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COMPARATIVE STUDIES ON THE PROCESSES OF HUMUS FORMATION IN SOILS FROM TURKEY, GREECE, BULGARIA AND SPAIN

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Introduction

In the classical soil science studies a great attention always was paid to the climatic factor of soil formation. This was one of the reasons for the organising the International Meetings on Soils with Mediterranean type of climate. Attending these Meetings we discovered that the soil are quite diverse and there is quite a diversity of humus systems, even though they all form in the countries with Mediterranean type of climate.

In his opening lecture of the 6th International Meeting on Soils with Mediterranean Type of Climate, held in Barcelona, Spain, in 1999, Alain Ruellan (1999) wrote: "When we think about Mediterranean soils, the first image that comes at our mind is the red colour, the red Mediterranean soils, the Terra Rossa". He divided the red soils into two groups.

Kolchakov *et al.,* (1999) described the Cinnamonic forest soils with red Bt horizons in Bulgaria and showed that even within only this unit there are six soil varieties. Danalatos *et al.,* 1999; Faz *et al.,* 1999; Martin *et al.,* 1999; Irmak *et al.,* 1999; Lepeshev and Belobrov, 1999; Madeira *et al.,* 1999; Mancini *et al.,* 1999, have shown that apart from the red soils there are many other soils in the territory of Greece, Spain, Turkey, Libya, Portugal, and Italy. Either the whole territory of these countries (or just the studied regions) belongs to the Mediterranean type of climate.

Different authors (Teoharov and Filcheva, 1995; Filcheva and Boyadgiev, 1995) and our own works (Sokolovska *et al.,* 1995; Grozeva and Petrova, 1999; Shishkov and Petrova, 1999; Sokolovska *et al.,* 1999) have discovered that there are some similarities in the humus amount, its distribution along the humus horizon and the composition of humus between the soils formed in different Mediterranean countries. We want to discuss in our paper these similarities, for which we have probable explanations. For that reason we compared processes of humus formation in soils from Turkey, Greece, Bulgaria and Spain.

Materials and Methods

We use in our work the method of the comparative- ecological analysis (Sokolov, 1993). The most concrete results of this method are received at mono-factorial comparison. The exact realisation of this condition in our study however, it is impossible, because the soil forming factors and humus formation factors respectively, are interrelated.

The representative soil from Turkey included in the study is one profile classified as Calcic Luvisol. The profile is described in the Excursion Program of the 3rd International Meeting on Red Mediterranean Soils held in Adana in 1993 as Profile 1. The profile is located 15 km north of Adana (37°05'N and 35°20'E) on an old Quaternary river terrace, at 120m of elevation. Soils are formed from conglomerate cemented by $CaCO_3$. Climate at the profile location is determined as typical Mediterranean with annual rainfall of about 600 to 650 mm, dry hot summer and mild rainy winter, with mean annual temperature of 18.7° C. The area surrounding the profile is used for growing vegetables and citruses.

From Greece, Vardar district, (about 40°N and 23°E) was chosen 1 profile classified as Chromic Luvisol and described in detail in the Technical Excursion Guide Book of the 4th International Meeting on Red Mediterranean Soils, Calkidiki, Greece, 1995 as profile 5 (Koroxenidis *et al.,* 1995). The soil is formed from unconsolidated marine sediments on a lower terrace at elevation of 50 m. Climate on that location is typical Mediterranean with 4 to 5 months warm and dry during the summer and relatively mild, humid winters lasting from October to April. Mostly there is sunny weather throughout the year, with mean annual temperature of 18.4°C and mean annual rainfall of 385.1mm. Profile 5 is located on arable land cultivated with annual crops.

The studies in Bulgaria included a profile classified as Chromic Luvisol, from south Bulgaria, in the river Struma valley, (about 42°N and 24°E) near the town of Kresna, at elevation of 500m and slope of 30°. Parent material is formed from Pliocene old Quaternary sediments of granites, gneisses and sandstones more or less weathered. The climate of Kresna district is characterised as Temperate- Mediterranean or sub-Mediterranean (Sabev and Stanev, 1963) with mean annual temperature of 12.5 to 14° C and mean annual precipitation 520-670mm. The main amount of precipitation falls by the end of autumn and the beginning of winter (November). The least amount occurs during the summer. Natural mixed Oak Forest vegetation (40-42 years old) predominates on these soils.

The soils from Spain, Catalonia, included in the study were represented by two soils: one Profondic Luvisol and one Petric Luvisol, or the profiles 1 and 2, respectively, described by Bech J., (1999). These soils are located southwest of Barcelona (profile 1- at 41°19'46"N and 2°00'38"E, profile 2- at 41°17'15"N and 1°57'09"E).

The Profoundic Luvisol is formed from Palaeozoic colluvium schist, at an elevation of 50m, and on a 50% slope. The studied soil is on northern slope, under evergreen oaks, and is not well drained. The Petric Luvisol is formed from Pleistocene colluvium silts, placed at an elevation of 160m, on 20 to 30% slope gradient. This is a well-drained soil, under calciphile shrubs and evergreen oaks. The region of Barcelona enjoys typical Mediterranean climate with mean annual precipitation of 650mm and mean annual temperature of 16°C. The summer is hot and dry, with temperatures over 20°C from June to September.

Total organic carbon amount was determined with the method of Tiurin (Arinushkina, 1970), humus composition with the method of Kononova-Belchikova, (Kononova, 1963), and the humus status criteria was determined by the scheme of Grishina and Orlov (1978).

Results and Discussions

One of the main parameters of humus status is the amount of humus in the surface horizons. Examining thus the amount of humus (Table 1) in these surface horizons for all the soils included in this study the following considerations could be drawn.

The surface horizon of the soils from Spain-Profondic Luvisol and from Bulgaria- Chromic Luvisol are in the group with medium amount of humus, (4 to 6% humus, Grishina and Orlov, 1978). Those are soils formed under forest ecosystems. Nevertheless, the Profondic Luvisol has a higher amount of humus in its surface horizon in comparison with the humus content in the surface horizon of the Bulgarian Chromic Luvisol.

The explanation for this is due to the fact that the Profondic Luvisol is poorly drained, which hinders mineralisation of organic matter. The Calcic Luvisol from Turkey and the Petric Luvisol from Spain are in the group with low humus amount in their surface horizons (2 to 4%). Those are well-drained soils. The soil from Turkey is under cultivation, therefore contains lower humus amount, compared to the soils in the first group. The soil from Spain is not arable, but it probably suffered anthropogenic impact- may be fire accident (there is charcoal evidence in the 7-28 cm horizon), due to which the shrubs on it are not well developed, and in consequence lower humus content was accumulated.

The surface horizon of the Calcic Luvisol from Greece is within the group with very low humus amount. This is an arable soil, however the main reason for the low humus content in its surface horizon is the low precipitation. Precipitation is less than half of what is recorded in the other three countries (385mm in Greece versus 650 to 670mm in the other three countries). The drought impedes crop growth and the result of this is a lower amount of plant remains and therefore lower material for the formation of humus.

Along the depth of the profiles, the amount of humus changes depending on the type of vegetation. In the subsurface horizon the amount of humus in the soils under forest decreased about 3 to 5 times in comparison with that in the surface horizons. In the arable lands the decrease is about twice and below the subsurface horizon, in all studied soils, there is a gradual decrease of humus content until very low amounts.

The degree of humification is expressed by the ratio between the carbon of the humic acids with total organic carbon (the carbon of humic acids X 100/total organic carbon ChaX100/C org.). For all the studied soils, the degree of humification of the surface horizons is below 20%, except for the Chromic Luvisol from Greece, where it is at medium level (from 20 to 30%). In the subsurface horizons of the Bulgarian Chromic Luvisol the degree is also medium (20 to 30%), while at the Calcic Luvisol from Turkey it is even higher (30 to 40%).

Table 1. Humus amount and composition of the studied soils

Horizon depth cm	Organic Carbon % To dry soil	Humus % To dry soil	Humic acids C% from total organic Carbon	Fulvic Acids C% from total organic Carbon	Cha Cfa	C% from Humic acids		Not extractable	E4 E6
						free or R_2O_3 bound	Ca bound	Organic Carbon % from total	
				Profile 1, Turkey - Calcic Luvisols					
Ap 0 - 11	2,01	3,47	20,40	11,94	1,71	0,0	100,0	67,66	4,73
AB 12 - 29	0,91	1,57	32,97	3,29	10,0	0,0	100,0	63,74	4,41
Bt 30 - 67	0,50	0,86	2,00	26,00	0,08	0,0	100,0	72,00	4,75
BC 68 - 77	0,31	0,53	19,35	9,68	2,00	0,0	100,0	70,97	5,00
				Profile 5, Greece - Calcic Luvisols					
Ap 0 - 42	0,86	1,48	23,26	11,62	2,00	0,0	100,0	65,12	4,24
Bt_1 43- 80	0,53	0,91	15,10	11,32	1,33	0,0	100,0	73,58	9,00
Bt_2 81-100	0,43	0,74	20,93	11,63	1,80	0,0	100,0	67,44	10,6
Bk 101-125	0,40	0,69	15,20	20,00	0,75	0,0	100,0	65,00	15,0
				Profile 3, Bulgaria - Chromic Luvisols					
A 0 -10	2,79	4,81	11,83	24,37	0,49	84,85	15,15	63,80	6,75
B t_1 11- 34	0,96	1,66	25,00	11,46	2,18	41,67	58,33	63,54	5,57
B t_2 35-90	0,45	0,78	24,44	22,23	1,10	0,0	100,0	53,33	2,20
Bk 91-110	0,23	0,40	0,0	34,78	0	0,0	0,0	65,22	-
				Profile 1, Spain - Profondic Luvisols					
A 0 -10	3,48	6,00	19,83	29,89	0,66	68,12	31,88	50,29	6,22
E 11 -20	0,72	1,24	9,72	25,00	0,39	0,0	100,0	75,00	4,52
Bt_1 21- 40	0,38	0,66	0,0	31,57	0,0	0,0	0,0	68,42	-
Bt_2 41-65	0,38	0,66	0,0	21,06	0,0	0,0	0,0	78,95	-
Bt_3 66-115	0,33	0,57	0,0	30,30	0,0	0,0	0,0	69,70	-
				Profile 2, Spain - Petric Luvisols					
A_1 0 - 7	1,41	2,43	7,80	17,73	0,44	0,0	100,0	74,47	4,51
A_2 8 - 28	0,64	1,10	10,94	7,81	1,40	0,0	100,0	89,06	3,00
Bt_1 29 -54	0,21	0,36	0,0	23,81	0,0	0,0	0,0	76,19	-
Bt_2 55 -82	0,35	0,60	0,0	8,57	0,0	0,0	0,0	91,43	-

A common feature for the studied soils from Spain, Bulgaria and Greece is the zero degree of humification in the deeper horizons, because of the absence of humic acids. This feature was observed and described in the Chromic Luvisol from Greece by Grozeva and Petrova, (1999). The horizons where is observed "O" degree of humification are calcareous. Calcium from the carbonates precipitates the colloidal humic acids as insoluble Ca-humates at some soil depth.

Between the soils discussed in this study, there are some with free or bound by R_2O_3 humic acids in their surface horizons, however, the rule is that humic acids are bound by Ca in all calcareous horizons. This is a similar feature found also in the soils from other climatic regions. In the surface horizons of the Profondic Luvisol from Spain and Chromic Luvisol from Bulgaria there are humic acids free or bound by the Fe and Al oxides. Those are the soils formed typically formed in the forest soils where is common the presence of free or bound to R_2O_3 humic acids in the soils surface horizons or along the depth of the whole profile.

Another feature of humus of the discussed soils is the relative distribution of humic and fulvic acids along the depth of the profiles. There are several types of the humic acids distributed along the depth of the profiles (Petrova, L., 1994). One of them is repeated in three from the five studied soils. This is the relative distribution at which humic acids predominate in the surface over the fulvic acids. With increasing depth, the fulvic acids increase, but at deeper layers the humic acids predominate again, as it happens in the Calcic Luvisol from Turkey.

The pattern could be vice versa- starting with a predominance of fulvic acids over humic ones and then changing places as the depth increase. This pattern is found in the Petric Luvisol from Spain and in the Chromic Luvisol from Bulgaria. This type of relative distribution of humuc acids along the depth of the profile shows drastic change in humus formation due to drastic change of environmental conditions, or to anthropogenic impact. Such kind of relative distribution of humic and fulvic acids along the depth of the profile is observed in most of the Chromic Luvisols from Bulgaria, confirming the relict character of their red horizons.

The soils from the Mediterranean countries are old soils. They underwent many changes due to the environmental or human impacts. This can be seen in the drastic change of the Petric Luvisol and reflected on the relative distribution of humic acids along the depth of the profile.

The soil from Turkey was formed on an old Quaternary river terrace. With time the alluvial soil developed to a Calcic Luvisol, with gradual decrease of the total organic carbon from layer to layer, preserving only the irregular change of its Cha/Cfa ratio along the depth of the profile.

The land use of the Bulgarian Cromic Luvisol included in this study, changed from grass to oak forest during the last 40- 42 years. In its surface horizons already predominate fulvic acids over humic acids and the process is being speeded by the higher humidity under forest, the exposition from east to north-east, and the slope of about 30-35^o.

The last but not the least, it is well known that humus amount and its type play an important role in determining the colour of all soils including the Mediterranean soils. If this colour is characterised with 10YR, as it is in the Profondic Luvisol from Spain and in the surface horizon of the Bulgarian soil included in the study, it is due mainly to the higher amount of humus and its dark colour. But humus plays also an indirect role in determining the colour of soils by participating in the oxidation- reduction reactions and in the moisture governed equilibrium of hematite goethite limonite that are responsible for the red colour.

Is the red colour of the Mediterranean soils relict or contemporary? It could be both. For the Bulgarian Cinnamonic forest soils (Chromic Luvisols) it was shown (Kojnov, 1964), that they have an ancient genesis, characterised by long-term soil formation. The process of Chromic Luvisols formation continues in the contemporary climatic conditions, and this allowed some authors to suggest that the red Mediterranean soils are contemporary formations.

Conclusions

The Mediterranean climate is a very important factor for soil humus formation in the soils of the countries influenced by this climate. However, its role can be modified by the parent material, type of vegetation, anthropogenic impact, and by the historical change of ecology. This study shows that all factors of soil formation are inter-related with each other. The main common features of the studied soils in relation to humus are:

1. Comparatively low amount of humus from medium to very low (6% to below 2%) in the surface horizons, and very low in the deeper horizons. The main cause for this is the hotter climate with higher mineralisation rates of the plant remains and low precipitation. The higher amounts of humus in the surface horizons are found at the soils under forest at higher elevations, where precipitation is higher and temperatures are lower.
2. The Mediterranean soils are very old and very young in the same time. Their formation started at the old Quaternary and Pliocene and they still form their contemporary humus profiles. They had been subject to erosion and consequently, degradation, mineralisation and environmental changes have influenced their humus status over long periods of years. The newly formed humic acids are bound by Calcium due to the high temperature, low precipitation, and the abundant calcareous materials in the surface or in the deeper horizons (the last stands for the soils under forests).
3. The Mediterranean soils humic acids frequently show a relative distribution along the depth of the profile, which is evidence of drastic historical changes of ecology or anthropogenic impacts.
4. The absence of humic acids in the deeper horizons of the Mediterranean soils could be due to high mineralisation rates, the alkaline reaction of the calcareous horizons full of abundant Calcium, which had precipitated the colloidal humic acids as insoluble Ca-humates.

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