Humus of Soils of the Altai Mountains

M. I. Dergacheva, E. I. Kovaleva, and N. N. Ryabova

Abstract—Data on the humus composition and specific features of soils in the Altai Mountains obtained in the long-term studies initiated by R.V. Kovalev are discussed. The average statistical values for the content of the main humus components and their ratios in different soil types were obtained by processing the data on 307 soil pits. The comparison of the soils belonging to the same type and occurring in the northwestern, central, and southeastern regions of the Altai Mountains in terms of the C ha/C fa ratio (one of the integral indices of the humus composition) showed that there were no significant differences between them. The overlapping intervals of the average values of this ratio testified to this fact. For instance, the average C ha/C fa ratios in the mountain tundra soils of the regions mentioned amounted to 0.70 ± 0.03; 0.72 ± 0.02; and 0.69 ± 0.03, respectively, and, in the mountain meadow soils, they amounted to 0.67 ± 0.03; 0.69 ± 0.04; and 0.67 ± 0.03, respectively. The mountain brown forest soils that are components of the soil cover only in the northwestern and central regions also differ insignificantly by this parameter (0.88 ± 0.05 and 0.89 ± 0.03, respectively). In the soils of the Altai Mountains, the dependence between the portion of humic acids and the mean annual air temperature (HA (%)) = 29.54 + 1.06T(°C), r = 0.71) and the ratio of the portion of fulvic acids to the mean annual precipitation (FA (%) = 9.70 + 0.029W, r = 0.74) was shown to be similar to those in all the soils of mountainous southern Siberia. These facts enabled us to apply regression equations for a quantitative reconstruction of the paleoclimate components according to the humus composition.

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INTRODUCTION

Roman Viktorovich Kovalev spent most of his life in the Caucasus region, and his main interests were soils of mountain territories. In the first years of his activities in Siberia, he created a team that began to study the soils and the soil cover of the Altai Mountains under his scientific supervision; he also participated in these investigations. The results of these studies were published in 1973 in a monograph entitled Soils of the Gorny Altai Autonomous Region [19]. Up to the present, there is no more detailed review of the soils in the Altai Mountains. It contains a systematic inventory of the soils, the main regularities of the soil cover pattern, and the soil-geographic zoning of the Altai Mountains based on the materials of detailed investigations of the physical, physicochemical, and biological properties of the soils. Later on, some separate phases, components of soils, and soil regimes were studied. Particularly, comprehensive studies of the humus in the soils of the Altai Mountains were initiated by Kovalev, since the materials on the soils were represented in the monograph by scarce data. First, they did not cover the whole soil diversity even concerning the main soil types. Second, they were obtained using different methods and modifications of studying the humus composition (Tyurin [22], Kononova and Bel’chikova [15], Ponomareva [17], and Ponomareva and Plotnikova [18]). The materials on the composition and properties of the humus in the soils of the Altai Mountains that existed at that time and appeared later [1, 2, 4–7, 14, 16] could not fill all the blank spots in the knowledge of this parameter, which is important from the standpoint of soil functioning. The same problems did not allow summarizing new data, since the data were scarce and incompatible because of the different analytical methods applied (incomplete schemes or methods) and different ways of sampling (average or individual samples from the main soil horizons or only from the A1 horizon). The available data on the humus were insufficient for the substantiation of quantitative relationships between the composition and properties of the humus and climatic and other parameters (the ingredients of the notion the “ecological conditions of formation and/or existence of soils”), as well as for the solution of applied problems of the national economy.

OBJECTS AND METHODS

The program of works for studying the humus included the inventory of the soils of the Altai Mountains according to their humus composition and research into the relationships between the humus properties and the environmental conditions.

This work summarizes the materials on the humus composition in the soils of altitudinal belts in the Altai Mountains. The samples were collected from 307 pits.
The database contains the main characteristics of the humus and humic acids' composition and some environmental parameters, including climatic ones calculated for each object by equations of regression. These equations demonstrate the quantitative relations between the climatic parameters and the altitude of the region [12].

Soil samples were collected every 5–10 cm taking into account the boundaries of the genetic horizons. The sampling was carried out in the late summer in the period when the humus composition is the most stable [8]. In the course of the field works, for each object, the following characteristics were determined: the altitude above sea level, topographical position, meso- and microrelief, slope aspect, soil type, and specific features of the landscape. The humus composition was studied using the methodologies of Ponomareva and Plotnikova in the modification of 1968 and strictly following the conditions of the analysis.

Methods of applied statistics (using the Statistica package) were applied. The statistical processing of the results concerning the composition of the humus and humic acids showed the representativeness of their characteristics at the 95% significance level.

**RESULTS AND DISCUSSION**

**The humus composition in the main soil types of the Altai Mountains.** The studies conducted allowed us to determine the average statistical characteristics for the contents of humic acids (HA), fulvic acids (FA), and their ratio \( C_{fa}/C_{ha} \) in soils of different genesis under different environmental conditions. The comparison of soils of the same type from different regions of the Altai region according to one of the integral characteristics of the humus composition—the \( C_{ha}/C_{fa} \) ratio—has shown the absence of significant differences between them (the \( F \) criterion was equal to 28.01 at a significance level \( P = 0.000 \)). The overlapped confidence intervals of the mean \( C_{ha}/C_{fa} \) values in the soils of the same type also confirmed this fact (Table 1).

<table>
<thead>
<tr>
<th>Soils</th>
<th>Northwestern</th>
<th>Central</th>
<th>Southeastern</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( n )</td>
<td>( \bar{x} \pm m )</td>
<td>( n )</td>
</tr>
<tr>
<td>Mountain-tundra</td>
<td>8</td>
<td>0.70 ± 0.03</td>
<td>12</td>
</tr>
<tr>
<td>Mountain-meadow</td>
<td>9</td>
<td>0.67 ± 0.03</td>
<td>15</td>
</tr>
<tr>
<td>Mountain-brown forest</td>
<td>14</td>
<td>0.88 ± 0.05</td>
<td>17</td>
</tr>
<tr>
<td>Chestnut</td>
<td>–</td>
<td>–</td>
<td>12</td>
</tr>
</tbody>
</table>

Taking into account the insignificant differences in the mean \( C_{ha}/C_{fa} \) ratios, the average statistical values for the contents of the main humus components and their proportion were calculated for the soils over the whole territory of the Altai Mountains (Table 2).

The results obtained showed that the variability of the main humus characteristics of the different soil types were within the limits characteristic of each type of mountain soils in southern Siberia [20]. The specific features of the humus composition were determined by the environmental conditions. These conclusions are not new, but they were made earlier, for the most part, at the qualitative level. Until now, the quantification of the relationships between the humus parameters and environmental conditions in the Altai Mountains has not been performed.

However, for the solution of a wide range of questions related to global climate change, changes in the environment and landscape situation, the evolution of soil types and soil-forming conditions, and forecasting the behavior of the environment in the nearest and remote future, a reliable quantitative assessment of the relationships between humus and environmental conditions is necessary.

**Ecologic–humus relationships.** In order to quantify the relationships between the humus of the soils and the soil-forming conditions, some climatic characteristics for each object were determined using the equations of regression showing links of the main climatic parameters with the altitude of the region [12]. For the whole territory of the Altai Mountains, these equations are as follows:

\[
\begin{align*}
T_{air} &= 2.52 - 0.0039h \quad (r = -0.90); \\
T_{ss} &= 3.62 - 0.0041h \quad (r = -0.86); \\
\Sigma t > 0^\circ C &= 2567.5 - 0.772h \quad (r = -0.90); \\
\Sigma t > 5^\circ C &= 2487.1 - 0.797h \quad (r = -0.97); \\
\Sigma t > 10^\circ C &= 2052.1 - 0.621h \quad (r = -0.93); \\
L_{sffp} &= 134.63 - 0.487h \quad (r = -0.75); \\
L_{sffp} &= 127.89 - 0.0557h \quad (r = -0.87),
\end{align*}
\]

where \( h \) is the altitude a.s.l., m; \( T_{air} \) is the mean annual air temperature, °C; \( T_{ss} \) is the annual temperature of the soil surface, °C; \( \Sigma t > 0^\circ C, >5^\circ C, >10^\circ C \) are the sums of temperatures higher than 0, 5, and 10°C; \( L_{sffp} \) is the duration of the frost-free period for the air; and \( L_{sffp} \) is the...