THE RELATIONSHIPS OF IRON CONTENTS BETWEEN RED MEDITERRANEAN SOILS AND ITS PARENT MATERIAL IN ANTALYA PROVINCE, TURKEY

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Abstract

In this research, Fe contents of Red Mediterranean soils and Fe contents of parent materials were determined in the west Mediterranean Region, Antalya, Turkey. Total six soil profiles were examined at the different elevations around Antalya. According to the variance analyses results, extractable Fe contents of profiles were not significantly different ($p<0.01$). The lowest Fe content in horizons obtained from C horizon. The Fe content of the solums at investigated soil profiles were found on average of 2.6 % and the Fe content of parent material were on average of 0.6 %. In addition, the existence of pressed clay material and kaolinite, in the soil profiles supports the theory that this soil was not formed wholly by the limestone weathering. They could be possibly developed in other location under the lateritic climatic conditions, transported and deposited in the present region.

Keywords: Red Mediterranean Soils, Terra Rossa, Limestone, Fe content, Dust Eolian

Antalya İlindeki Kırmızı Akdeniz Toprakları ve Ana Materyallerinin Fe İçerikleri Arasındaki İlişkiler

Özet

Bu çalışmada, Türkiye'nin batı Akdeniz bölgesinde yer alan Antalya ilindeki, Kırmızı Akdeniz Toprakları ve ana materyallerindeki Fe içerikleri belirlenmiştir. Antalya çevresindeki, farklı yükselti basamaklarında, toplam altı profilde çalışılmıştır. Profillerdeki Fe içerikleri varyans analizine tabi tutulmuş ve önemli bir ilişki bulunamamıştır. Toprak profillerinde, ana materyallerdeki Fe içeriği ortalama % 0,6 iken solum içerisindeki horizonların Fe içeriği ortalama % 2,6 civarında belirlenmiştir. Aynı zamanda profillerdeki kil tipinin kaolinit olması da bu toprakların sadece kireçtaşı ana kayasının ayrışması sonucu değil, aynı zamanda lateritik iklim bölgelerinde oluştuktan sonra, taşınarak Akdeniz'in farklı lokasyonlarına depolandığını ve gelişim sürecine devam ettiği teorisini desteklemektedir.

Anahtar Kelimeler: Kırmızı Akdeniz Toprakları, Terra Rossa, Kireçtaşı, Fe İçeriği, Rüzgar Tozları

1. Introduction

The term "Terra Rossa" has been widely applied to red soils overlying limestone in temperate climatic zones, particularly in Mediterranean climates with district wet and dry seasons (Olson et al., 1980). The major objection to the limestone being the primary parent material of Terra Rossa soils is that the amount of insoluble residue is often too low to explain the observed thicknesses of Terra Rossa soils (Macleod, 1980 and Olson et al., 1980). A number of researchers (e.g. Nihlen and Olson, 1995 and Yaalon, 1997) have concluded that there must have been significant additions of eolian material to form the thicknesses of Terra Rossa observed in many regions today. Airborne accessions of dust have been shown by number of authors to significantly influence soil development and soil characteristics (Brimhall et al., 1988 and Simonson, 1995).

At least four attributes make the Mediterranean world indeed different and largely determine the nature of its soils: specific climate, its mountains, dust from desert, and the long term effects of humankind. Characteristics landscape attributes are the high proportion of mountains with steep slopes, significant additions of Saharan desert dust to

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practically all soils of the region, and a large proportion of limestone and other calcareous rocks as soil parent materials (Yaalon, 1997).

The allochthonous red soils have likely inherited their color from their parent materials that were transported from the originally formed residual soils on hard limestone. The soils retain the red color in the thermo-Mediterranean zone only on sloping terrains. The soils on these landscapes are frequently stratified (Yassoglou et al., 1997). According to a study of Mee et al., 2004, Terra Rossa soil from the Coonwarra has a tick, clayey B-Horizon which is geochemically homogeneous and dominated by smectite and kaolinite. In the Terra Rossa the clay content is very high (87%) weathering of feldspars and above all of phyllosilicates resulted in a formation of illites and kaolinites (Bronger and Kalk, 1984).

The close association between Terra Rossa and the underling limestone can therefore be seen in the role the rock plays for the water and air regimes of the soil rather than the material characteristics of them (except for soil pH). Neither on the Fe content of the solum nor the addition of eolian or alluvial material can therefore be used as an argument against a genetic relationship between Terra Rossa and its underlying limestone (Boero and Schwertman, 1989).

Hematite appears to be significant amounts in the A and B horizons of the soils and to have originated mainly from the weathering of the Fe-bearing clay minerals (Torrent and Cabedo, 1986). Iron compounds released from the weathering of minerals, including iron oxihydroxides are precipitated as poorly crystalline ferrihydrites or very fine-grained hematite (Fe_2O_3) which coat the clays and the coarser particles (Yaalon, 1997).

The formation of single domain, super paramagnetic magnetite and hematite are linked genetically to the weathering of the aeolianite that leads to the formation of Terra Rossa (Khadkikar and Basaviah, 2004). The hematite content determines nearly all Terra Rossa sample pairs the quite different fraction of red (the hue notation) of the (Munsell) colour. Two exceptions are valid for the Terra Rossa with their limestone residue have in both cases as follows; the Terra Rossa and its limestone residue have the same or nearly the same colour, but the hematite content in the Terra Rossa is quite higher than in the accompanying limestone residue. These results show that a rubefication in the Terra Rossa could have been established the extent of which is mostly but not always determined by the hematite content and obviously independent of the intensity of weathering, in most of the Terra Rossa no mineral weathering and clay formation was verifiable (Bronger and Kalk, 1984). Neither the content and particle size distribution nor the bulk and clay mineralogy of the insoluble residue of limestone and dolomite support development of Terra Rossa entirely by dissolution of carbonate rock. If Terra Rossa developed only from the insoluble residue of limestone and dolomite, its clay content, due to weathering, should be higher than that in the insoluble residues which is not the case. Analyses performed indicate that, both losess older than that of the upper pleistocene age and flysch might have contributed in the genesis of Terra Rossa (Durn et al., 1999).

This study aims to assist in creating definite parameters in research into the characteristic of the Red Mediterranean soil which covers a significant area in Turkey, in the determination of its relationships with the world's other Red Mediterranean soils and in the genesis and classification of these soils.

2. Material and methods

2.1. Material

The climate of the region is a typical Mediterranean climate with hot, dry summers and warm, rainy winters. Depending on the prevailing climate, topography and altitudes of the region in which it is located, the research area's vegetation cover is mainly made up of maquis and mixed forest.

In Antalya basin, located within the research area is found Paleozoic, Mesozoik, Tertiary and Quaternary Age geological formations. The geological formations of the area, the research was carried out, are Cretaceous Period formations from the former seabed forced upwards as a result of tectonic action and mostly made up of well-crystallized limestone.

This research was carried out on limestone land over a 40 km in distance starting from the coastline at Antalya and extending to the hill of Kadındağı to the north. From two defined sections, the western and eastern, on the edges of the area in question, and along a north-south vector, three soil profiles each were examined making a total of six. So as to create a Catena, the soil profiles were selected according to altitude stages of 1250, 750 and 350 m.

The western edge profiles are the first level profile B1 at Çubukbeli (1250 m), the second level profile B2 on Mount Termessos (750 m) and the third level profile B3 in the Güver Canyon (350 m). The estern edge profiles are, at the first level, the D1 profile to the southeast of Dag township which provides a comparison with the western edge's B1 profile, at the second level, the D2 profile from east of Camili village which provides a comparison with the B2 profile, and, at the third level, the D3 profile from southeast of Kirişçiler village which provides a comparison with the B3 profile.

In the current study, the six soil profiles have been evaluated according to Soil Taxonomy (Soil Survey Staff, 2006) and classified as Ordo, Sub-Ordo, Main Group and Sub-Group. The soil profiles have been classified as Typic Xerocrept (profiles D1 and B1), Lithic Rhodoxeralf (profiles D2, D3 and B3) and Typic Rhodoxeralf (profile B2) (Table 1).

2.2. Methods

For site selection in the research area, 1/25000 scale topographical maps and aerial photographs and in this way an even distribution of the soils profiles in the context of the catena were ensured. The soil profiles referred were determined within the principles of Soil Survey Division Staff 1993. The physical, chemical and mineralogical properties of soils obtained from each profile according to the genetic horizon principle were determined as follows; Experimental soil, tailings and amended tailings samples were chemically analyzed after they had been air dried and passed through a 2 mm sieve. The texture according to the hydrometer method (Bouyoucos, 1955). Extractable iron with sodium sitrat-dithionit-bicarbonat method (Jackson, 1967) and Clay mineralogy analyses in an X-Ray difractometer (Jackson, 1975); using by disturbed soil samples. Classification of the soil profiles was carried out according to (Jackson, 1975). The Iron data were analyzed by standard ANOVA procedures.

Table 1 Classification According to Soil Taxonomy' of Soil Profiles

Horizons	Soil Taxonomy
D1	Typic Xerocrept
B1	Typic Xerocrept
D2	Lithic Rhodoxeralf
B2	Typic Rhodoxeralf
D3	Lithic Rhodoxeralf
B3	Lithic Rhodoxeralf

3. Results and Discussion

3.1. Interpretation of the morphological and physical characteristics of the soil profiles

The horizon levels of the profiles investigated in this research were defined in A/B/C form and the B horizons were defined as having developed in Bw and Bt forms, the soils being different in their catena relationships (Table 2). The profile colors were determined as 7.5 YR and 5 YR in the upper strata and in the lower strata one of the profiles as 2.5 YR and the others as 5YR (Table 2). These color characteristics of the soil were also supported by the high iron content possessed by the soil. Strong relationships were found between the horizon levels and color characteristics in the soil profiles and also the similar

Table 2 Selected Some Chemical Properties of Soil Profiles

Profile	Horizon	Sandy %	Loam %	Clay %	Texture	Fe %
D1 Profile	A1	22.3	31.0	46.7	C	1.9
	A2	23.3	26.0	50.7	C	2.1
	2Bw1	23.3	26.0	50.7	C	2.2
	2Bw2	22.3	26.0	51.7	C	2.3
	2Bw3	21.3	26.0	52.7	C	2.0
	2C	39.3	28.3	32.4	C	1.2
B1 Profile	A	31.3	28.0	40.7	C	1.9
	2A	23.3	24.0	52.7	C	2.2
	2Bw1	22.3	24.0	53.7	C	2.6
	2Bw2	20.3	25.0	54.7	C	2.3
	2BC	23.3	26.0	50.7	C	2.5
	2C	40.3	28.0	31.7	C	0.2
D2 Profile	A1	27.3	26.0	46.7	C	1.1
	A2	19.3	24.0	56.7	C	1.8
	2Bw	23.4	19.3	57.4	C	1.9
	2Bt1	25.3	16.0	58.7	C	1.8
	2Bt2	27.3	14.0	58.7	C	1.7
	2C	36.7	30.0	33.3	C	0.6
B2 Profile	A	23.3	28.0	48.7	C	2.2
	2AB	35.3	12.0	52.7	C	2.4
	2Bt1	22.3	37.5	52.7	C	2.6
	2Bt2	9.3	36.0	54.7	C	2.4
	2C	37.3	29.0	33.7	C	0.7
D3 Profile	A1	19.3	34.0	46.7	C	3.2
	A2	19.3	34.0	46.7	C	3.2
	Bt1	17.3	30.0	52.7	C	3.1
	Bt2	17.3	28.0	54.7	C	3.1
	Bt3	15.3	20.0	64.7	C	3.5
	C	29.0	24.0	47.0	C	0.1
B3 Profile	A	22.7	31.9	45.4	C	2.9
	Bt1	16.7	28.0	55.3	C	3.2
	Bt2	21.6	22.9	55.5	C	2.9
	Bt3	21.3	19.3	59.4	C	2.7
	2C	35.3	23.3	41.4	C	0.8

characteristics determined in other countries. For example, an investigation of the genesis, morphology and mineralogy of red soils in Spain, the horizon level types A/Bt/C or A/E/Bt/C were most frequently observed (Aguilar, 1993). It has also been determined that the profile was A/B/C in Red Mediterranean soils of southern carstic areas Turkey and the profile color was even more reddened especially on the B horizons (Sarı, et al., 1986). In a similar fashion, the profile color was determined as 5YR-2YR in the soil of a karstic region in Italy (Karaman and Kapur, 1991).

The structure of the soil was found mainly semi-angular blocks on the surface horizons and in the main of a strongly developed prismatic structure on the B horizons. With these characteristics, it is clear that the soil in question is a typical Red Mediterranean soil affected in an intensive manner by the soil formation processes. Moreover, it was established that this soil has the texture of clay and also clay accretions were found on the upper surfaces. This finding was supported by the texture analyses (Table 2). It is understood that, this soil has experienced genetic occurrences at an advanced level and that in the profiles, translocation, intensive decomposition occurrences and alteration of the structure of the clay.

3.2. Interpretation of the results of extractable iron of the soil profiles

According to the results of chemical analysis on each of the total of six soil profiles (Figure 1), it was determined that organic matter was present at a high or very high level in all the profiles. Concerning the free Fe, which is extremely Red Mediterranean Soils, the research area soils presented an interesting situation. As a result of analyses carried out on the limestone bedrock C horizon the Fe content was 0.18 % (Table 3), while this Fe content was reached very high values such as 3.5 % in the main body (Table 2). As it can be seen in (Table 2), while there were no important differences between the iron contents of the soil profiles, significant differences between the iron contents of the soil horizons of the profiles was found ($p<0.01$). As indicated in research carried out in many places in the world, this significant difference between the iron content of the bedrock material and that of the soil itself is believed to be related more to an allochthonous than to an autochthonous formation and also that lateritic areas are the source of the high iron content.

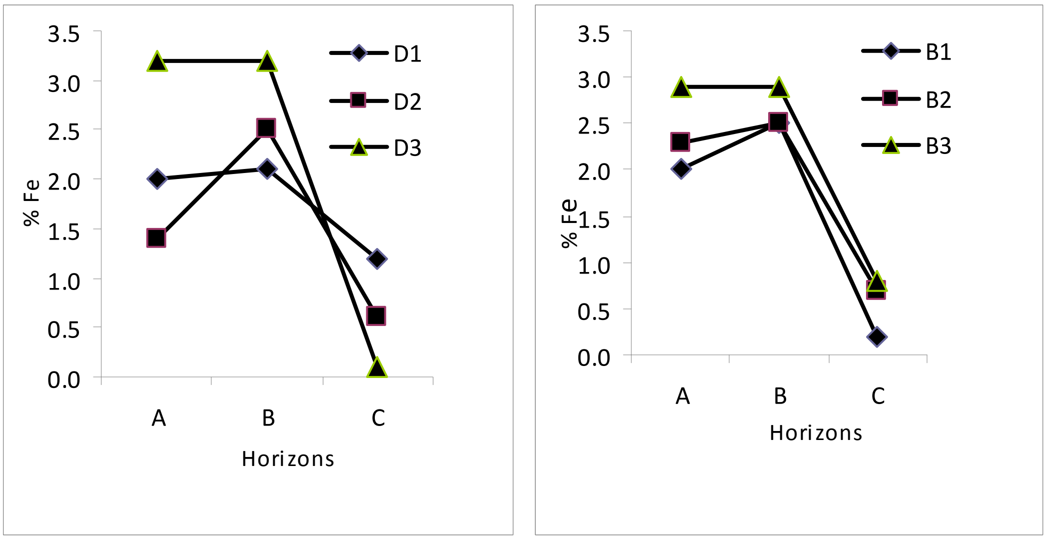

Figure 1 Fe (%) Content of D and B Profiles

Table 3 Selected Some Chemical Properties of Parent Material of B1 Profile

SiO_3	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Loss by heat	Immeasurable	Total
0.73	0.60	0.18	54.59	0.50	-.--	43.31	0.09	100

3.3. Interpretation of the results of mineralogical analysis of the soil profiles

The clay mineral kaolinite was found prevalent in the profiles of the research area. Moreover, it was established that smectite and paligorscite minerals were intensively present in the soil which is natural for Red Mediterranean soils. Also, it has been pointed out by many researchers that, these soils are at the final stage of the pedogenetic processes and the other minerals in the profiles have turned into kaolinite type clay minerals with a 1:1 lattice structure. Neoformation occurrences were found in all profiles, less in the D1 and D2 profiles, but more in the D3, B1, B2 and B3 profiles. Many researchers have determined that the predominant clay mineral is kaolinite in the Red Mediterranean soils (Sarı, 1982 and Pan et al., 1993). The others have observed that these soils are rich in smectite, followed by kaolinite and illite (Güzel et al., 1977).

Taking as the basis the result obtained from the studies referred to and the findings determined in the literature, it is possible to say that the hard crystal found in the Antalya region was formed by the decomposition of the limestone bedrock. However, in particular in these soils which have reached the final stage of decomposition, their having suffered from such an intensive weathering has rarely been observed in Mediterranean climatic conditions. Because of this, the conclusion, is reached that, according to the Kaolinite-Smectite-Paligorsgite mineral distribution and the high iron content of the soil profiles, the soil in question was formed in the place where all it elements were located as a result of weathering. For this reason it has been established that the soil in question began forming on top of the limestone bedrock in extremely early times and this has continued to the present and that although some have found certain relationships between the soil and the bedrock material, the soil located at the upper levels of soil profiles, especially its clay mineralogy, is not in conformity with the bedrock material. Its having been established for the levels that there definite nonconformity with the bedrock material, it is considered that while the formation of this soil on top of the autochthonous limestone is continuing, it may be that on top of this a portion of soil material, showing signs of weathering to a degree impossible under the still prevailing climatic conditions, is being imported from other regions on deposited in varying thicknesses. As the source of these materials, which are thought to be transported by various geomorphologic forces from the lateritic regions again attract the attention. This idea is in keeping with the high level of Fe contained in the soil of the research area. At the same time, the differences between the clay mineralogy characteristics of the horizons in the research area on the surface and at one level below the surface and those of the bedrock horizons are such as to support the ideas above.

3.4. Statistical analysis of extractable iron content of the soil profiles

The free Fe contents of the soil profiles examined in the research area, were applied to variance analysis as seen in the Table 4. This analysis results, are in harmony with morphological and chemical analysis results. According to the results of variance analysis there were no important relationships according to the free Fe contents between the profiles at Catena level. The free Fe contents between the horizons were found statistically important at 0,1 % level.

The LSD test applied to the horizons where the variance analysis results found important at 0.1 % level. The free Fe content in A and B horizons of totally six profiles in the research area were statistically similar (a), C horizon was statically different (b) Table 5. Whole Fe contents were near to each other in A and B horizons, it was higher then C horizon. This means that, this soils was not only formed only in their place but also exposed different processes during the formation at the same time.

Table 4. Variance Analysis of Soil Profiles

Source	D.F	F
Profile	5	1.64 ^{ns}
Horizon	2	28.32 ***
Error	10	

Significance levels: *** $p<0.001$; ns: not significant

Table 5. Fe % of Soil Horizons

Horizons	Fe (%)
A	2.2833 a
B	2.5167 a
C	0.6000 b
F Value	28.32 ***

[a] Different letters in the same column indicate a significant difference at $p< 0.05$

[b] Significance levels: *** $p<0.001$; ** $p<0.01$; * $p<0.05$; ns: not significant

4. Conclusion

According to the findings of morphological, physical, chemical and mineralogical analyses the Fe content is very low in the bedrock and parent materials of the six profiles, Fe is present at high levels in the soil. In addition to this, the existence of kaolinite in the soil profiles supports the theory that, this soil was not formed wholly by the limestone weathering. Moreover, the soil in question has been continuing since the Miocene Age and still forming the top of the limestone in the Mediterranean region. The existence of kaolinite type clay and amorphous clay is evidence of transformation from lateritic areas. As for the means of transportation, it is thought that this has been accomplished by means of Sirocco winds originated in Africa.

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