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IMPERMEABLE LAYERS IN SALT AFFECTED SANDY SOILS IN NORTHEAST THAILAND

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ABSTRACT

Detailed observations in the salt affected sandy areas revealed that one of the unknown factors which control movement of water and salt and growth of weeds was the presence near the soil surface of rather thin impermeable layers which were rich in clay and organic matter. In the rainy season, weeds were absent and salt crust was quickly formed after termination of rain at patches where the impermeable layers were exposed to or located near the soil surface. This was considered to be caused by the fact that salt content was high and reductive state was developed in these impermeable layers. Salt crust was formed by being supplied with salt from the impermeable layers and weeds were obliged to be tolerant to both salr and reductive state. This consideration was supported by field tests. Consequently, the impermeable layers were regarded as the secondary source of salt, the primary source of salt being the salty groundwater.

INTRODUCTION

A large part of the vast sandy areas in Northeast Thailand are salt affected. Previous investigations clarified that the salt accumulated in these soils was supplied from saline groundwater and that the salt of the groundwater, in turn, originated from salt bearing sedimentary deposits such as Mahasarakham formation[1-3]. Accordingly, many investigations have been conducted to establish feasible techniques to ameliorate moderately to strongly salt affected bare lands and/or to improve growth and yield of crops in salt affected arable lands through understanding of salinization processes in each place, by measuring time-course of the level and EC of the groundwater[4-6].

However, we considered that there must remain some unknown factors controlling plant growth in these salt affected areas and made a new approach to this subject.

METHODS AND RESULTS

Preliminary field survey at Ban Phra Yun

When we observed a moderately to strongly salt affected sandy area at Ban Phra Yun, Khon Kaen Province, in the rainy season (September, 1989), we noticed that poor native plant cover was very heterogeneous (Fig. 1) and that thin salt crust on the soil surface (Fig. 2), which formed fairly quickly after rain, was also heterogeneous.

This observation led us to consider

1. The heterogeneous plant cover was a reflection of the heterogeneous accumulation of salt in the root zones of these plants.
2. The heterogeneous salt crust was formed by being supplied with salty water from some "salt source" which was heterogeneously distributed near the soil surface.
3. The salt crust quickly formed at patches where the "salt source" located very near to the soil surface and plant could grow at patches where the "salt source" was absent or located far from the root zone.
4. The "salt source" was not the ground water, because the groundwater level was about 1m deep when we made the field survey.

We searched for a candidate for the "salt source" by digging a few shallow trenches from the patches with plant cover to those without plant cover or from the patches with salt crust to those without salt crust. We recognized dark clayey layers of varying thickness at varying depth almost everywhere. The clay layers appeared to meet all the above mentioned requirements of the "salt source". For instance, the plant cover was scarce or absent and the salt crust rapidly formed at the patches where the dark clay layer was exposed to the soil surface or was covered with a thin sandy layer (less than about 10 cm) (Fig. 3). On the contrary, the plant cover was somewhat abundant and the rapid formation of the salt crust did not occur at the patches where the sandy surface layer was more than about 5cm thick.

In addition, we recognized that many iron mottlings were present inside and near the dark clayey layers.

On the basis of these observations, we supposed the processes (movement of water and salt and oxidation-reduction reactions) were occurring in this area by being affected by the dark clayey layer in the following way:

1. In the rainy season, water, if it rains, more easily moves laterally through the surface sandy layer than vertically through the dark clayey layer, because permeability of the former is much higher than the latter. Thus, removal of salt from the dark clayey layer is more difficult than that from the surface sandy layer. After termination of the rain, the surface sandy layer is supplied with salt from the dark clayey layer by diffusion or by capillary rise of salty water.

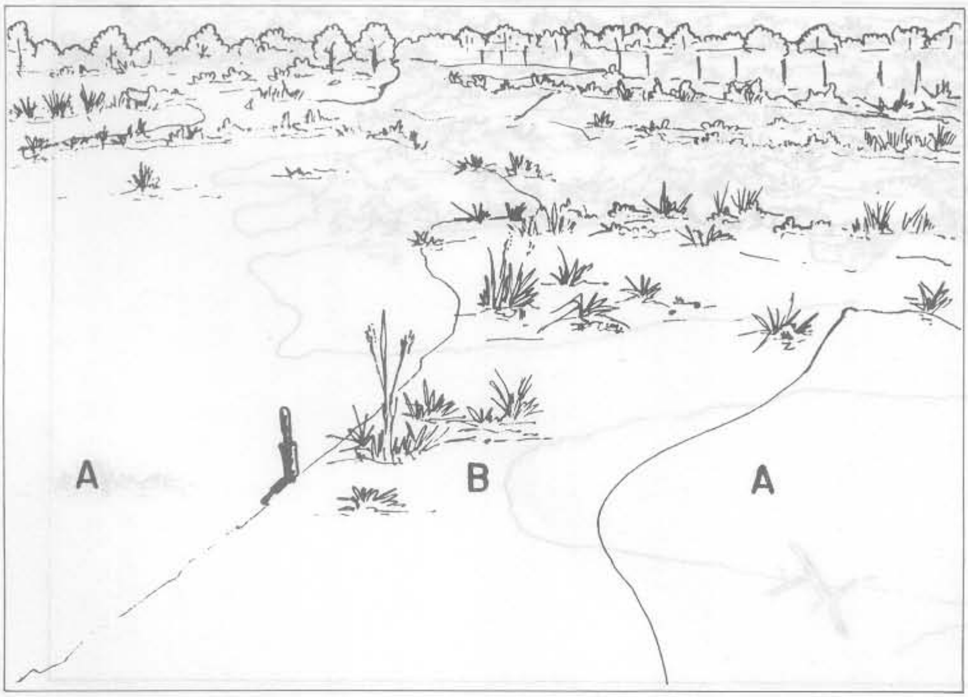

Fig. 1 Patchy distribution of weeds

Weeds were absent at the places where impermeable layer was exposed or present close to the soil surface

A : Bare B : Weeds were present

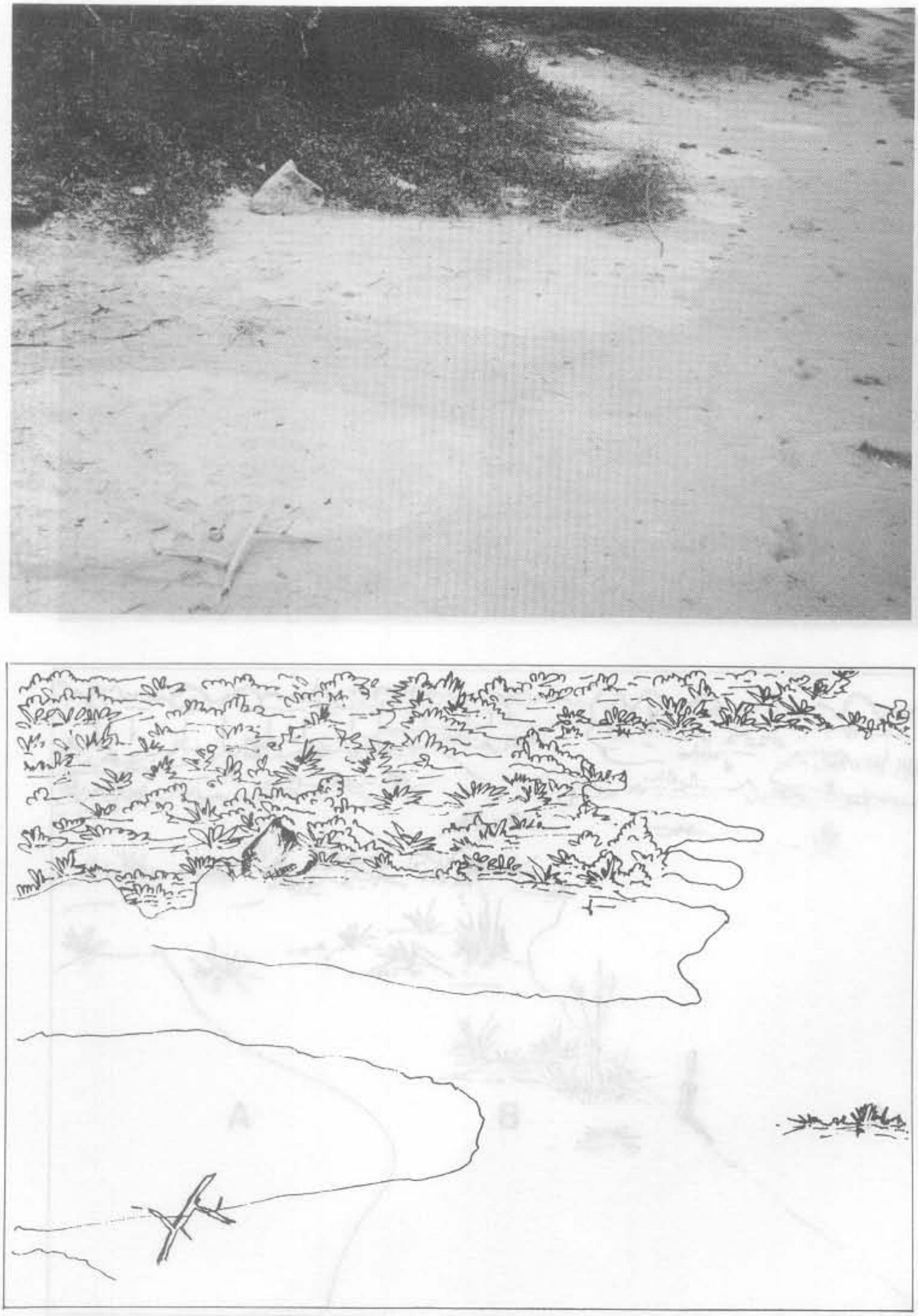

Fig. 2 Patchy distribution of salt crust
Salt crust was formed at the places where impermeable layers were exposed to the soil surface (white patches in the photo were salt crusts)

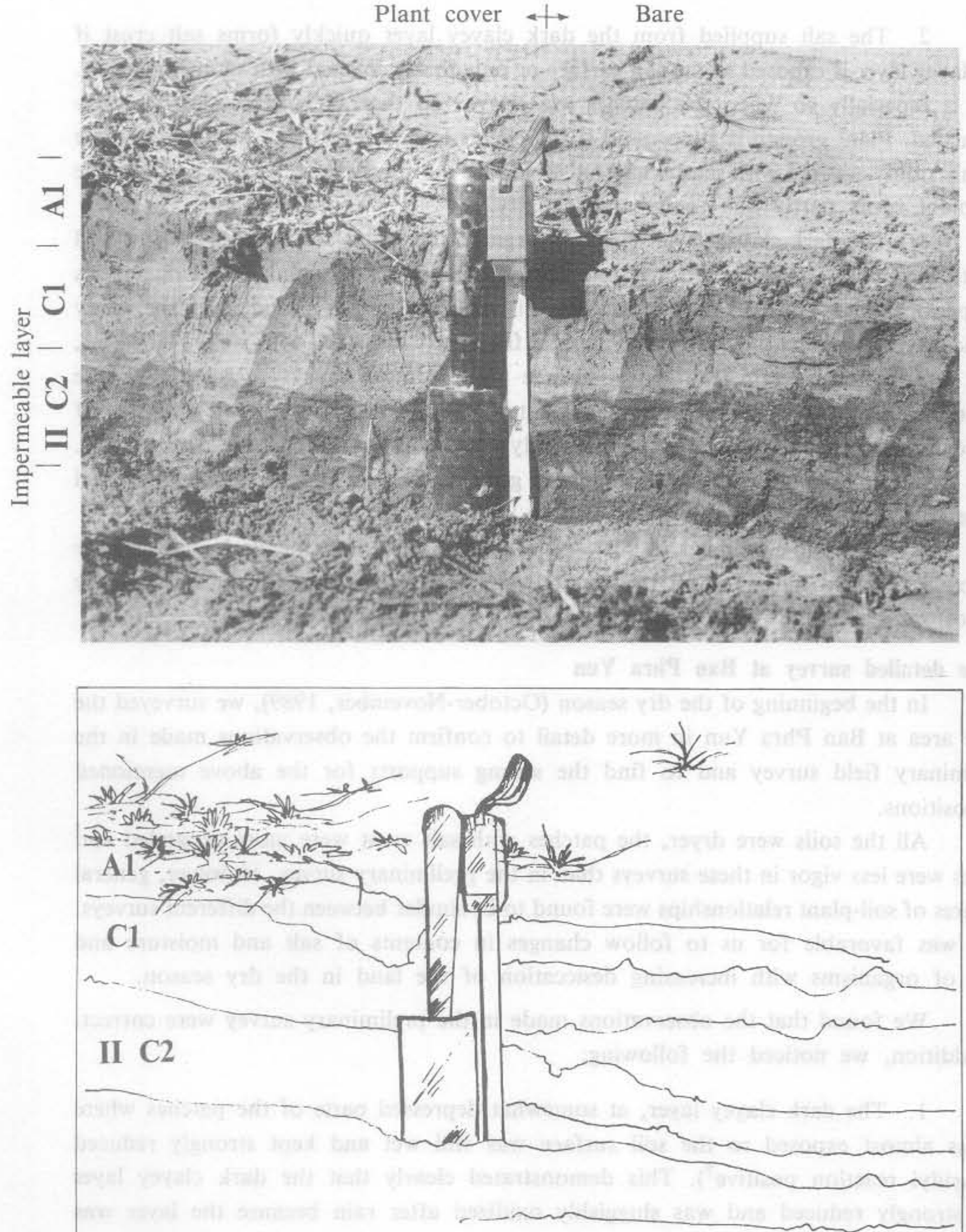

Fig. 3 The impermeable layer and plant growth

2. The salt supplied from the dark clayey layer quickly forms salt crust if the clayey layer is exposed to the soil surface or only thinly covered with sandy materials. This is especially so when the patches are convex so that the soil surface is easily desiccated. Plant growth is suppressed if the clayey layer is exposed to the soil surface or only thinly covered with sandy materials, because the clayey layer itself is unfavorable for plant roots partly due to its high salinity.

3. The dark clayey layer is rich in organic substrates for microorganisms and is saturated with water for a long time during the period of high rainfall due to its low permeability. Thus the dark clayey layer is reduced. In this period, even the sandy surface layer overlying the dark clayey layer is frequently saturated with water. However, after termination of rain, the sandy surface layer is more quickly aerated than the underlying dark clayey layer, because the rates of removal of water and entrance of molecular oxygen are far higher in the sandy surface layer than in the clayey layer. This means that in the rainy season plants growing in this upland area are obliged to be tolerant not only to salt but also to reductive state.

4. The salt contained in the whole solumn including the dark clayey layer is slowly supplied mainly from the groundwater during the dry season by capillary rise of salty water.

More detailed survey at Ban Phra Yun

In the beginning of the dry season (October-November, 1989), we surveyed the same area at Ban Phra Yun in more detail to confirm the observations made in the preliminary field survey and to find the strong supports for the above mentioned suppositions.

All the soils were dryer, the patches with salt crust were more expanded and plants were less vigor in these surveys than in the preliminary survey. However, general features of soil-plant relationships were found to be similar between the different surveys. This was favorable for us to follow changes in contents of salt and moisture and lives of organisms with increasing desiccation of the land in the dry season.

We found that the observations made in the preliminary survey were correct. In addition, we noticed the following:

1. The dark clayey layer, at somewhat depressed parts of the patches where it was almost exposed to the soil surface was still wet and kept strongly reduced (dipyridyl reaction positive[7]). This demonstrated clearly that the dark clayey layer was strongly reduced and was sluggishly oxidized after rain because the layer was kept saturated with water for a rather long period after rain, especially at the depressed parts.

2. The profile of the shallow trench dug in the previous survey was fairly desiccated and marked salt deposit was recognized only at the dark clayey layer. This was the direct evidence that showed salinity of the clayey layer was higher than that of other layers in the shallow profile.

3. Growth of Eucalyptus planted in the moderately to strongly salt affected patches appeared to improve with increasing depth of the thickness of the surface sandy layer.

4. Among the patches where the sandy surface layer was more than about 5cm, convex parts were more rapidly covered with salt crust than concave parts. This may be a reflection of the difference in the rate of desiccation.

To find conclusive evidence that water moved laterally in the surface sandy layer rather than vertically through the dark clayey layer, we made the following simple experiment in the field. We added 1,500ml red water (red ink diluted 10 times with water) into a vinyl tube (diameter: 8cm, height: 10cm), which was pushed vertically into the surface sandy layer (thickness: 15 cm) so that lower 5cm of the tube was inserted in this layer. After the added red water vanished from inside the tube, we dug a shallow pit at the place where the red water was added and examined the soil profile (Fig. 4) The red stained parts in the soil profile indicated that the added water really moved laterally through the surface sandy layer and did not enter into the dark clayey layer.

We dug a pit near the place where the above mentioned experiment was done. Its profile revealed (Table 1):

1. The dark clayey layer was composed of many thin clayey layers, sandy material being sandwiched between them. Filmy iron mottlings were recognized at the boundary between the thin clayey layers and the sandy material.

2. The thin clayey layers themselves were composed of thin clay lamellac. Exfoliated surfaces of these lamellae were lined with filmy iron mottlings.

3. A layer underneath the dark clayey layer was more pale in color (grayish) than underlying sandy layers (brownish yellow).

4. Water came up at about 1m depth. Salinity of the water was very high (22.2 ms/cm).

These observations suggested:

1. The dark clayey layer was not a buried surface soil (Alb). It was a clayey sediment transported from other areas.

2. The dark clayey layer was really strongly reduced and produced reducing organic substances which moved downward mainly by diffusion and made the underlying layer weakly reduced. This process was the same as that found in the paddy soil with an impermeable layer[8].

3. The water coming up from the depth was the salty groundwater.

Supplementary field survey at Ban Daeng Yai

A previous investigation[4] reported that Kula-Ronghai series with "natric horizon" was present at a depression of Ban Daeng Yai, Khon Kaen Province. We made a field survey at Ban Daeng Yai in the hope that we could find a relation between the dark clayey layer and the "natric horizon", because Ban Daeng Yai

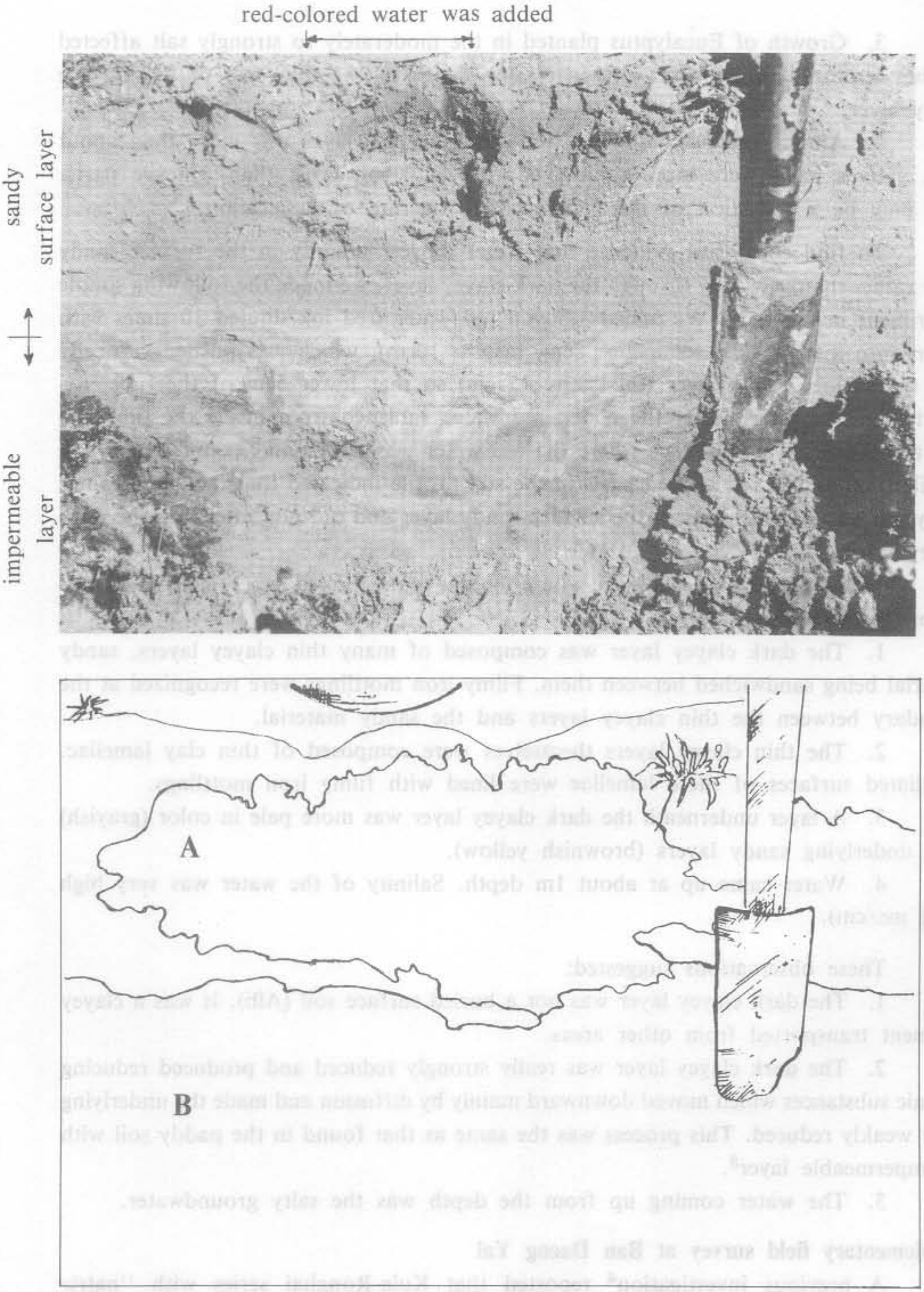

Fig. 4 Movement of red-colored water in the soil

The water could not percolate through the impermeable layers and moved laterally inside the sandy surface layer

A : red-stained part B : impermeable layer

TABLE 1 Soil profile at Ban Phra Yun (Nov. 8, 1989)

Horizon (cm)	Depth (cm)	Color	Texture	Mottles
1	0-7	7.5YR 6/4	SL	
2 A1	7-10	5YR 5/2	LS-S	
3 C1	10-17	5YR 6/3	LS-S	many distinct Fe
4 II C2	17-22	5YR 5/3	LS	many distinct Fe
5 II C3	22-27	5YR 5/2	LS	many distinct Fe (less than 4th horizon)
6 III C4	27-40	7.5YR 7/3	LS	few faint Fe
7 III C5	40-60	7.5YR 6/4	SL	grey mottling surrounding dead roots of trees
8 III C6	62+	7.5YR 6/6	SL	

Note

1. 1st horizon was an artificial cover
2. 4th & 5th horizons were impermeable layers, 4th horizon included more sandy materials than 5th horizon
3. Groundwater level was 80 cm from the surface
4. 6th horizon might be formed by being weakly reduced with substances formed in 4th & 5th horizons
5. Grey mottlings in 7th horizon were surrounding dead roots and appeared to be weakly reduced

TABLE 2 Soil profile at Ban Daeng Yai (Nov. 16, 1989)

Horizon	Depth (cm)	Color	Texture	Mottles
1	0-10	5YR 5/6	LS	
2	10-15	5YR 6/3	SCL	
3	15-25	5YR 5/6	SL	
4	25-45	5YR 5/8	LS	
5	45-60	7.5YR 6/1 5YR 6/3	SL	few fine faint Fe, few fine faint Mn mottles
6	60-80	7.5YR 6/1 5YR 6/3	SCL	few fine distinct Fe, few fine faint Mn mottles
7	80 − 110+	7.5YR 6/3	SCL	common coarse distinct Fe, common medium distinct Mn mottles few Mn concretion

Note

1. Groundwater level was 110 cm deep from the surface
2. Natric horizon : 6th & 7th horizons
3. Impermeable layers : included in 2nd & 3rd horizons
4. Color of Fe mottles : 5yr 5/8
   Color of Mn mottles : 7.5yr 3/2

was not remote from Ban Phra Yun and these two places were geomorphologically similar.

Examination of the profile of a pit made at the depression revealed (Table 2):

1. A "natric horizon" was really present in the depth and was covered by a thick sandy layer.
2. The "natric horizon" was composed of many thin dark clayey layers and the thick sandy layer was also composed of many thin sandy layers.
3. Several thin dark clay layers were present inside the upper part of the sandy layer.
4. The "natric horizon" appeared similar to the dark clayey layer in color, texture and structure, though the former was much thicker than the latter.
5. Iron mottlings were absent and many manganese mottlings instead were recognized in the "natric horizon" and its adjacent layers.
6. Iron mottlings were recognized in the upper part of the sandy layer containing the thin dark layers.
7. Very saline water (EC: 35 ms/cm) probably the groundwater came up at 110cm depth.

These observations suggested:

1. The "natric horizon" was an old sediment transported from other areas in the same way as the dark clayey horizon. At that time, clayey material rich in organic matter sedimented under rather aerobic conditions, permitting most of the good organic substrates to be aerobically decomposed by microorganisms. Consequently, the "natric horizon" was not strongly reduced even when it was saturated with water.
2. The sandy layer also contained sediments transported from other areas.
3. If all the parent materials of this soil were sediments transported from other areas, alternation of the sandy material and the clayey material corresponded to the severity of erosion. The clayey sediments were formed when the erosion was not severe and the sandy sediments were formed when the erosion was severe.
4. If the above mentioned supposition is tenable, we can imagine the forming process of the parent materials of this soil:

(a) The "natric horizon" was formed when the natural vegetation was not destroyed by man and runoff water which carried mainly clayey material rich in organic matter.

(b) The sandy layers were formed when erosion became severe as a result of human activities such as shifting cultivation which destroyed natural vegetation.

(c) The upper part of the sandy area was formed in rather recent years when paddy fields became wide spread, which somewhat suppressed erosion.

DISCUSSION

Most of the studies which have examined salt affected sandy soils in Northeast Thailand seemed to have assumed that the sandy soils were permeable to water so that rain water fairly quickly percolated through the soil and reached the ground water[2]. From the geological viewpoint covering wide space and time, this assumption may be safe. However, from the agronomical and/or ecological viewpoint which covers only limited space and time, presence of impermeable layers in the upper part of the sandy soils is expected to be crucial, because movement of water and salt and oxidation-reduction reactions in the root zone of plants are strongly controlled by the location and nature of the impermeable layers.

As discussed above, our observations in the field clarified the presence of dark clayey impermeable layers in the root zone of plants and indicated how the dark clayey layers control plant growth by modifying movement of water and salt and oxidation-reduction reactions.

These results suggest that the useful criteria to classify the sandy soils are presence or absence of impermeable layers and location and nature of the impermeable layers, if they are present. These criteria can be used at phase level in the soil classification system adopted in Thailand.

In terms of source of salt to the root zone of plants in the rainy season, the dark clayey layer is more important than groundwater: the dark clayey layer can be called a secondary salt source while the ground water can be called a primary salt source. Accordingly, techniques to ameliorate salt affected saline soils can be divided into two: the one related with the dark clayey layers and the other with groundwater.

In addition, some of the so-called crust which covered the soil surface and inhibited intake of rain water appeared to be actually thin impermeable layers which were exposed to the soil surface due to erosion.

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บทคัดย่อ

รายละเอียดจากการสังเกต พื้นที่ดินทรายที่เป็นดินเค็มแสดงให้เห็นว่าแฟคเตอร์ตัวหนึ่งที่ยังไม่มีข้อมูลเป็นตัวควบคุมการเคลื่อนที่ของน้ำ เกลือและการเจริญเติบโตของวัชพืช ได้แก่ ชั้นดินบาง ๆ ที่มีการซึมซาบไม่ดีเกิดขึ้นใกล้กับพื้นผิวหน้าดิน ซึ่งชั้นดินนี้อุดมด้วยดินเหนียวและอินทรียวัตถุ พบว่าในหน้าฝนวัชพืชหายไปและเกิดแผ่นคราบเกลือขึ้นอย่างรวดเร็วภายหลังหมดฝนแล้ว ในจุดที่ชั้นดินดังกล่าวโผล่ขึ้นเหนือหรือใกล้กับพื้นผิวหน้าดิน สิ่งนี้แสดงถึงสาเหตุอันเนื่องจากความจริงที่ว่าในชั้นดินที่มีการซึมซาบไม่ดี เกลือจะสะสมอยู่เป็นปริมาณมากแล้วสภาวะรีดักชั่นก็เกิดขึ้นตามมา คราบเกลือที่เกิดขึ้นมาจากปริมาณเกลือที่สะสมอยู่ในชั้นดินดังกล่าว และวัชพืชก็ถูกปรับสภาพให้ทนต่อความเค็มและสภาวะรีดักชั่น ความคิดเห็นนี้ถูกสนับสนุนโดยผลการทดลองในภาคสนาม ดังนั้น จึงอาจกล่าวได้ว่า ชั้นดินที่มีการซึมซาบไม่ดีเป็นแหล่งเกลืออันดับสองโดยที่แหล่งเกลืออันดับหนึ่งคือน้ำเค็มใต้ดิน