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Clay Minerals and Iron Oxides of Selected Red and Yellow Soils in Northeast Plateau and Southeast Coast, Thailand

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ABSTRACT

A study on clay minerals and iron oxides was conducted on five selected red and yellow soils in the Northeast Plateau and the Southeast Coast Thailand, using x-ray diffraction analysis and differential thermal analysis methods. The results reveal that the red and yellow soils have kaolinite as the dominant clay mineral. Vermiculite, smectite and illite are also present in minor quantities in the soils. The iron oxide content of these soils varies according to their parent materials. The iron oxide minerals found include hematite, goethite and magnetite. The clay minerals and iron oxides in these soils account for their poor fertility status and care should be taken on soil system for fertilizer application. The soils belong to Ultisols and Oxisols and can be correlated well with established soil series in Thailand.

INTRODUCTION

Red and yellow soils are widely distributed in the tropics and in Thailand (Panichapong, *et al*, 1978; Sanchez, 1976). Most of these soils belong to Ultisols, Oxisols and Alfisols according to soil taxonomy (Kheoruenromne, 1982, 1983; Saifuk, 1983; Soil Survey Staff, 1975). Mineral components of these soils are not clearly different among soils horizons (Cady, 1967). They are usually deep, well drained and with the present of low activity silicate clay minerals particularly kaolinite (Alwis and Pluth, 1976). These soils are generally considered to have a low fertility status. However, some studies had revealed that in some environments these soils can have high cation exchange capacity and base saturation percentage (Buol, 1979; Siderius and Muchena, 1979). Intense weathering in these soils induces the formation of iron oxides (Suddhiprakarn, 1978; Theng, 1980). The iron compounds can form as amorphous material at first and subsequently they accumulate in soils as coatings along with silicate clays (McCaleb, 1967; Uehara, 1979). The amorphous form can be changed to iron oxide minerals such as goethite and hematite with time. The presence of oxides and hydroxides of iron can reduce the availability of phosphorus appreciably in these soils (Schwertmann and Taylor, 1977). Though kaolinite is always found as dominant silicate clay mineral species, smectite and illite can sometimes be found in minor quantities for red and yellow soils in Thailand (Panichapong *et al*, 1978; Soil survey Division, 1977).

There are several red and yellow soils in the Northeast Plateau and Southeast Coast of Thailand. The environments of soil formation of these two physiographic regions (Moormann

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and Rojanasoonthon, 1972) are quite different. The Northeast Plateau is in the tropical savanna climatic regime (Köppen, 1931). The soils in this region have been developed under dry evergreen forest type under ustic soils moisture regime[1] (Moncharoen, 1980a; Soil Survey Staff, 1975). These soils show a marked dry spell during summer (hot and dry season). On the other hand, the Southeast Coast in under tropical monsoon climate with a higher and more evenly distributed rainfall. Vegetation of this region is evergreen forest grading towards tropical rain forest type. The soils in this region generally have a longer moisture efficient period for plant growth. Thus they are under udic soil moisture regime[2].

Under the different types of environment, the red and yellow soils between these two regions should portray some difference in their clay mineralogy and iron oxides which control the soil system. It may be expected that, with current soil forming processes, soils under udic moisture regime should have more advanced development due to a more continuous condition of leaching and oxidation (Kheoruenromne and Suddhiprakarn, 1984). They should contain more inert minerals and with substantial amounts of iron and aluminum oxides (Moncharoen and Vijarnsorn, 1979; Eswaran and Sys, 1976). However, soils under ustic moisture regime on particular types of parent material can sometimes show this characteristic and they can pose more serious problems on management practices due to the dry spell condition with a lack of available moisture. In both environments, the soils are considered to have isohyperthermic temperature regime[3]. This paper intends to demonstrate the differences and similarities of the clay minerals and iron oxides of these soils which would be reflected in their chemical systems vital to management practices and fertilizer application.

MATERIALS AND METHODS

Five locations were selected as sample sites for detailed study of these soils. Three locations (R1, R2 and Y1) are in the Northeast Plateau and two others (R3 and Y2) are in the Southeast Coast. Their locations are shown in Figure 1. Pedon analysis was carried out in the field and soil sampling was based on

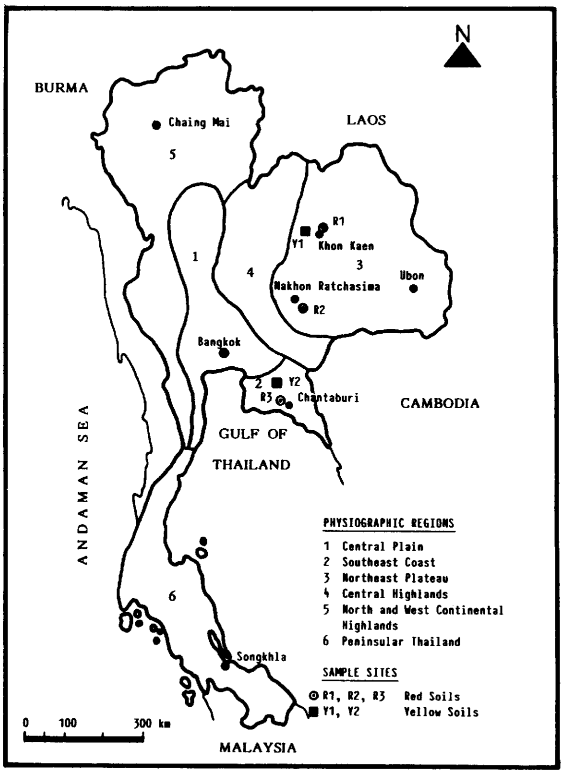

Figure 1 Location map of sample sites with physiographic regions (modified from Moormann and Rojanasoonthon, 1972).

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[1] The soil moisture control section is dry in some or all parts for 90 or more cumulative days in most years.

[2] In most years the soil moisture control section is not dry in any part for as long as 90 days (cumulative).

[3] The mean annual soil temperature is 22°C or higher and the difference between summer and mean winter temperature is < 5°C.

genetic horizons (Soil Survey Staff, 1974). Disturbed soil samples of approximatelly 2 kg were collected from each horizon. Laboratory analysis of soil includes:

1. Particle size analysis by pipette method (Kilmer and Alexander, 1949; Day, 1965; Soil Survey Staff, 1951, 1982).
2. Soil reaction (pH) in water and in 1N KCl using a ratio soil:water and soil:1N KCL of 1:1 (Soil Survey Staff, 1982).
3. Mineralogical analysis by x-ray diffraction and differential thermal analyses (Jackson, 1965).
4. Identification and quantity estimation of minerals in samples based on comparison with standard minerals (Barshad, 1965; Jackson, 1964, 1965; McKenzie, 1957; Whittig, 1965).
5. Separation of free iron oxides from silicate clay minerlas by dithionite citrate-bicarbonate extraction (Mehra and Jackson, 1960).

Quantity rating of clay mineral species present in the samples is based on the following scale: trace (< 5%), small (5 – 20%), moderate (20 – 40%), large (40 – 60%) and dominant (60%).

RESULTS

Results of this study can be presented in three different aspects. They include the general physical and chemical characteristics of the soils, silicate clay minerals of the soils and iron oxides in the soils.

General Physical and Chemical Characteristics of the Soils

The soils in this study varies in their parent materials and their geomorphic settings. R1 and Y1 have been developed from old alluvium terraces and their characteristics are quite typical for Ultisols of the Northeast Plateau. R2 and R3 are residual soils of basalt on a dissected lava flow plain but under different broad climatic regimes. R2 is in the tropical savanna climate environment but R3 is under the tropical monsoon climate. Y2 is a granite residual soil of the Southeast Coast. The characteristics of R2 and R3 are well within the limit of Oxisols in Thailand and Y2 is one of the Ultisols under udic soil moisture regime. Selected physical and chemical data of these soils are summarized in Table 1.

According to Table 1, R1, Y1 and Y2 show considerable amounts of sand in the profile and its percentage in the soils decreases with depth. The silt fraction of these soils has an irregular trend with depth and Y2 has the lowest amount of silt in the profile. The distribution of clay within the profiles however, shows an increasing trend with depth in these soils. The R2 and R3 have very high amounts of clay in the profile but the distribution of clay within the profile of these two soils is different. The R2 shown a marked increase of clay percentage in the upper part of subsoil and the percentage of clay has a generally stable trend with depth. The R3 has a quite interesting trend of clay distribution in the profile. Within the depth of 100 cm the clay show a decreasing trend but the marked accumulation of clay can be clearly observed in the lower part of the profile.

All of these soils are acidic. They also have small negative pH values indicating an oxide-coated layered silicate system (Sanchez, 1976; Uehara, 1979). The amount of free iron oxides is noticeably higher in R2 and R3 than the values in R1, Y1 and Y2. Among the red soils R1 has the lowest percentage of free iron oxides. The Y1 profile has the lowest values of iron oxides among these soils.

Silicate Clay Minerals of the Soils

Results obtained by x-ray diffraction analysis reveal that kaolinite is the dominant silicate clay mineral conforming with the typical situation of soils in the tropics. Vermiculite and illite in trace amounts can also be detected in some of these soils such as in R1, R2, Y1

Table 1 Summary on some chemical and physical characteristics of selected red and yellow soils in the Northeast Plateau (R1, R2 and Y1) and Southeast Coast (R3 and Y2), Thailand.

Site	Depth	Horizon	Color	% Soil separate			Textural	pH 1 : 1		% Free
	(cm)			Sand	Silt	Clay	class[1]	H_2O	1N KCl	Fe-oxide
R1	0-18	Ap	5 YR 4/4	75.6	17.9	6.5	SL	5.60	4.20	0.31
	18-33	AB	5 YR 4/6	75.3	17.7	7.0	SL	4.60	3.60	0.36
	33-45	Bt 1	2.5 YR 3/6	65.1	21.0	12.9	SL	4.60	3.50	0.53
	45-88	Bt 2	2.5 YR 4/6	68.6	14.4	17.0	SL	4.65	3.55	0.63
	88-180+	Bt 3	2.5 YR 4/6	63.5	17.0	19.5	SL	4.70	3.55	0.72
R2	0-16	A	2.5 YR 2.5/4	22.8	27.3	49.9	C	5.25	4.35	5.83
	16-52	Bt 1	2.5 YR 2.5/4	21.7	12.5	65.8	C	4.50	3.60	6.73
	52-95	Bt 2	2.5 YR 2.5/4	21.2	13.3	65.5	C	4.80	3.55	3.98
	95-157	Bt 3	2.5 YR 2.5/4	23.3	12.2	64.5	C	5.10	3.55	3.93
	157+	Bt 4	2.5 YR 2.5/4	24.0	18.8	67.2	C	4.95	3.50	3.51
R3	0-10	A	5 YR 3/3	22.0	25.6	52.4	C	5.00	4.65	13.86
	10-30	Bo 1	5 YR 3/4	23.3	19.4	57.3	C	5.10	4.00	12.71
	30-65	Bo 2	5 YR 3/4	21.9	33.5	44.6	C	4.85	3.80	12.71
	65-100	Bo 3	5 YR 3/4	30.1	30.5	39.4	CL	5.00	4.00	13.34
	100-180+	Bt	5 YR 3/4	7.8	23.7	68.5	C	5.10	4.25	15.68
Y1	0-28	Ap	10 YR 4/3	71.1	22.3	6.0	SL	4.95	3.85	0.17
	28-40	E	7.5 YR 4/4	74.5	17.5	8.0	SL	5.15	4.05	0.26
	40-77	Bt 1	5 YR 4.6	67.5	16.9	16.6	SL	5.00	3.85	0.48
	77-130	Bt 2	5 YR 4/6	59.4	25.5	15.1	SL	4.60	3.70	0.41
	130-180+	Bt 3	5 YR 4/6	65.0	21.5	13.5	SL	4.70	3.70	0.48
Y2	0-18	A	7 YR 3/2	71.1	10.9	18.0	SL	4.35	3.70	0.29
	18-30	Bt 1	10 YR 5/4	63.1	8.5	28.4	SCL	4.25	3.60	0.45
	30-70	Bt 2	10 YR 5/6	59.3	7.3	33.4	SCL	4.35	3.50	0.40
	70-115	Bt 3	10 YR 5/6	51.5	10.2	38.3	SC	4.55	3.55	0.40
	115-150	Bt 4	10 YR 5/6	46.5	13.1	40.4	SC	4.90	3.60	0.89
	150+	BC	10 YR 5/6	47.3	13.3	39.4	SC	4.75	3.55	1.46

[1] SL = Sandy loam, SCL = Sandy clay loam, SC = Sandy clay, C = Clay, CL = Clay loam.

and Y2. Traces of 14 A° group of clay minerals were found in most horizons of R1 but they were found only in the deeper horizons of Y1 and Y2. For R2 and R3, the presence of some x-ray amorphous materials was noted in all horizons. Quartz was also present in the clay fraction of R1 and Y1 but in small quantities. A summary on clay mineral species and other minerals after the free iron oxides have been extracted from the soil samples is shown in Table 2. The presence of kaolinite in the clay fraction is reflected well in the x-ray diffraction pattern of these soils. The position related to d-spacing and the shape of the peak indicating

Table 2 Mineral present in clay fraction of selected red and yellow soils in the Northeast Plateau (R1, R2 and Y1) and Southeast Coast (R3 and Y2) (after extraction of iron oxides). Kao = Kaolinite, Ver = Vermiculite, Ill = Illite, Sm = Smectite, Int = Interstratified (10 and 14 A°) clay minerals, Qtz = Quartz.

Site	Depth	Horizon	Mineral Species						
			Kao.	Ver.	Ill.	Sm.	Int.	Qzt.	Others
R1	0-18	Ap	xxxx	-	-	-	-	xx	trace of 14 A° clay mineral
	18-33	AB	xxxx	-	-	-	-	x	trace of 14 A° clay mineral
	33-45	Bt 1	xxxx	-	-	-	-	x	trace of 14 A° clay mineral
	45-88	Bt 2	xxxx	trace	-	-	-	x	-
	88-180+	Bt 3	xxxx	-	-	-	-	x	trace of 14 A° clay minerals
R2	0-16	A	xxxx	-	-	-	-	-	some x-ray amorphous materials
	16-52	Bt 1	xxxx	-	-	-	-	-	some x-ray amorphous materials
	52-95	Bt 2	xxxx	-	trace	-	-	-	some x-ray amorphous materials
	95-157	Bt 3	xxxx	-	trace	-	-	-	some x-ray amorphous materials
	157-180+	Bt 4	xxxx	-	trace	-	-	-	some x-ray amorphous materials
R3	0-10	A	xxx	-	-	-	-	-	x-ray amorphous materials
	10-30	Bo 1	xx	-	-	-	-	-	x-ray amorphous materials
	30-65	Bo 2	xxx	-	-	-	-	-	x-ray amorphous materials
	65-100	Bo 3	xxx	-	-	-	-	-	x-ray amorphous materials
	100-180+	Bt	xxx	-	-	-	-	-	x-ray amorphous materials
Y1	0-28	Ap	xxxx	trace	-	trace	-	xx	-
	28-40	E	xxxx	trace	-	-	-	x	-
	40-77	Bt 1	xxxx	trace	-	-	-	x	-
	77-130	Bt 2	xxxx	trace	-	-	-	x	-
	130-180+	Bt 3	xxxx	-	-	-	-	x	trace of 14 A° clay minerals
Y2	0-18	A	xxxx	-	trace	-	-	-	-
	18-30	Bt 1	xxxx	-	-	-	-	-	-
	30-70	Bt 2	xxxx	-	-	-	-	-	-
	70-115	Bt 3	xxxx	-	-	-	-	-	-
	115-150	Bt 4	xxxx	-	-	-	-	-	-
	150-180+	BC	xxxx	-	-	-	-	-	trace of 14 A° clay minerals

xxxx = dominant, xxx = large, xx = moderate, x = small.

kaolinite are well defined and can be confirmed by a systematic treatment (Jackson, 1965) as shown in Figure 2. The x-ray diffraction pattern also shows a quartz peak in R1 and Y1. A small amount of kaolinite was also found in the silt fraction of the deeper horizon (BC) of Y2. This indicates a strong weathering condition of feldspar in granite.

The results of x-ray diffraction analysis were confirmed by the differential thermal analysis (DTA). The pattern of kaolinite is also well defined for all soils after the free

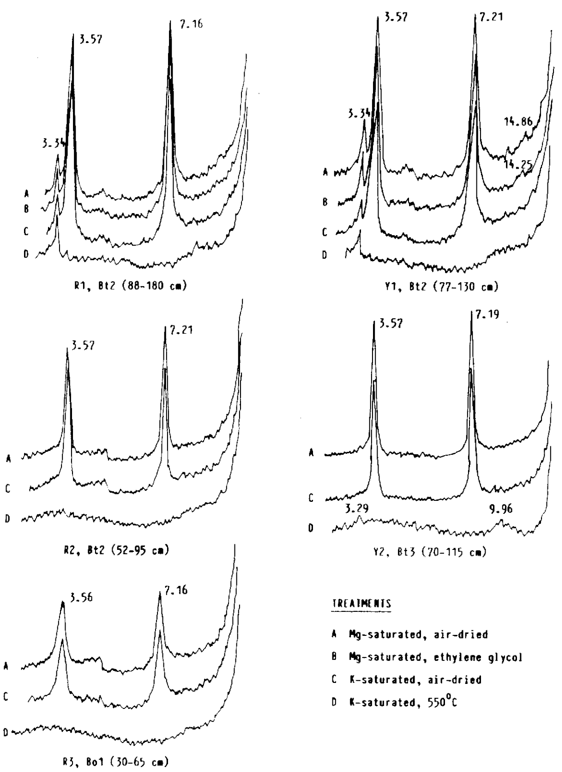

Figure 2 X-ray diffraction patterns (in Angstrom, A°) of clay fraction in the B horizons of selected red and yellow soils in the Northeast Plateau (R1, R2, Y1) and Southeast Coast (R3, Y2) (after extraction of iron oxides).

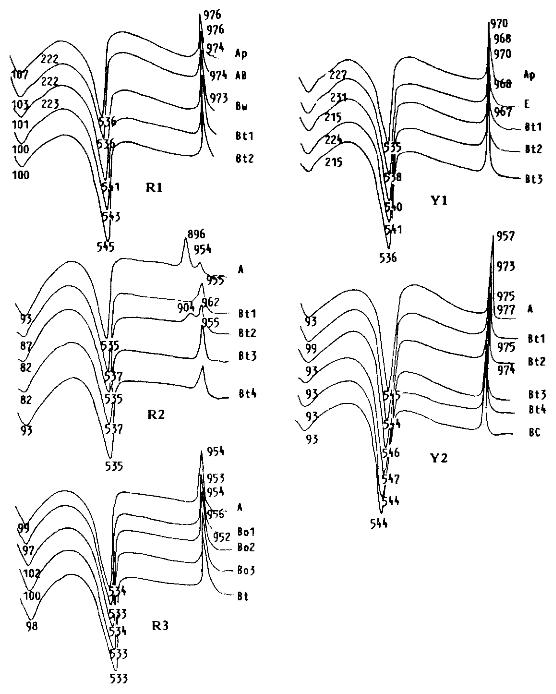

Figure 3 Differential thermal analysis (DTA) patterns (in °C) of clay fraction of selected red and yellow soils in the Northeast Plateau and Southeast Coast (after extraction of iron oxides).

iron oxides have been extracted from the samples. The differential thermal curves are shown in Figure 3. It should be noted here that R2 was analyzed without the extraction of iron oxide since hematite does not have a thermic property.

Iron Oxides in the Soils

Chemical analysis of these soils reveals that they differ in iron oxides content as shown in Table 1. The yellow soils (Y1 and Y2) generally have low values of iron oxides as expected. However, R1 also has low percentages of iron oxides in the profile though the soil color is quite red. The values of iron oxides content of these soils show a mild inverse trend with the sand percentage and direct relationship with clay content in sand enriched soils (R1, Y1, Y2). However, these relationships could not be found in R2 and R3.

The x-ray diffraction patterns of clay fraction, without the extraction of free iron oxide content of the soils nevertheless show peaks of hematite and goethite as illustrated in Figure 4. It was found that the clay fraction of R1 contains a small amount of goethite and hematite throughout the profile. In R2 only a small amount of hematite was observed. A small amount of goethite was found in the surface layer of R3 whereas at depth the clay fraction of this soils contains appreciable amounts of goethite and hematite. For the yellow soils, a very small amount of goethite was found in the clay fraction of Y1 particularly

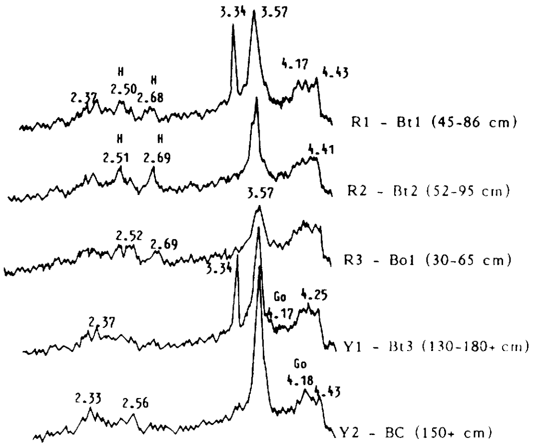

Figure 4 X—ray diffraction patterns (in A°) of clay fracion of soils without the extraction of iron oxides. (H = Heamatite, Go = Goethite).

in the deeper horizon (130 – 180 cm). A small amount of the same mineral also appears at a depth of 150 cm in Y2.

In the silt fraction, a substantial amount of hematite and a small amount of magnetite were found throughout the profile of R3. Traces of the same minerals were found in all horizons of R2, whereas no iron oxide mineral was found in R1 and the yellow soils. The marked difference in the presence of iron oxide minerals in these soils obviously indicates the difference in their parent materials since R2 and R3 have been developed from a basalt residuum.

DISCUSSION

From general characteristics of these soils it is clear that all of them are well developed, well drained and highly leached soils (Buol, *et al.*, 1980; Kheoruenromne and Suddhiprakarn, 1984). Their pH values are quite low and the difference between the pH values in water and potassium chloride is small. Therefore, they can be considered to belong to the oxide-coated layered silicate system. The clay minerals found by x-ray diffraction analysis and differential thermal anlaysis consist of kaolinite as the dominant species whereas vermiculite, smectite and illite can also be found in quite small amounts. The clay mineral aspect of these soils indicate very small net negative charges in natural condition and their charges can very according to pH (Herbillon, 1980; Sanchez, 1976).

The iron oxides content of these soils varies according to their nature of parent materials and soil forming environment. In sandy materials derived from clastic rocks such as R1 and Y1 or from coarse-grained acidic igneous rock such as Y2, the amounts of iron oxides in the soils are quite low comparing to R2 and R3 which developed on a residuum of basic igneous rock. The form of iron oxide minerals in these soils, however varies according to the moisture status of the soil environments. Goethite seems to favor the more moist condition since it was found as only a small amount in R1 but it was found more exclusively in the soils of udic moisture regime or in the deeper layer of soils. Hematite is a classic example for materials developed in an intense weathering condition since it was found in R2 and R3. These two soils have an assemblage of minerals that show oxic properties (Soil Survey Staff, 1975).

One of the most interesting feature of these soils is that the presence of iron oxide minerals in the silt fraction. This condition indicates a continuous environment for the oxidation and aging of iron compounds to form crystalline minerals. It also indicates the highly developed status of soils. The presence of oxic horizons and argillic horizons in these soils confirms the previous statement (Eswaran and Tavernier, 1980; Isbell, 1980).

As far as the data on mineralogy and iron oxides content are concerned, the amount of iron oxides does not reflect much on soil color in the red soils but it has a good bearing on the comparison between the red soils and the yellow soils. It may be logical enough to suggest that yellow soils should have a relatively lower iron oxide content. However, the form of iron oxide mineral may not be a conclusive criterion to judge by the color of the soils. In this paper, it shows that R3 has considerably more hematite than R2 but the R2 shows much more reddish color than the R3. Goethite, however, can be present in both red and yellow soils and it cannot be used as color indicator. From the data presented in this paper, the authors are inclined to believe that though the form of secondary iron oxide minerals may be generally important as indicator of red and yellow soils, in some soil environments moisture condition in more important for the determination of red and yellow colors in the soils.

With kaolinite as the major clay mineral species and a substantial amount of iron oxides in the soils, the fertility status of these soils is low but they are manageable. The relatively low cation exchange capacity nature of the minerals in soils (Barder and Rowell, 1972) should be considered seriously in fertilizer application practices.

These soils can be classified into Ultisols (R1, Y1 and Y2) and Oxisols (R2 and R3) and they are correlated well with the established soils series in Thailand (Moncharoen, 1980b; Saifuk, 1983). R1, R2 and R3 can be correlated with Yasothon series, Chok Chai series and Tha Mai series respectively. Y1 is Warin series and the characteristics of Y2 are quite close to that of Phang-nga series. The details on morphology, chemistry and potential use of these soils will be reported separately.

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