012 are above the line, and the data for October of 2012 are above the line

Depth, cm	C_{CaCO_3},	C_{org}	N	C/N
0–10	2.40/2.27	0.88/0.85	0.14/0.12	6.3/7.1
10–20	2.36/2.29	1.00/0.89	0.13/0.13	7.6/6.8
20–30	2.35/2.23	0.69/0.7	0.13/0.1	5.3/7.0
30–40	2.43/2.21	0.51/0.58	0.10/0.08	5.1/7.3
40–50	2.49/2.49	0.42/0.42	0.07/0.07	6.0/6.0
0–10	2.38/2.35	0.86/0.77	0.15/0.12	5.7/6.4
10–20	2.39/2.29	0.81/0.77	0.13/0.12	6.2/6.4
20–30	2.32/2.31	0.72/0.65	0.11/0.11	6.5/5.9
30–40	2.32/2.28	0.62/0.57	0.08/0.10	7.8/5.7
40–50	2.32/2.26	0.45/0.57	0.08/0.09	5.6/6.3
50–60	2.39/2.27	0.45/0.51	0.03/0.09	15/5.7

The composition of the microbial community was reconstructed according to the microbial markers (fatty acids and their derivatives—fatty hydroxyacids and aldehydes) that were determined after the acid methanolysis of the soil samples using the molecular method of gas chromatography—mass-spectrometry (GCh–MS). The analysis was performed using a GCh–MS system (HP-5973 Agilent Technologies (USA)). This methodology is described in detail in [3, 8, 23, 24].

RESULTS AND DISCUSSION

The soils studied are heavy-textured along their whole profile (Fig. 1). According to the international classification, their particle-size composition is silty clay (44.8% clay, 54.2% coarse silt, and 1% sand); by the Kachinskiy classification, they are referred to medium clay. At the depth of 40 cm, the soil texture becomes heavier, and the soil density increases. Probably, these changes in density and texture are related to the agricultural practices (compacting of the subsoil by agricultural machines) or to the natural lessivage of fine particles into the deeper layers. It should be emphasized that, despite the heavy texture and low organic matter content, these soils have high porosity and a stable porous structure. This fact is confirmed by numerous measurements of the filtration coefficient

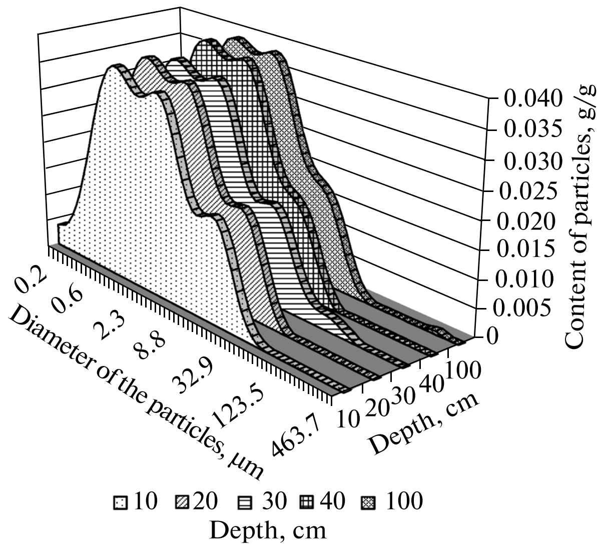

Fig. 1. Diagram of the particle-size composition of the alluvial soil.

by the method of flood areas. The values of this coefficient are unusually high for heavy-textured soils: they range from 250 to 360 cm/day. As a rule, the soils of the same texture (light clay–medium clay) are characterized by low (3–7 cm/day) filtration coefficients if they do not have a well pronounced stable aggregate structure. In the soils studied, there were no agronomically valuable aggregates. At the same time, the results of studying the water permeability of the soils showed that, in the first and last hours of the observations, the rate of absorption weakly decreased testifying to stable water conducting ways. The latter is an important and agrophysically valuable property. The reason for the stable favorable agrophysical status of the studied soil is not clear, but it appears to be related to the high content of carbonates and to some other processes that stabilize the porous space and soil structure under these conditions.

Studying the water regime of the irrigated soils permitted us to obtain chronoisopleths of the moisture for the 0- to 60-cm layer. For plot 1, the chronoisopleths for the whole growing period (120 days) are presented in Fig. 2. Even upon drop irrigation using particular doses of watering, the water penetrates deep into the soil, thus moistening the layers to the depth of 50–55 cm. In the highly permeable soils studied, favorable conditions are formed for sugar beets with a well-developed root system. Only in some cases at the depth of 40 cm does water stagnate for short-term periods, probably, due to the heavier soil texture. The analysis of the water regime of the alluvial soils when using drop irrigation evidences their good hydrological properties.

An attempt was made to assess the agrophysical status of the soils using the agrophysical criteria known at the present moment [1, 2, 7, 11]. The following criteria are usually used: a complex agrophysical estimate of soils after Medvedev [6, 7], the index of the optimal water regime taking into account the periods of excessive moistening and the moisture shortage in the calculations [12, 13], and a number of criteria accepted abroad. Thus, Loveland and Webb [17] consider that the main factor limiting the agrophysical properties is the content of organic matter. They suggest a threshold at 2% organic carbon for loamy soils. An absolute agrophysical criterion is the porosity of the soils. In a very compact soil, it restricts the respiration of the microorganisms [22]. Some authors note that the favorable agrophysical status of clayey soils may be related to the $CaCO_3$ content, the concentration of which should be in the range of 9–19% [14].

According to the criteria accepted in Russia, the soils studied belong to favorable ones in terms of their agrophysical status. However, the low organic carbon

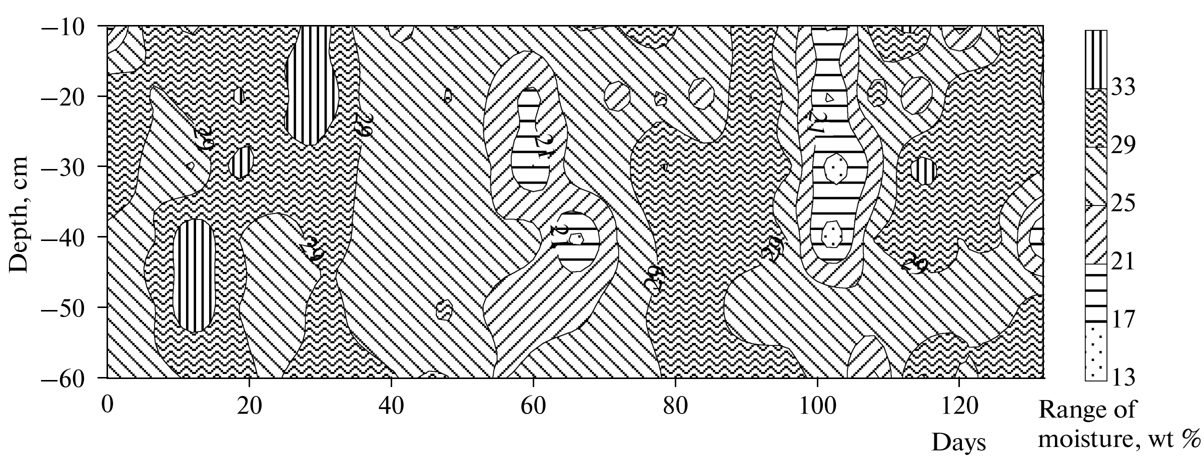

Fig. 2. Chronoisopleths of the soil moisture during the growing period of 2012 (plot 1).

content (up to 1%), the low C/N ratios, and the low content of carbonates presuppose a low level of agrophysical conditions [14, 20, 21] (table). This fact is considered interesting and very important for understanding the agrophysical assessment of the soils. We suggested that the favorable agrophysical status of the alluvial soils in the Çumra region is provided by their rich and diverse microbiota and its high activity in these well heated clayey soils.

The results of the total microbiological characterization of the studied soils showed that four phyla predominated there. Among them, the *Actinobacteria* phylum is the dominant one (Fig. 3). In this phylum, both higher (*Streptomyces* forming mycelium) and lower (three species of *Rhodococcus*) actinobacteria were found in elevated amounts. These species are actinobacteria, for which the main ecological niche is the anaerobic zone of the soil, where they perform the hydrolysis of complex substrates, for instance, the hydrolysis of cellulose and even carbohydrates [4, 25]. In addition, the antibiotic activity of *Streptomyces* is important in the formation of the microbial community, where *Streptomyces* act as a factor regulating the composition of the cenosis, which inhibits the development of one species and provides conditions for the reproduction of other ones [9]. *Rhodococcus* is able to produce bioactive steroids and acrylic acid [18]. Consequently, the role of these dominating actinobacteria appears to be determined not only by their strong hydrolytic features in relation to complex polymers but also by their capacity to regulate the structure of the soil microbial community. These species are present in the soils of the control variant and of plot 1 (Fig. 3).

Anaerobic hydrolytics of this phylum are no less important. We found *Bifidobacterium* sp., which was not observed in the control soil, in the soil of plot 1, probably, due to the exudates of sugar beets cultivated on this soil. This genus is useful for soil fertility, since it has the ability to excrete some enzymes, amino acids, and regulators of the plant growth [9].

On the whole, the diversity of microorganisms is rather high—47 species of bacteria from 35 genera. The total number is 10^7 cell/g soil. It is worth noting that, at the humus content of 1%, this number of bacteria and their diversity are considered rather high. The C/N ratio in the soil is close to that characteristic of microbial cells (6.2) [5], thus showing favorable soil conditions for the development of microorganisms. Probably, the high biodiversity at the great number of bacteria and the developed trophic interrelations in the microbial community promote the balanced production of specific metabolites, including gaseous ones (CO_2, H_2). This fact allows the clayey soil studied to actively protect the porous space against consolidation and to maintain the optimal density, porosity, and hydrological properties. This conclusion is preliminary, and a detailed study of the structure of the microbial communities and numerous tests are needed. It points to the necessity to continue research on the determination of the relations between the physical properties and the agrophysical processes and the composition, properties, and functioning of the soil biota.

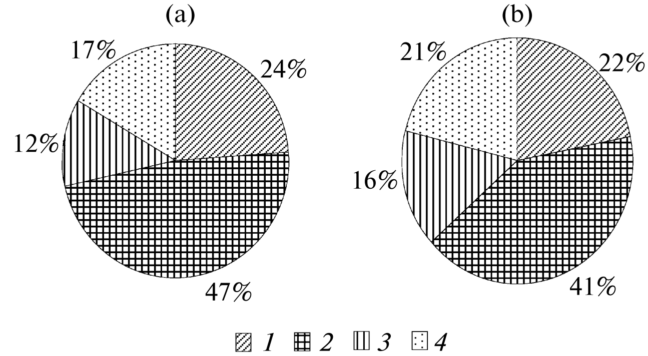

Fig. 3. Total (for all the depths) ratio of the bacterial phyla in the soil of the control variant (a) and plot 1 (b). The designations are as follows: (*1*) *Proteobacteria*; (*2*) *Actinobacteria*; (*3*) *Firmicutes*; (*4*) *Bacteriodetes*.

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