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# A comparative study of the mineralogy of rice soils of the Kedah and Kelantan Coastal Plains of Peninsular Malaysia

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**Abstract :** The Kedah Plain in the Northwest and the Kelantan Plain in the Northeast of Peninsular Malaysia represent two of the major rice growing areas of Malaysia. In both of these areas the rice is double-cropped using irrigation systems. However, the yields of rice in these two areas are quite different.

Mineralogical studies of the clay and silt fractions of the soils found in these two areas show that in the Kedah Plain the soils are rich in smectite minerals with minor amounts of kaolinite. In the Kelantan Plain however the mineralogy is dominated by kaolinite and illite. This difference in mineralogy and its resultant difference in fertility status of the soils are believed to be responsible for the differences in the yield of rice.

The paper discusses the factors which influence the origin and differences in mineralogy of these two areas. The presence and genesis of gypsum crystals in some soils of the Kedah Plain is also discussed.

**Abstrak:** Dataran Kedah di barat-laut dan Dataran Kelantan di timur-laut Malaysia mewakili dua kawasan terbesar penanaman padi di Malaysia. Padi ditanam dua musim dengan menggunakan sistem pengairan pada kedua-dua kawasan tersebut. Tetapi hasil padi kedua kawasan ini adalah berbeza.

Kajian mineral bahagian lempung dan kelodak tanah-tanah kedua kawasan ini menunjukkan bahawa tanah-tanah di Dataran Kedah kaya dengan mineral smektit dengan sedikit kaolinit. Tetapi kaolinit dan ilit adalah kaya di Dataran Kelantan. Perbezaan mineralogi ini dan sebabnya perbezaan status kesuburan adalah bertanggungjawab kepada perbezaan hasil padi.

Kertas kerja ini membincangkan faktor-faktor yang memainkan peranan kehadiran dan perbezaan mineralogi di kedua-dua kawasan ini. Kehadiran dan pembentukan hablur gipsum dalam beberapa tanah di Dataran Kedah juga dibincangkan.

## INTRODUCTION

The coastal alluvial plains of Peninsular Malaysia have been the main-stay of agriculture of this country. A major part of the coastal plains which have been opened up for agriculture is being utilized for the planting of rice, rubber, oil palm, coconut, coffee and cocoa. The distribution of the coastal plains in Peninsular Malaysia is shown in Fig. 1. Rice which is the traditional staple food

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of most of the peoples in Malaysia is often grown on these low-lying coastal plains. The two larger areas that have been used for double-cropped rice with irrigation are the Kedah-Perlis or Muda Plain and the Kelantan or Kemubu Plain. These areas are thus both agriculturally and economically important to the country. However, for a long time it has been known that yields of rice have been consistently higher (often almost double) in the Kedah-Perlis or Muda Plain compared to that in the Kelantan or Kemubu Plain (Paramananthan, 1978). This difference in the yield has been attributed to differences in the fertility status of the two areas resulting from their mineralogical differences.

The objective of this paper is to make a comparative study of the mineralogy of the Kedah and Kelantan coastal plains. The study also hopes to explain the presence of gypsum in some soils of the Muda Plain.

## PREVIOUS WORK

Detailed studies on soils mapped in Peninsular Malaysia have been carried out only in the last decade. However, many of these studies have concentrated on soils under plantation crops in particular those on the well drained upland areas. Comparatively padi soils have received considerably less attention. Soils surveys in the Muda and Kemubu areas were first initiated in 1955 by McWalter (1956). This work was initially carried out in the Muda area during the off or dry season when rice was not planted. The work was again continued in the 1957-1959 period and a tentative map produced. Work in the Muda Plain was revived in 1964 when the Muda Irrigation Project to double-crop the area with rice was proposed. A semi-detailed soil map was subsequently produced in 1972 (Soo, 1972a). Soil surveys in the Kada or Kelantan Plain were carried out in the periods 1955-1960 and 1968-1969 and a semi-detailed soil map produced in 1972 (Soo, 1972b). Most of these studies however only gave morphological and chemical properties of these soils.

Mineralogical studies of the soils in the two areas were first carried out by Kawaguchi and Kyuma (1969) as part of a broadscale study of the rice soils of Southeast Asia. Kawaguchi and Kyuma (1969) comparing the soils in the two areas suggested that the soils in the Muda area were juvenile and that they have a watertable close to the surface. They added the nature of the parent materials in these soils was clearly reflected in the differences in mineralogy - smectites on the west coast and kandites on the east coast. Allbrook (1975) also confirmed the smectitic nature of the soils of the Muda Plain. Similarly Diemont and Wijngaarden (1974) studying the tidal flats of the west coast attributed the heavy textures of these soils to the marine origin of these sediments resulting from the shallow Straits of Malacca after agitation of bottom muds by wave action. Soo (1972a) also reported the presence of some gypsum crystals and slickensides in soils of the Muda Plain. Further studies on the genesis were carried out by Goh (1979),

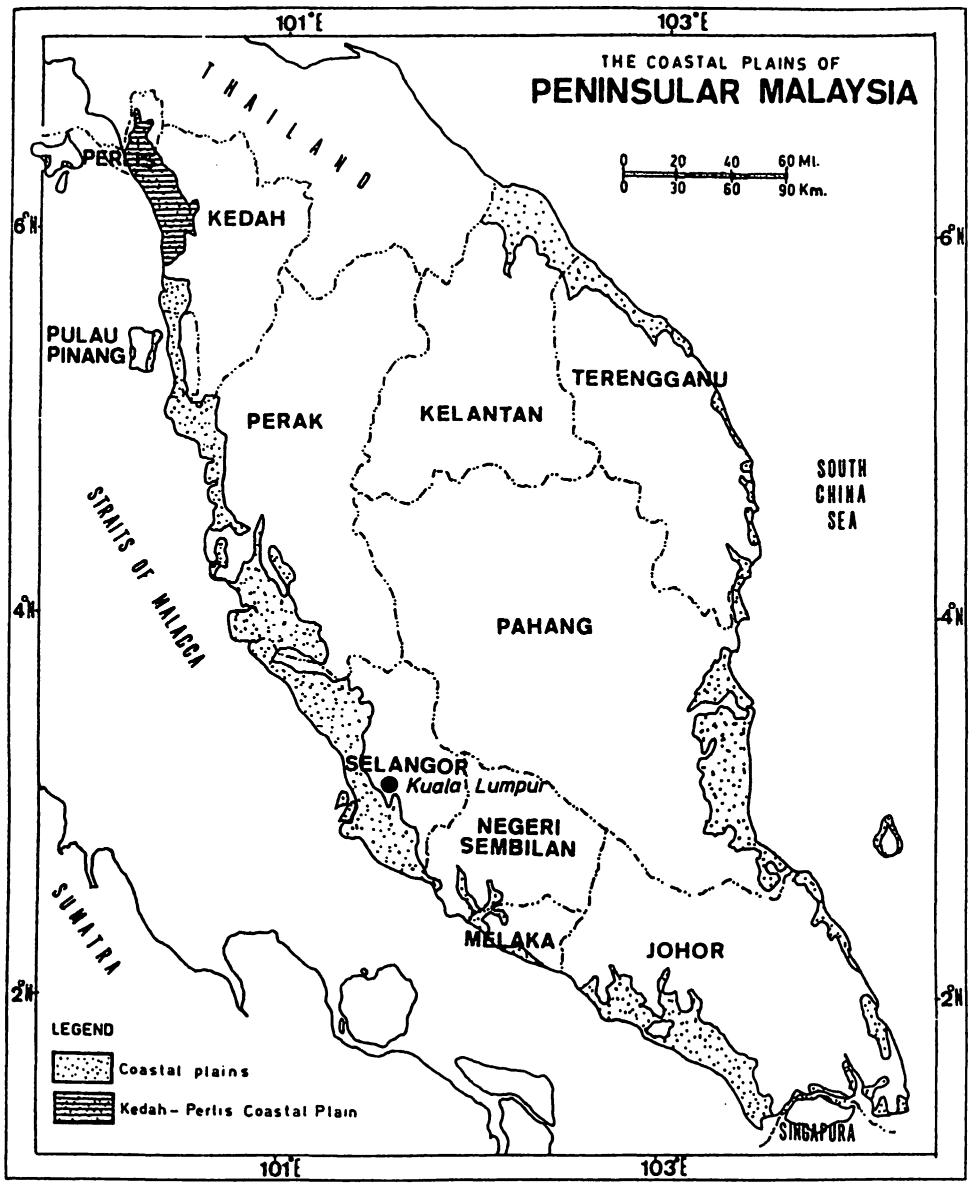


**Figure 1 :** Location of the Kedah-Perlis Coastal Plain of Peninsular Malaysia

Siew (1978) and Azmi (1982) for soils in the Muda Area and Abdul Halim (1980) for soils in the Kelantan Plain.

## MATERIALS AND METHOD

Soils pits were dug in both the Muda and Kemubu Plains on the different soils mapped in these two areas. The soils were selected in accordance with the cross-section of the soils in the Muda Plain proposed by Paramananthan (unpublished cross-section of soils of the Muda Plain, Department of Agriculture, 1981) and the cross section of the Recent Terrace Alluvium (Paramananthan, 1984). The soils were described and sampled for both routine chemical and mineralogical analyses.

For the mineralogical analyses, 15 g of the fine earth fraction (< 2 mm) was heated in about 200 ml of 30% hydrogen peroxide in a one-litre beaker to destroy organic matter and manganese oxides. The sample was then transferred to a plastic beaker and 25 ml of 2% sodium carbonate was added for effective dispersion. The beaker was topped with distilled water and stirred thoroughly. After 8 hours, the top 10 cm of the soil suspension containing particles less than 2 microns, was siphoned off and 10 ml of 2% HCl added to flocculate the clay. The clay suspension was then centrifuged at 1500 rpm and washed with ethyl alcohol to remove free chlorides. The chloride-free clay was dried in an oven at 60°C and stored.

## X-RAY DIFFRACTION ANALYSIS (XRD)

The X-ray analyses were carried out on oriented samples of clay. Clay suspensions in water were deposited on glass slides using a pipette and allowed to dry in air. A preliminary investigation by XRD was run on the untreated samples. The sample was then divided into two portions for saturation with K and Mg ions respectively. X-ray diffraction analyses was then carried out. Where necessary for characterisation of the minerals, heat treatment of the K-saturated samples were carried out before further XRD was run. The Mg-saturated samples were also saturated with glycol where necessary.

The X-ray diffraction analysis was carried out using a Phillips X-ray diffractometer (PW 1050/25) with $CuK_\alpha$ radiation and a time constant of one second. The various mineral species were identified according to their basal spacings as reported by Brown, 1961; Jackson, 1964; Grim, 1971; and De Coninck, 1978.

## RESULTS AND DISCUSSION

### Geomorphological setting

The Kedah-Perlis coastal plain is one of very low relief except in the inland area were it grades into the hills. The elevation is about 2 m and gradually rises to 5 m. Three major landforms can be recognized namely the coastal plain, the backswamp and the low river terraces. The plain is cut by three major meandering rivers. In the north and northeast a number of isolated limestone hills rise up from the plain. The plain represents the surficial deposits of unconsolidated Quaternary sediments that were deposited during the late Pleistocene and Holocene due to a slight drop in relative sea level (Stauffer, 1973). The thickness of these sediments range from 18 to 22 m near the coast to 15-18 m inland. However in some areas the sediments as deep as 150 m have been reported (Alexander, 1962).

The Kelantan or Kemubu Plain is an emergent land surface, composed of unconsolidated Quaternary marine and fluviatile alluvium, underlain by bedrock of granite and sedimentary rocks (Hoong and Kiat, 1975). The unconsolidated sediments overlying these rocks appear to have a wedge structure, being thinner inland and thickening seawards where maximum thickness is about 180 m (Stauffer, 1973; Pfeiffer and Shin, 1974). These sediments are complex and consist of interstratified and intercalated deposits with marine and non-marine strata which range from sand to clay. The intermixing of marine and non-marine sediments developed as a result of several major fluctuations (+70 m to -50 m ) in sea-levels during the Quaternary (Tjia, 1973). Overlying these deposits are a sequence of marine and non-marine sediments appearing in fairly ordered lateral succession. Along the coast is a series of beach ridges which not only limit the influence of the sea but together with the silting of the low lying areas they cause a slowing down of streams draining the plain thus promoting the formation of riverine alluvium through the process of aggradation.

### Morphology of the soils

Fifteen soils on a variety of parent materials have been identified in the Muda Plain while ten soil types have been identified in the Kemubu Area. All these soils have been cultivated to double cropping of wetland rich with irrigation. In the Muda Area the parent materials of the soils range from marine, marine estuarine , brackish water and finally to riverine and colluvial materials further inland. The main morphological properties of these soils are given in Table 1. From Table 1, it can be seen that the soils in the Muda Plain are developed over three main types of parent materials viz marine/estuarine deposits, brackish water deposits and riverine/colluvial deposits. The morphological properties such as the matrix colour, mottling, and other features such as slickensides are related to the nature of the parent materials.

Ten different soil types have been identified on the fluvial deposits of the Kemubu Plain (Soo, 1972b). These soils form a geomorphic and drainage sequence of the levee and backswamp type of the Kelantan River (Paramananthan, 1984). The criteria used to separate these soils were geomorphic position, drainage class, texture, colour and the presence of manganese concretions. The main morphological properties of the soils of the Kemubu Plain are given in Table 2. From this table it can be seen that the soils form a drainage sequence from somewhat excessively drained soils on the levee to very poorly drained soils in the backswamps. This difference in drainage class is expressed by their colour (brownish yellow to gray). In general textures are also heavier when moving from the levee soils to the backswamp. The larger proportion of sand, lower water-tables and the presence of manganese specks in these soils make them quite different from those of the Muda Plain.

## Physico-chemical characteristics

The physico-chemical properties of subsoils of the Muda and Kemubu Plains are summarised in Table 3 and 4 respectively. The clay content of soils developed over the marine, estuarine, brackish water deposits is over 50% but gradually decreases in the soils over the riverine deposits. In the Kemubu Plain the clay content increases with the distance from the levee. The soils over the marine clays have an almost neutral reaction while most of the other soils range in pH between 4.0-5.0. Soils developed on brackish water deposits such as the Guar and Telok Series are acid sulphate soils and have a pH around 3.0 to 4.0. Free iron contents range between 1 - 5% in most soils in both areas. The cation exchange capacity which is dependant on the mineralogy is distinctly higher in the Muda area especially on soils developed over marine, estuarine and brackish water deposits being over 20 meq/100 g soil. In the Kemubu area the values are less than 10 meq/100 g soil reflecting their lower fertility status. In the soils of the Muda Plain particularly in soils over the marine sediments calcium and magnesium dominate the exchange complex. In the Kemubu soils the exchangeable cations are low. This difference in the fertility status is also reflected in the base saturation.

## Mineralogy

The mineralogy of thirteen of the fifteen soils studied in the Muda Plain have very similar mineralogies. Only the Hutan and Sembrin Series developed over riverine and colluvial materials is somewhat different. The clay fraction of most of the soils of the Muda Plain are dominated by mica, smectites and kaolinite while the silt fractions are dominated by quartz, micas, and feldspars. The Hutan and Sembrin Series are however dominated by kaolinite in their clay fractions. Minor amounts of geothite and lepidocrocite are also often present.

**Table 1**: Main morphological properties of soils of the Muda Plain

| SOIL SERIES | PARENT MATERIAL | HORIZONATION | DEPTH TO BLUISH MARINE CLAY (cm) | COLOUR OF B HORIZON (50 cm) | COLOUR OF DOMINANT MOTTLE | OTHER CHARACTERISTICS |
|---|---|---|---|---|---|---|
| KUALA KEDAH | Marine | A/C | <25 | Greenish gray | – | High 'n' value |
| TEBENGAU | Marine | A/BC/C | <25 | Greenish gray | – | Low 'n' value |
| SEDAKA | Marine | A/B/C | 50-100 | Light gray/Olive gray | Olive gray/Olive yellow | Slickenside |
| ROTAN | Marine | A/B/C | 50-100 | Gray/light gray | Red | Slickenside |
| KANGKONG | Marine | A/B/C | >100 | Light olive gray | Reddish yellow/Olive | Slickenside |
| KUNDOR | Marine | A/B/C | >100 | Gray/Grayish brown | strong brown | Olive deposits at depth |
| CHENGAI | Mixed marine/Estuarine | A/B/C | >100 | Light olive gray/Gray | Olive yellow/Red | Slickensides/Gypsum |
| KUALA PERLIS | Brackish water | A/B/C | 50-100 | Gray/Light gray | Yellow (Jarosite) | Peaty surface |
| GUAR | Brackish water | A/B/C | 50-100 | Grayish brown/Gray | Yellow (Jarosite) | Sand pockets/Organic surface |
| TELOK | Brackish water | A/B/C | >100 | Gray/Light gray | Yellow (Jarosite > 50 cm) | – |
| KANGAR | Riverine over marine | A/B/C | >100 | Gray | Red | Slickensides/Gypsum Red mottles hardening |
| TUALANG | Riverine over marine | A/B/C | >100 | Gray/Light gray | Brownish yellow/ | Red mottles hardening Red |
| IDRIS | Riverine over marine | A/Bt/C | >100 | Gray/Light gray | Red/Brownish yellow | Red mottles hardening |
| HUTAN | Riverine/Colluvial | A/Bt/C | >100 | Light gray | Yellow brown/Red | Loamy surface texture Red mottles hardening |
| SEMBRIN | Riverine/Colluvial | A/Bt/C | >100 | Brownish yellow | Yellowish red, Gley spots | Mn specks |

**Table 2 :** Main morphological properties of soils of the Kemubu Plain

| SOIL SERIES | POSITION IN THE LANDSCAPE | HORIZONATION | COLOUR OF B HORIZON (50 cm) | COLOUR OF DOMINANT MOTTLE (depth) | DRAINAGE CLASS | OTHER CHARACTERISTICS | TEXTURE |
|---|---|---|---|---|---|---|---|
| TELEMONG | Levee | A/C | Brownish yellow | – | Somewhat excessive | Lithologic discontinuities, mica flakes | Sandy loam |
| TOK YONG | Edge of levee | A/Bt/C | Yellowish brown | Yellowish red (>75 cm) | Well | Mn specks, mica flakes | Fine sandyclay |
| CHEMPAKA | Upper sub-terrace | A/Bt/C | Yellowish brown | Yellowish red (<75 cm) | Moderately well | Mn specks, fine mica flakes | Fine sandy clay |
| LUNDANG | Transition uppe to middle sub-terrace | A/Bt/C | Yellow | Yellowish red/light gray (< 75 cm) | Moderately well | Mn concretions | Fine sandy clay |
| LATING | Middle sub-terrace | A/Bt/C | Light gray | Red | Imperfect | Sand pockets, soft iron-concretions | Fine sandy clay |
| TEPUS | Lower sub-terrace | A/Bt/C | Brownish yellow/light gray | Yellowish red/Red | Somewhat poor | – | Fine sandy clay to clay |
| JABIL | Lower sub-terrace | A/Bt/C | Light gray | Red | Poor | – | Clay |
| BINJAI | Backswamp | A/Bw/C | Light gray to white | Olive | Very poor | – | |
| LUBOK SENDONG | Backswamp | A/Bw/C | Light gray to white | – | Very poor | – | Clay |
| LUBOK ITEK | Backswamp | A/C | Light gray to white | – | Very poor | Organic soil below 50 cm | Clay |

**Table 3**: Physico-chemical properties of subsoils of the Muda Plain

| SOIL SERIES | % | | % | | pH $H_2O$ | 1N -KCl $Al^{3+}$ | ELECT COND. mmhos | % $Fe_2O_3$ | Soluble P ppm | CEC $NH_4OAC$ meq/ 100 g soil | EXCHANGEABLE CATIONS | | | | BASE SAT. % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CLAY | SILT | C | N | | | | | | | Ca | Mg | Na | K | |
| Kuala Kedah | 65 | 28 | 0.4 | 0.11 | 7.2 | 0 | 1.1 | 2.4 | 18 | 23 | 5.4 | 9.4 | 10.0 | 2.1 | 100 |
| Tebengau | 64 | 29 | 0.4 | 0.09 | 6.9 | 0 | 0.6 | 3.16 | 22 | 26 | 7.0 | 18.9 | 4.3 | 1.1 | 100 |
| Sedaka | 71 | 26 | 0.2 | 0.05 | 7.0 | n.d | 0.6 | 1.75 | 21 | 35 | 8.2 | 23.0 | 3.4 | 1.0 | 100 |
| Rotan | 65 | 27 | 0.3 | 0.06 | 7.1 | n.d | n.d | 3.83 | 27 | 26 | 9.8 | 21.0 | 1.9 | 0.8 | 100 |
| Kangkong | 71 | 27 | 0.2 | 0.06 | 6.4 | n.d | 0.5 | 1.2 | 8 | 25 | 8.7 | 0.5 | 2.0 | 0.8 | 100 |
| Kundor | 61 | 29 | 0.8 | 0.12 | 4.0 | 2.4 | 0.3 | 4.8 | 5 | 23 | 4.5 | 9.4 | 1.1 | 0.3 | 68 |
| Chengai | 62 | 27 | 0.3 | 0.05 | 3.6 | 2.2 | 0.5 | 7.4 | 2 | 28 | 9.8 | 15.0 | 1.3 | 0.4 | 95 |
| Kuala Perlis | 66 | 27 | 0.6 | 0.12 | 6.9 | n.d | 0.3 | 2.2 | 5 | 25 | 6.8 | 3.6 | 2.7 | 0.4 | 5 |
| Guar | 59 | 29 | 1.0 | 0.10 | 3.8 | 8.0 | 0.2 | 1.2 | 4 | 22 | 2.4 | 4.5 | 0.2 | 0.4 | 35 |
| Telok | 54 | 25 | 0.5 | 0.06 | 3.5 | 8.5 | 0.2 | 1.9 | 2 | 6 | 1.8 | 3.2 | 0.3 | 0.4 | 31 |
| Kangar | 68 | 16 | 0.4 | 0.09 | 4.9 | 5.2 | 0.2 | 8.2 | 1 | 23 | 15.0 | 1.8 | 0.5 | 0.1 | 76 |
| Tualang | 50 | 34 | 0.4 | 0.08 | 4.0 | 11.0 | 0.1 | 8.4 | 1 | 16 | 0.6 | 0.9 | 0.2 | 0.2 | 12 |
| Idris | 58 | 26 | 0.2 | 0.06 | 3.8 | 11.7 | 0.1 | 9.3 | 0 | 19 | 0.4 | 2.0 | 0.2 | 0.2 | 14 |
| Hutan | 44 | 31 | 0.2 | 0.05 | 4.7 | 3.6 | n.d | 2.8 | 3 | 7 | 0.4 | 0.2 | 0.1 | 0.2 | 11 |
| Sembrin | 45 | 34 | 0.2 | 0.06 | 6.4 | 3.7 | n.d | 3.7 | 2 | 12 | 8.5 | 2.3 | 0.1 | 0.1 | 92 |

**Table 4:** Physico-chemical properties of subsoils of the Kemubu Plain

| SOIL SERIES | % | | % | | pH $H_2O$ | 1N -KCl $Al^{3+}$ | Mn (OXALATE) ppm | % $Fe_2O_3$ | CEC $NH_4OAC$ meq/ 100 g soil | EXCHANGEABLE CATIONS | | | | BASE SAT. % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CLAY | SILT | C | N | | | | | | Ca | Mg | Na | K | |
| Telemong | 15 | 7 | 0.33 | 0.02 | 4.7 | n.d. | n.d. | n.d | 3 | 0.1 | 0.4 | tr | 0.3 | 26 |
| Tok Yong | 26 | 10 | 0.44 | 0.06 | 5.0 | 1.7 | 500 | 2.1 | 4 | 0.3 | 0.3 | 0.1 | 0.1 | 20 |
| Chempaka | 39 | 20 | 0.39 | 0.05 | 4.7 | 2.2 | 500 | 3.3 | 5 | 0.1 | 0.3 | 0.1 | 0.1 | 10 |
| Lundang | 42 | 35 | 0.28 | 0.06 | 5.7 | tr | n.d. | 4.4 | 10 | 5.8 | 3.4 | 0.1 | 0.1 | 96 |
| Lating | 46 | 27 | 0.32 | 0.06 | 5.3 | 1.5 | 83 | 4.6 | 6 | 0.2 | 0.2 | tr | 0.1 | 10 |
| Tepus | 58 | 38 | 0.46 | 0.07 | 5.1 | 3.2 | tr | 3.5 | 6 | 0.3 | 0.3 | tr | 0.1 | 12 |
| Jabil | 64 | 35 | 0.30 | 0.06 | 5.0 | 4.6 | tr | 1.5 | 7 | 0.4 | 0.3 | 0.1 | 0.1 | 11 |
| Binjai | 55 | 41 | 0.28 | 0.05 | 4.7 | 4.7 | tr | 0.3 | 7 | 0.7 | 0.4 | 0.1 | 0.1 | 17 |
| Lubok Sendong | | | | | | | Not sampled for analysis | | | | | | | |
| Lubok Itek | 87 | 8 | 0.39 | 0.06 | 4.9 | n.d. | n.d. | n.d | 9 | 1.2 | 1.5 | 0.2 | 0.1 | 34 |

Soils of the Kemubu Plain are even more uniform in their mineralogy. The clay fraction is dominated by kaolinite and mica with minor amounts of quartz and gibbsite. The silt fraction has a similar mineralogy of kaolinite, mica and quartz.

Gypsum crystals have been described in the field in the Kangar and Chengai Series. These occur as fine crystals of sand size but are probably dissolved in the sample preparation. The presence of gypsum in these soils is unique considering its solubility and the heavy rainfall in Malaysia. Gypsum is mainly found in soils of the arid regions. The better drained soils of the Kemubu Plain such as the Tok Yong, Chempaka and Lundang have manganese specks or nodules. The genesis of these is discussed below.

The qualitative evaluation of the clay fractions of soils of the Muda Plain shows that the mineralogy of the marine, estuarine and brackish water deposits is smectitic while those of the riverine/colluvial deposits are more kaolinitic. This change in the mineralogy is clearly reflected in the change in the cation exchange capacity from over 20 meq to less than 10. The high cation exchange capacity of more than 20 meq suggests a mixed mineralogy. The relatively high amount of smectitic minerals are probably formed both through neosynthesis and through the transformation of mica. Most tropical soils are dominated by kaolinite and weathering under the high ambient temperatures and rainfall is intense breaking down of primary minerals to kaolinite and the removal of calcium and magnesium by leaching. In the Muda area, however, the high water tables both natural and irrigation for double-cropping results in the retardation of the weathering and leaching processes. Smectite can be synthesized in a moist environment containing high amounts of Ca and Mg (Barshad, 1964; De Coninck, 1978).

The presence of gypsum in the estuarine or mixed riverine/marine deposits is possibly due to the reaction between calcium ions in the groundwaters originating from the limestone hills and the sulphate ion present in the marine deposits. The sulphate ion could also originate from the hydrolysis and oxidation of pyrite found in these marine sediments viz.

$$FeS_2 + 3H_2O \longrightarrow Fe(OH)_3 + S_2 + 3H^+$$
$$S_2 + 8H_2O \longrightarrow 2SO_4^{-2} + 16H^+$$

In the absence of the calcium ion to react with the $SO_4$ ion to form gypsum, an acid sulphate soil such as the Guar, Telok and Guar can develop with the formation of yellow jarosite mottles in these soils viz.

$$FeS_2 + 3\tfrac{3}{4}O_2 + 2\tfrac{1}{2}H_2O + \tfrac{1}{3}K^+ \longrightarrow \tfrac{1}{3}KFe_3(SO_4)_2(OH)_6 + 1\tfrac{1}{3}SO_4^{-2} + 3H^+$$

The mineralogy of all the soils of the Kemubu Plain are identical in spite of their differences in drainage class. Their uniform kaolinitic mineralogy is reflected in their low (< 10 meq) cation exchange capacity. Another important difference in these soils when compared to those of the Muda Plain is the presence of gibbsite. In sedentary or *in situ* soils the presence of gibbsite is an indication of an advanced stage of weathering (Tarvenier and Eswaran, 1972; Paramananthan, 1977). The presence of gibbsite in these alluvial soils cannot be attributed to weathering. The gibbsite is probably inherited with the deposition. This hypothesis is further supported by the dominance of kaolinite even in the poorly drained soils. Thus the origin of these alluvial deposits is probably from the preweathered soils in the hinterlands where the mineralogy is kaolinitic.

A distinctive feature of soils of the Kemubu Plain is the presence of both iron and manganese mottles and concretions. Mottlings and nodule formation involve the processes of dissolution and location of iron and/or manganese. Van Wambeke (1967) attributed this to a specific condition of wetting and drying under high temperature. The Kelantan Plain appears to satisfy this specific climate. Temperatures are high (> 25°C) and the wet months occur from November to December (570-680 mm) while the dry months are from February to April (64-96 mm). During the wet months soils under paddy cultivation are wet favouring the dissolution of the iron and manganese. These then migrate down the profile from the more reduced surface horizon to the less reduced subsoil. As the soils dry out resulting in the concentration and precipitation of iron and manganese as mottles which eventually form nodules. It is to be noted that the poorly drained soils have a high watertable and hence do not encourage the formation of mottles and nodules unlike the better drained soils nearer the levee.

**Table 5:** Mineralogy of the soils of the Muda Plain

| SOIL SERIES | MINERALOGY | |
|---|---|---|
| | Clay Fraction | Silt Fraction |
| Kuala Kedah | M, S, K, q | Q, M, F, K, li |
| Tebengau | M, S, K, q | Q, M, F, K, li |
| Sedaka | M, S, K, q | Q, M, K, F, amphibole |
| Rotan | M, S, K, li | Q, M, K, F |
| Kangkong | M, S, k | Q, M, K, F |
| Kundo | M, S, K | Q, M, K, F, amphibole |
| Chengai | M, S, K go | Q, M, K, F |
| Kuala Perlis | M, S, K | Q, M, K ch, f |
| Gua | M, S, K | Q, M, k, F, anatase |
| Telok | M, S, K | Q, M, K, F, anatase |
| Kangar | M, S, K | Q, M, F, K |
| Tualang | M, S, K go, li | Q, M, K |
| Idris | M, S, K, q | Q, M, K |
| Hutan | K go, li q, m, s | Q, M, K |
| Sembrin | K, M, q, s | Q, M, f, k |

**Key:**

M = Mica
S = Smectite
K = Kaolinite
Q = Quartz
F = Feldspar
Go = Goethite
Gi = Gibbsite
Li = Lepidocrocite
C = Chlorite

Capitals - dominant
lower case - traces

**Table 6:** Mineralogy of the soils of the Kemubu Plain

| SOIL SERIES | MINERALOGY | |
|---|---|---|
| | Clay Fraction | Silt Fraction |
| Tok Yong | K, M, q, gi | K, M, Q |
| Chempaka | K, M, q, gi | K, M, Q |
| Lating | K, M, q, gi, go | K, M, Q |
| Tepus | K, M, q, gi | K, M, Q |
| Jabil | K, M, q, gi, li | K, M, Q |
| Binjai | K, M, q, gi | K, M, Q |

Key: K = Kaolinite
M = Mica
Q = Quartz
Gi = Gibbsite
Li = Lepidocrocite
Go = Goethite

Capital = dominant
lower case = traces

## RICE PRODUCTIVITY

The differences in moisture regime, texture and mineralogy of the soils of the Kemubu and Muda Plains can be expected to strongly influence the rice yields in these areas. However in making such yields comparisons one must bear in mind that different varieties of rice may perform differently in different environments. Many agronomic trials have been carried out in the Muda area and the results published. However less work on the Kemubu area has been published. Table 7 gives some yield data of some trials carried out by MARDI (Chen, *et al.*, 1980). From this table, it is evident that soils on the east coast of Peninsular Malaysia such as those on riverine soils of the Kemubu and Besut areas have yields in the range of 1.4-4.2 tons/ha while those areas on the marine clays of the west coast such as the Muda and Tanjong Karang 2.8-6.0 tons/ha. The yields on the riverine soils of the Kemubu are similar to those of area in Negeri Sembilan and Malacca where rice is also grown in minor valleys of riverine soils. The lower water tables, lower fertility status of these soils also means additional water requirement and fertilizer coats to produce the yield obtained. Thus the cost of production of these riverine soils is much higher. It is therefore not surprising that many farmers on these soils belong to the low income group. It is perhaps time to consider seriously whether an alternative crop such as oil palm or cocoa is better suited in these areas from the point of view of the farmer.

**Table 7 :** Yield data obtained from Project Development Trials

| Varieties | Locations | Seberang Perai | Muda | Tg Karang/ S. Bernam | Parit/ Krian | Kemubu | Besut/ Trengganu | Negeri Sembilan | Malacca |
|---|---|---|---|---|---|---|---|---|---|
| Setanjung (MRI) | kg/ha | 3524-5206 | 4258-5550 | 5099-5814 | 2253-6668 | – | – | 3167-6359 | 1487-6794 |
| | gtg/ac | 562-830 | 679-925 | 813-926 | 359-1063 | | | 505-1019 | 237-1083 |
| Sekencang (MR7) | kg/ha | 2452-3223 | 3356-5512 | 2872-6039 | 1543-4390 | 1411-4283 | 2459-4848 | 2114-4792 | |
| | gtg/ac | 391-514 | 537-882 | 458-962 | 377-987 | 264-700 | 225-683 | 424-774 | 337-764 |
| Sekembang (MR10) | kg/ha | – | – | – | 3769-6115 | 2346-5583 | 1929-5504 | – | – |
| | gtg/ac | – | – | – | 601.975 | 373-954 | 307-872 | – | – |

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