Available online at:
http://journal.unila.ac.id/index.php/tropicalsoil
DOI: 10.5400/jts.2016.21.2.123

Characteristic and Genesis of Black and Red Soil Vertisol in Jeneponto Regency

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Received 29 January 2016/ accepted 24 April 2016

ABSTRACT

One of factors that is interasting from Vertisol to be investigated beside the management of the soil fertility was color variations which can vary from gray to brown and brownish red. Exclusive characteristics of Vertisol are shrink swell capacity with clay dominant clay that make agricultural activities in the Jeneponto area less productive. The purpose of this study was to assess the differences of physical and chemical characteristics of black and red Vertisol in Jeneponto R.egency. The research location was based on the difference and overlaying of soil color. Black soils were taken from the village Bontomarannu and Tonrokassi Timur while red soil and overlaying colors of red and black soil were taken from the village Sarroanging. Results showed that one of the chemical characteristic which was very differences between black and red soils were calcium carbonate and base saturation. Generally $CaCO_3$ on black soil was higher (ranged of 13.20-36.73%) than red soil (ranged of 2.21-13.86%). As for overlaying colors of red and black soil were ranged of 2.62-3.88%. The highest base saturation was found in the black soil that was> 100%, red soil between 40-89% and overlaying colors red and black soil between 80-83%. While Fe, Mn and Al concentrations were highest with citrate dithionite bicarbonate extracts followed by oxalate and pyrophosphate extracts. Clay montmorillonite minerals were present in all profiles observed.

***Keywords**:* Black vertisol, jeneponto, red vertisol, shrink-swell

ABSTRAK

Salah satu faktor yang menarik dari Vertisol untuk diteliti selain pengelolaan kesuburan tanah adalah adanya variasi warna yang dijumpai. Vertisol dapat bervariasi dari kelabu sampai coklat dan merah kecoklatan. Sifat khas yang dimiliki oleh Vertisol seperti mengembang dan mengerut dengan tekstur yang dominan klei membuat kegiatan masyarakat khususnya kegiatan pertanian di daerah Jeneponto kurang produktif. Tujuan dari penelitian ini adalah untuk mengetahui karakteristik fisik, kimia dan mineralogi Vertisol hitam dan merah. Lokasi penelitian didasarkan pada perbedaan lereng dan warna tanah. Tanah berwarna hitam diambil di Desa Bontomarannu dan Tonrokassi Timur, sedangkan tanah berwarna merah dan tumpang susun warna diambil di Desa Sarroanging. Hasil penelitian menunjukkan bahwa perbedaan karakteristik kimia yang begitu signifikan antara tanah berwarna hitam, merah dan tumpang susun warna adalah $CaCO_3$ dan kejenuhan basa. Umumnya kadar $CaCO_3$ tertinggi terdapat pada tanah berwarna hitam yang berkisar antara 8.63-19.37%, sedangkan pada tanah berwarna merah berkisar antara 3.64-9.43%. Untuk tumpang susun warna merah dan hitam berkisar antara 1.98-2.21%. Kejenuhan basa tertinggi juga terdapat pada tanah berwarna hitam yakni >100%, tanah berwarna merah berkisar antara 63-87% dan tumpang susun warna merah dan hitam berkisar antara 64-68%. Untuk Fe, Mn dan Al tertinggi dijumpai dengan ekstrak dithionit sitrat bikarbonat diikuti oleh oksalat dan pirofosfat. Mineral klei Montmorillonit terdapat pada semua profil yang diamati.

***Kata kunci**:* Jeneponto, vertisol hitam, vertisol merah, shrink-membengkak

INTRODUCTION

One of factors that interesting to be investigated from Vertisol, beside the management of soil fertility, is the color varians encountered. Vertisol can vary from gray to brown and brownish red. Agusman (2006) has conducted a research on color transition of Vertisol above the ground karst formations in Gunung Kidul, Yogyakarta. The results of these studies found the correlation between the black and red colors on the ground and the value of the cation exchange capacity and base saturation. The black color has a high of cation exchange capacity and a high base saturation, while the red color indicates a low cation exchange capacity and a low base saturation, it is also found the presence of mixed minerals termed montmorillonite-kaolinite.

Some experts suggested several opinion about the causes of the colordiversity of Vertisol soil. Van de Weg (1987) said the rock influence the color variation of Vertisol. The real black color aberration is formed in deposition beach, river and delta sediment in wet tropical areas, while gray to brown and brownish red is developed from the new alluvial material.

Research conducted by Kusumayudha (2000) about Vertisol in the source of rock karst of Wonosari, Yogyakarta have found that no difference about micro rocks between the red and black soil. It is different with the results of the geochemical composition measurement of limestone that observed by Mulyanto and Surono (2009) who stated that the rock with an iron relatively high performed the black color in soil, while the rocks containing relatively little iron would produce the red soils. Mulyanto and Surono (2009) also said the topographic shape influenced the formation of ground color classes. The wavy relief topography tended to form the red soil, while the flat topography might form the black soil.

Jeneponto area which has a dry climate, generally dominated by Vertisol with soil dominant clay texture and the appearance of the soil caracteristics that swelled when it wet and shrinked when it dry. Vertisol in this area was under-utilized as agricultural land although in chemical side the soil fertility has a good potential especially the eigh of base saturation and cation exchange capacity. Vertisol frequently encountered in this area was black vertisol, and red for e few cases. Due to these reason, the vertisol soil of Jeneponto was needed to be studied to know the development of the characteristics of Vertisol black and red in Jeneponto area.

MATERIALS AND METHODS

The study was conducted in Jeneponto, South Sulawesi Province. Sampling processes were taken in some places; Bangkala (1 profile), Tamalatea (1 profile) and Batang (2 profiles). The color of soil and topography were used to determine the point of observation area, *i.e.* 2 profiles of black Vertisol (on flat and sloping topography), 1 Vertisol profiles of red soil (on the sloping topography) and 1 Vertisol profile of overlaying red and black.

The study was divided into three stages: the first was observationof soil profile to investigate the soil morphology, rock material, landscape, drainage, landforms, the land use, the second was the laboratory analysis included the physical properties of soil, soil chemical properties, mineralogy of soil, and the third was data analysis. The study was conducted from February to August 2015.

Soil Analysis

The physical characteristic and chemical properties of soils were analysed on each horizon. Types and methods of analysis are presented in the Table 1.

RESULTS AND DISCUSSION

Climate

Based on the rainfall data of the last 10 years (2005-2014) which were obtained from Gantinga station, the research areas had rainfall distribution with rainfall rate ranged ± 1000-1600 mm per year and the rain intensity per month 100-300 mm. Based

Table 1. Soil properties and analysis methods.

No.	Soil Characteristic	Method/tools
Physics		
1	Texture (10 fraction)	Pipette
2	COLE	Comparison the weight oven dry soil on oven dry volume with the weight oven dry soil on 1/3 atm volume.
Chemical		
1	pH (H_2O dan KCl)	pH-meter
2	CEC	NH_4OAc 1N pH 7
3	Ca- dan Mg –dd	NH_4OAc 1N pH 7, AAS
4	K- dan Na –dd	NH_4OAc 1N pH 7, Flamephotometer
5	$CaCO_3$	Used HCl. Surplus HCl by titration with NaOH 0.1 N
6	Fractionation of Fe, Mn, Al	ammonium oxalate extracts 0.2 M pH 3.0, citrate dithionite bicarbonate and pyrophosphate extracts.

Table 2. Soil physical characteristics on each soil profile.

Profile	Depth (cm)	COLE	Sand				Silt			Clay	
			1000-500 microns	500-200 microns	200-100 microns	100-50 microns	50-20 microns	20-5 microns	5-2 microns	2-0.5 microns	<0.5 micror
NH1	0-22	0.69	0.05	0.16	0.14	0.12	9.92	6.77	12.85	10.52	59.48
	22-47	0.65	0.05	0.21	0.26	0.28	3.40	5.24	24.17	27.84	38.54
	47-72	0.61	0.19	0.69	1.13	1.02	11.48	6.31	16.29	6.30	56.60
	72-110	0.62	0.52	1.21	2.07	1.39	11.75	21.10	6.11	10.96	44.89
NH2	0-35	0.62	0.59	0.94	1.07	0.84	14.63	5.08	9.76	4.09	63.01
	35-75	0.40	2.34	10.95	8.59	4.65	56.95	2.85	0.88	0.32	12.46
NM	0-15	0.59	0.15	0.48	1.06	1.01	13.18	6.46	8.56	4.40	64.70
	15-25	0.50	0.14	1.28	3.58	2.65	21.41	7.40	0.17	16.68	46.69
	25-50	0.24	0.17	1.45	4.20	2.81	29.21	0.63	0.10	22.67	38.75
NMH	0-37	0.67	0.59	2.09	3.86	1.71	4.41	13.26	3.13	5.45	65.52
	37-60	0.44	5.54	10.28	6.55	2.86	45.84	7.54	3.63	5.48	12.28

*NH 1 and NH2 (black soil), *NM (red soil), *NMH (overlaying red and black soil)

on Oldeman classification system, the type of climate research areas were clasified as E3 group, which has a continued wet month less than 3 months and 4-6 months of dry months. In addition, the research area also has an air temperature rate ranged of 22-25^{o}C, the maximum temperature and the minimum temperature ranged of 25-27^{o}C and 21-22^{o}C respectively, the soil temperature was 26.7^{o}C.

Soil Physical characteristics

Physical characteristics of the land were based on the assessment of the physical properties of the soil in the field observations and laboratory analysis. The analysis results of physical properties are presented in Table 2.

Table 2 shows the texture of the soil in all the observed profiles were generally dominated by clay texture with clay containing > 50%, followed by silt and sand. Generally, fraction of clay for each profile tended to decrease depend on the depth of the horizon. The highest clay fraction found in black soil and overlaying colors. This texture affected total porosity in the soil. This was in accordance with Agusman (2006) who stated that the more smooth texture of the soil the more total porosity of the soil.

COLE value measurement was performed to measure process of shrink and swell that occured in the profile. Based on the Table, the value COLE for all profiles ranged from 0.24 to 0.69. The highest COLE value was at the black soil followed by red soil and the overlaying color. According to Hardjowigeno (2003) the value of COLE> 0.03 indicated the mineral of clay monmorillonit was found quite a lot in the soil.

Table 3. Soil chemical properties on each soil profile.

Profile	Depth (cm)	pH H_2O	pH KCl	$CaCO_3$ (%)	CEC (me/100g)	Base saturation (%)
NH1	0-22	7.0	5.8	13.20	74.4	>100
	22-47	7.1	6.9	13.40	74.3	>100
	47-72	7.2	6.8	13.80	71.2	>100
	72-110	7.4	7.0	15.76	68.4	>100
NH2	0-35	7.0	6.7	36.73	55.9	>100
	35-75	7.6	7.3	32.23	47.1	>100
NM	0-15	7.2	7.0	13.86	24.2	68.28
	15-25	7.2	6.9	9.25	17.3	89.31
	25-50	7.1	6.8	8.92	17.2	89.36
NMH	0-37	5.8	5.4	2.62	20.7	80.71
	37-60	6.6	5.5	3.88	19.1	83.74

*NH1 and NH2 (black soil), NM (red soil), NMH (overlaying red and black soil)

Table 4. Result of the chemical analysis with citrate dithionite bicarbonate, ammonium oxalate and phrophospate extracts.

Profile	Depth (cm)	Fe_d	Fe_o (%)	Fe_p	Mn_d	Mn_o (%)	Mn_p	Al_d	Al_o (%)	Al_p
NH1	0-22	1.48	0.14	0.06	0.06	0.02	0.003	0.58	0.30	0.28
	22-47	1.23	0.15	0.06	0.05	0.02	0.01	1.17	0.29	0.21
	47-72	1.07	0.09	0.07	0.05	0.02	0.01	1.11	0.26	0.26
	72-110	1.16	0.08	0.07	0.03	0.02	0.01	0.36	0.28	0.38
NH2	0-35	1.07	0.35	0.05	0.29	0.09	0.02	1.59	0.38	0.22
	35-75	0.20	0.03	0.03	0.02	0.004	0.01	0.22	0.03	0.23
NM	0-15	2.34	0.11	0.15	0.01	0.01	0.01	1.53	0.05	0.14
	15-25	1.44	0.08	0.08	0.01	0.01	0.01	0.53	0.07	0.05
	25-50	0.96	0.07	0.03	0.02	0.01	0.01	0.49	0.08	0.05
NMH	0-37	1.66	0.27	0.18	0.13	0.06	0.01	1.01	0.13	0.72
	37-60	1.70	0.23	0.20	0.12	0.04	0.01	0.07	0.08	2.19

*d (citrate dithionite bicarbonate (CDB), *o (oxalate), *p (phrophospate)

Soil Chemical characteristics

The analysis results of soil chemical properties are presented in Table 3 and Table 4. The content of $CaCO_3$ on a black ground was higher than on the red soil and the overlaying color. The black soil content of $CaCO_3$ ranged between 13.20% to 36.73%. Red soil ranged from 8.92% to 13.86% and the overlaying colors ranged from 2.62% to 3.88%. The significant difference of $CaCO_3$ between the black and the red soil and the overlaying color were related to the rock in the profile, which were the limestone was contained in the black soil and welded tuff was contained in the red soil and the overlaying red and black.

The soil pH in all profiles were acidity to neutral pH H_2O (5.8-7.6) and pH KCl (5.4-7.3). Soil profile of NH1, NH2 and NM have pH value by neutral either pH H_2O or pH KCl. But, in NMH profil which have pH of strongly acid to neutral (H_2O) and strongly acid (KCl). It was affected by cation, rock or the use of the land which caused the difference in the profile.

Vertically, CEC (cation exchange capacity) of soil for all profiles decreased with depth of the soil horizon. The amount of CEC in all profiles ranging between 17.2-74.4 me 100 g^{-1}. The highest CEC values was found in NH1 profile ranged between 68.4-74.4 me 100 g^{-1}, while the lowest CEC value was found in NMH profile overlaying color that ranged between 19.1-20.7 me 100 g^{-1}.

Base saturation in all profiles ranged from 40% to>100%. The highest base saturation was found in the black soil profile of NH1 and NH2 (> 100%), the lowest was found in the profile of overlaying red and black colors of NMH (80-83%). This is consistent with the soil CEC value that significantly different between black soil, red and the overlaying color. The high base saturation in the black soil was affected by limestone.

The results of Fe, Mn and Al measurement with citrate dithionite bicarbonate extract (CDB), oxalate and pyrophosphate showed the contents of Fe, Mn and Al was the highest on citrate dithionite bicarbonate extract (CDB) followed by oxalate and pyrophosphate extracts. According to Walker (1983) the amount of iron oxide liberated by extracting CDB (Fe_d) should be equal or greater than that liberated by extracting iron oxalate (Fe_o). The highest of Fe_d (0.96-2.34%) was in the red soil, Fe_o (0.03 to 0.35%)

Table 5 Results of XRD interpretation for mineral sand and clay in the soil profile

Profile	Sand fraction minerals (%)				Clay fraction minerals (%)				
	Calcite	Sanidin	Quartz	Magnetite	Illite	Montmorillonite	Halloysite	Goetite	Hematite
NH1	51	0	49	0	57	43	0	0	0
NH2	51	0	49	0	0	100	0	0	0
NM	33	32	34	0	0	44	56	0	0
NMH	0	25	25	50	17	12	15	25	31

Source: Tekmira Laboratory, 2015.

was in the black soil and Fe_p (0.18 to 0.20%) was in the soil overlaying red and black colors. The highest Mn either Mn_d, Mn_O or Mn_p was in the black soil that was Mnd (0.02 to 0.29%), Mn_O (0.004-0.09%) and Mn_p (0.003-0.02%). For the highest of Al_d and Al_o was also found in the black soil that was Al_d (0.22 to 1.59%), Al_o (0.03 to 0.38%) while the highest Al_p was in the range of 0.72-2.19% found in the soil of overlaying red and black colors. This indicated the red soil contained more crystalline iron oxide while the black soil contained a lot of amorphous iron oxide and manganese oxide either in the form of crystalline, amorphous or bonded to C-organic. For soil with overlaying color contained a lot of iron oxide and aluminum which were bonded with C-organic.

Soil Mineralogy

The results of the mineral analysis of sand fraction and clay are presented in Table 5. The represented horizon to be analyzed were horizon A and horizon B but only horizon A for the soil that does not have a horizon B. The analysis results of minerals showed the sand fraction was dominantly containing with easily weathered minerals (calcite and sanidin) and difficult weathered mineral (quartz) as well as additional mineral (magnetite). Easily weathered minerals that found in the soil indicated the presence of high nutrient reserves. It can be seen in profile of NH1 and NH2 which have the mineral calcite as the dominant mineral of sand fraction. Its different with NM profile which is dominant by quartz mineral and the NMH profile with magnetite mineral indicated that weathering more continuesly occured, resulting the nutrients of NM and NMH profiles were lower than NH1 and NH2 profile. These was in accordance with the opinion of Mulyanto (2008) who stated the soil that contained mineral quartz and opaque have a futher level of weathering with decreased nutrient compared to labradorite mineral and mafic minerals due to the quartz mineral which was more resistant to weathering but the mineral labradorite and mafic were susceptible to weathering.

Table 5 shows the dominant clay mineral of black soil is illite, in the NH1 profile and montmorillonite in NH2 profile. Unlike the red soil (NM), which was dominated by halloysite and overlaying color (NMH), was dominated by the Hematite. One identifier of Vertisols can be seen by the presence of montmorillonite minerals found in all soil profiles in both the black and the red soil as well as overlaying color.

Soil Genesis

Based on the Geological map of Jeneponto scale of 1: 180.000 derived from the overlay map RBI (Team Reppmit Bakosurtanal 1991) and Geology map of regional sheets Jeneponto showed the black soil profile (NH1 and NH2) were in Tonasa with formation of limestone. While the red soil profile (NM) and overlaying color (NMH) were in Mount Lompobattang with formation of conglomerate rocks, lava, breccia. Soil on NH1 and NH2 profile indicated growing of limestone by the soil itselfs. This was evident by the limestone that has been decaying into the parent material so the mineral calcite was primary mineral that dominant in the profile. Similarly, NM and NMH profiles were also growing from the rock underneath because the rock had rotted into the parent material. It also affects the soil properties that originate by the dissolution of the parent rock.

The Weathering level of the soils are at the stage Virile, the stage is characterized by the dominance of easily weathered minerals, clay content have started to increase and also occasionally found the difficult decaying component (Mohr and Van Baren 1960). It can be seen by the dominant texture of clay and the presence of easily weathered minerals such as calcite, sanidin and magnetite in the profile that are in large enough proportion and have hard minerals such as quartz.

The climate influences the soil formation. The rainfall in the area was classified as the dry area with rainfall 1000-1600 mm $year^{-1}$. It influenced the formation of Vertisol which expands in the wet condition and shrink in the dry condition, that affected by montmorillonite mineral and texture clay.

The vegetation affected soil characterictics in the research area. Soil properties such as soil clay content, soil structur, shrink and swell which were caused by the vegetations were limited to palm trees, teak which had dept roots, because the plants with a dept root were still able to cope the root damage due to the soil cracking during the dry season. Shallow rooted plants are usually only able to grow during the rainy season, but once the dry season the plant will die. Plants that often cultivated by local farmers are corn, green beans, and rice.

The soil topography in the research area is relatively flat, especially on the NH1and NH2 profiles. The Flat topograph influenced the behavior of ground water movement. Flat topography can reduce run off, so that the movement of ground water is likely to move vertically which will influence soil development. Unlike the NM and NMH profiles which have a slightly sloping topography. Although the obesrved profiles were still relatively flat but it was not far from the observation points that have a slope which could affect the leaching process. This condition is a factor that affects the leaching process in the soil.

Soil Classification

Soil Survey Staff (2014) was used as the classification system for this research. The preparation of soil classification started from the ordo level, sub ordo, great group, sub-group and family.

The soil profile was classified into ordo of Vertisol because it has a layer thickness of more than 25 cm, clay content of > 30%, and it has a montmorillonite mineral and slickenside. Soil moisture regime was classified as ustik because it had a long enough dry months of 4-6 months, so it was classified as subordo Usterts.

Usterts contained on the horizon or as a whole has a pH value more than 4.5, it has no horizon salik, gipsik and calcic in 100 cm from the soil surface. It was categorized as the great group of Haplusterts.

Haplusterts on NH 1 and NH2 profiles were not eligible to be classified into lithic, halic, sodic, petrocalcic, gypsic, calcic, aridic, leptic, entic and chromic, thus it was classified into subgroup Typic Haplusterts. While the NM and NMH profiles were it was classified into sub-groups of Chromic Haplusterts because it has a color value 4 with 3 chroma or more.

The soil Class of grain size which was dominated by smooth texture clay, clay mineral was montmorillonite, it also encountered a mixture of montmorillonite and halloysite with the regime of soil temperature was Isohipertermik, so that, the family category of NH1 and NH2 profile named Typic Haplusterts, smooth, montmorillonitik, isohipertermik, while the profile of NM and NMH named Chromic Haplusterts, smooth, mix (montmorillonitik and halloysite), isohipertermik.

CONCLUSIONS

Based on the research results, some conclusions about the characteristics and genesis of Vertisol black and red could be drawed as follow: The differences of physical characteristics between black and red Vertisol significantly could be seen by the color, while the significant differences in the chemical characteristics between black and red Vertisol was the contain of $CaCO_3$, cation exchange capacity, base saturation, Fe, Mn and Al either by citrate dithionite bicarbonate, ammonium oxalate or pyrophosphate extract. Soil for all profile were formed by rocks that presence below of the soil such as black Vertisol was formed by carbonate sediment, red Vertisol and overlaying color were formed by sediment. This could be seen from the rocks that have experienced weathering into the parent material either on the host rock carbonate sediment or host rock sediment. Factors that influence the formation of the profile were climate, vegetation, topography, mineralogy and others. Soil on NH1 and NH2 profiles were classified as Typic Haplustert, smooth, montmorillonitik, isohipertermik while soil in NM and NMH profiles were classified as Chromic Haplustert, smooth, mix (montmorillonitik and halloysite), isohipertermik.

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