Poorly Drained Acid Sulfate Soils at Ta-an Township in the West Coast of Central Taiwan

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Summary

Poorly drained acid sulfate soils at Ta-an was discovered by the authors in the spring of 1977. This survey was conducted to study their characters and distribution. In this survey, it was found that acid sulfate soils were widely distributed in this coastal township. The total acreage was estimated above 500 ha. Lots of them are poorly drained all around the year, and generally 20 to 30 ha constituting a poorly drained area. Therefore, there are many poorly drained areas scattering around the villages in the township to become a special kind of abnormally low-yielding problem soils. The rice yields in these areas are about 2,000-4,000 kg/ha in the first crop and 1,000-2,000 kg/ha in the second crop.

The sulfides contents in a lot of these soils were very high, and mostly existing in the shallow layers of the soils. However, the highest were found in different layers of the soils from the surface to the deepest sampled depth of 60cm depending on places. This concentration and depth of sulfides may greatly affect the chemical properties of the soils in the rooting layers, and thus influence the growth of the crops.

The soil pHs were neutral, and the soil ECs were normal in the freshly sampled poorly drained acid sulfate soils. However, hydrogen sulfide was detected in the field test and in the freshly sampled soils in the laboratory. This suggested that under the poorly drained conditions the acid sulfate soils were highly reduced and easy to induce the formation of hydrogen sulfide. This was the main cause of the root rot, missing hill, persistent chlorosis of rice plants, and abnormally low yields of rice in this area.

The results of chemical analysis for the air-dried soils showed that the pH of many soils sharply declined from 6.7-7.5 to 2.7-6.6, the EC of many soils abruptly rised from 1.0-2.7 mmhos/cm to 1.3-15.7 mmhos/cm, and the soluble ions including SO_4, Ca, Mg, Fe, Mn, and Al, etc. had become toxic to the crops upon air-drying. These facts tell us that the chemical properties of the soils were largely changed in the course of air-drying apparently dur to the oxidation of sulfides into sulfuric acid and sulfates. This was the reason why rice plants were easy to die at heading stage after artificial drainage or at tillering stage during the spring drought.

Since most poorly drained acid sulfate soils at Ta-an are coarse-textured and their sulfides mostly existed in the shallow layers, they were easily oxidized and removed through the drainage water if a proper drainage system is constructed. Applying limestone (quick lime) at the rate of 4 tons/ha will be enough for raising the soil pH to a favorable value for the growth of crops. Higher

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rates of limestone are discouraged because of the sandy texturure. Rice yields were often doubled or tripled after the establishment of drainage system. This was the first discovery of acid sulfate soil in Taiwan. It is possible that there are other acid sulfate soils existing in the other coastal low-land area. It is expected that the results of this study will become a reference for the reclamation of the other acid sulfate soils.

Introduction

Poor growth and low yields of rice have popularly been complained by the farmers at Ta-an, a township in the west coast of central Taiwan. This problem has attracted the interest of the authors since a township agricultural extension worker came to ask for help in the spring of 1977. The pH and the electrical conductivity of the paddy soils and water were checked on the spot and found normal. Missing hills of rice plants were very serious in many parts of the fields. The rice plants were universely retarded in growth and chlorotic even after the application of nitrogen fertilizer. The paddy soils were dug up and found very dark in color. The rice roots were seriously hurt and truned black. The soil was sampled for pot culture. After air-drying for two weeks it was transferred to the pots and the rice seedling was transplanted to it. All of the transplanted seedling in the pots were completely killed the next day. The pH of the pot soils has changed from 7.0 to 2.5, and the electrical conductivity has rised from 1.8 mmhos/cm to 11 mmhos/cm at 25℃ upon drying. The sulfate content of the soil was extremely high when tested with barium chloride. It was thus identified to be an acid sulfate soil. As high as 37.3 m .e. sulfate per 100g of soil has been detected later. The lowering of soil pH from neutral to very stronly acid upon drying was considered to be due to the formation of sulfuric acid in the soil from the bacterial and chemical oxidation of the sulfides. These acid sulfate soils are mostly planted to rice. The ground water tables in many of these soils are on the surface all around the year. It may become slightly lower in the fall through winter or during the spring drought. Rice plants were often widely killed after artificial drainage in the later part of growing stage or during an unexpected spring drought.

The discoveries of acid sulfate soils have been reported in many parts of the world (2,3,6,7,11,15,16). They are widely distributed in the coastal swamp area at different depths, and their influences on the crops are different. If they are existing in the deep layer of the soil, the growth of shallow-rooted crops may not be affected. The chemical properties of acid sulfate soils under reduced and oxidized conditions have been studied by some workers (4,5,6,9,10). Control of ground water table over the pyrite layer to prevent the oxidation of sulfur to sulfuric acid and sulfates was beneficial to crops in some cases (3,8). Draining followed by heavy leaching with fresh water and liming were also recommended for the reclamation of acid sulfate soils (1,12,13,14,15). Some acid sulfate soils are often called “cat clay” (16). They are rather difficult to reclaim due to high clay contents and low leaching rates.

This survey is aimed at studying the distribution as well as the physical and chemical properties of acid sulfate soils at Ta-an for helping arrange their improvement plan.

Materials and methods

The first step of this survey was visiting the farmers and farms to make a whole understanding on the farm conditions and their cropping history and rice yields. The second step was selecting one poorly drained area at each of the three villages, Shi-an, Fu-ch ́ u, and Yung-an for soil profile study. Three pits each with a width of about 60cm x 120cm and a depth of 60cm were dug in each area. The soil color of the different layers of soil profile was determined on the spot, and the soils were then sampled in layers of 15cm from the surface to the depth of 60cm. The organic matter contents of the soils were determined by Walkley-Black method. Soil particle sizes were determined by Bouyoucos method. The pH of the soils was measured in the freshly sampled soil pastes, the saturated pastes from air-dried soils, and the 1 : 1 suspension of air-dried soil in hydrogen peroxide. The electrical conductivities were measured in the extracts from freshly sampled soils and the extracts from the saturated pastes of air-dried soils. The exchangeable bases were determined by neutral ammonium acetate method. Exchangeable iron, manganese, and aluminum were extracted by 1 N potasium chloride. The soluble ions were determined in the extract from the saturated pastes of air-dried soils.

The lime requirements of the acid sulfate soils were tested by adding different rates of calcium hydroxide to the suspension of 20gm of air-dried soil in 20cc of distilled water, and then the pH was measured after two weeks.

The hydrogen sulphide (H_2S) in the poorly drained acid sulfate soils was tested as follows : Soak filter paper in 1 N lead acetate solution and make it dry. (1) For testing the hydrogen sulfide of the soil in the laboratory : Put 20gm of newly sampled soil in a 250ml Erlenmeyer flask, and cover the mouth of the flask with the above treated filter paper. Heat the flask until the vapor come up to the mouth of the flask for 5 minutes. The part of filter paper in the mouth of flask will turn into brown to silver-brown color depending on the amount of the hydrogen sulphide produced. (2) For testing the hydrogen sulphide of the soils in the fields: Dig the soil in the paddy fields with hand and immediately take a treated filter paper over the hole in the soil to catch hydrogen sulphide. Dig and catch several times. The filter paper will turn into brown to silver-brown color depending on the amount of hydrogen sulfide present.

Results and discussions

In this survey it was found that the acid sulfate soils are widely distributed in this coastal township. They are estimated at least above 500 ha. Lots of them are poorly drained all around the year and generally 20 to 30 ha constitute a poorly drained area. Therefore, there are many poorly drained areas scattering around the villages in the township (Fig. 1,5,6). The rice yields in these poorly drained areas were usually from 2,000 to 4,000 kg/ha in the first crop, and 1,000 to 2,000 kg/ha in the second crop.

The analytical results showed that except the pit 3 at Yung-an village, most of the sampled pits had layers of very high sulfate. However, the highest amounts of sulfate were found in the different depths of soils from the surface layer to the deepest sampled layer of 60cm depending on places (Table 3.1, 3.2, 3.3). Since air-drying can only partly oxidize the soils, the detected sulfates in the saturation extract of the air-dried soils were only parts of the sulfate in the soils. Treatment of the soils with hydrogen peroxide (H_2O_2) completely oxidized the soils and made the soil pH still lower (Table 2.1, 2.2, 2.3). This suggested that the sulfur contents in the sampled soils were much higher than the amounts detected.

The above degrees and depths of sulfate accumulation may greatly change the soil chemical properties to affect the growth of rice plants either under the reduced or oxidized conditions. This explanation is further verified by the analyses of the freshly sampled soils and the air-dried soils.

In the analyses of the freshly sampled soils the soil pHs were neutral, and the soil ECs were normal in all cases (Table 2.1, 2.2, 2.3). However,hydrogen sulphide was discovered in the field (Fig. 4) and the laboratory tests (Fig. 3). This suggested that under the poorly drained conditions most soil factors were not harmful to rice plants except hydrogen sulfide which was easily formed with prolonged submergence and reduction. The root system of rice plants was firstly hurt (Fig. 2) and thus the missing hill and persistent chlorotic symptoms were induced (Fig. 1, 5, 6). These symptoms were more severe in the second crop due to the higher reduced conditions to induce more hydrogen sulfide in the soils as the results of the higher temperature in the second crop during the summer season.

It was found in the analyses of the air-dried soils that the soil pHs had decreased from 6.7-7.5 to 2.7-6.6, and the soil ECs had risen from 1.0-2.7 mmhos/cm to 1.3-15.7 mmhos/cm upon air-drying (Table 2.1, 2.2, 2.3). Besides, the soluble ions, SO_4, Ca, Mg, Fe, Mn, and Al, etc., had become toxic to rice plants (Table 3.1, 3.2, 3.3).

This was the main reason why rice plants were easily killed at heading stage after artificial drainage (Fig. 7,8), and at tillering stage during the spring drought (Fig. 9). When the paddy field was irrigated after the drought, large amounts of iron salts could be seen in the water (Fig. 10).

The liming test for the soils showed that calcium hydroxide at the rate of 4 tons/ha may raise the pH of the above soils to a value of 4-7.2 favorable for the growth of rice plants (Table 5.1, 5.2, 5.3). Since most soils in this acid sulfate soil area are coarse-textured (Table 1.1, 1.2, 1.3), and their cation exchange capacities are low (4.1, 4.2, 4.3), applying higher rates of quick lime or other similar liming material are discouraged.

The results of mechanical analysis showed that most soils in this area are sandy loam, loamy sand, and sand (Table 1.1, 1.2, 1.3). Judging from the coarse texture and the shallowness of the sulfur layers, it is very clear that the excessive sulfur in Ta-an acid sulfate soils are easily removed by draining and leaching. Therefore, for the reclamation of these soils, the first step is to construct a drainage system to drain away the excessive water. After the soils have become dry enough, common irrigation water may be introduced to the field to leach the soils. Proper rates of limestone may also be applied to the soils depending on the sulfur content of the soils. After several times of drying and leaching, the soils will become good enough for the growth of many kinds of crops. Some preliminary tests showed that the rice yields were doubled or tripled after the proper improvement in drainage system (Fig. 11, 12).

This was the first discovery of acid sulfate soils in Taiwan. It is possible that there are some more acid sulfate soils existing in the other coastal low-land area. We hope that the results of this study will become a good reference for the reclamation of the other acid sulfate soils in this island.

Table 1.1 Some physical properties of the acid sulfate soils at Shi-an village (sampled on July 10)

Pit number	Depth cm	Color	Organic matter %	Texture	Sand %	Silt %	Clay %	Ground water table cm
1	0-15	1.7/10BG	3.97	Sandy loam	66.3	29.1	4.6	60
	15-30	3/5 G	2.40	Sandy loam	69.0	22.3	8.7	
	30-45	4/10G	2.37	Loamy sand	77.2	16.2	6.6	
	45-60	4/10G	2.37	Sandy loam	73.1	18.3	8.6	
2	0-15	4/5BG	4.90	Sandy loam	72.3	20.3	7.4	0
	15-30	4/10G	2.93	Loamy sand	79.3	15.4	5.3	
	30-45	4/10G	1.60	Sand	89.4	6.3	4.3	
	45-60	4/10G	2.56	Loamy sand	83.4	11.3	5.3	
3	0-15	3/5BG	3.45	Loamy sand	77.1	16.3	6.6	0
	15-30	3/5BG	3.03	Sandy loam	75.3	16.2	8.5	
	30-45	7/10YR	1.46	Sand	87.4	8.1	4.5	
	45-60	5/10GY	1.91	Sandy loam	65.5	27.9	6.6	

Table 1.2 Some physical properties of the acid sulfate soils at Fu-ch′u village (sampled on July 10)

Pit number	Depth cm	Color	Organic matter %	Texture	Sand %	Silt %	Clay %	Ground water table cm
1	0-15	2/10G	4.27	Sandy loam	63.0	26.4	10.6	0
	15-30	3/5BG	3.09	Sandy loam	73.1	18.3	8.6	
	30-45	5/7.5Y	1.41	Loamy snad	87.4	6.1	6.5	
	45-60	5/7.5Y	1.45	Loamy sand	87.4	6.0	6.6	
2	0-15	2/5BG	4.38	Sandy loam	58.4	38.5	3.1	0
	15-30	2/5BG	4.11	Sandy loam	62.4	35.1	2.5	
	30-45	4/7.5GY	2.68	Loamy sand	75.7	19.2	5.1	
	45-60	4/10GY	2.47	Loamy sand	76.2	18.1	5.7	
3	0-15	3/5BG	4.91	Sandy loam	68.3	27.6	4.1	0
	15-30	4/5BG	3.21	Sandy loam	70.2	25.1	4.7	
	30-45	3/10G	2.86	Loamy sand	78.6	16.4	5.0	
	45-60	3/10G	2.78	Loamy sand	81.0	14.6	4.4	

Table 1.3 Some physical properties of the acid sulfate soils at Yung-an village (sampled on July 10)

Pit number	Depth cm	Color	Organic matter %	Texture	Sand %	Silt %	Clay %	Ground water table cm
1	0-15	3/10GY	4.15	Sandy loam	63.1	30.4	6.5	0
	15-30	3/5BG	3.82	Sandy loam	72.3	21.3	6.4	
	30-45	3/5BG	3.38	Sandy loam	71.4	20.4	8.2	
	45-60	4/10GY	2.74	Sandy loam	56.5	34.4	9.1	
2	0-15	3/10GY	4.28	Sandy loam	61.0	38.5	0.5	0
	15-30	3/10G	3.27	Sandy loam	69.3	30.3	0.4	
	30-45	3/5G	2.93	Sandy loam	63.0	30.5	6.5	
	45-60	3/5G	3.48	Sandy loam	69.5	24.4	6.1	
3	0-15	3/5BG	3.92	Sandy loam	67.3	27.6	5.1	0
	15-30	3/5BG	2.78	Sandy loam	65.2	32.4	2.4	
	30-45	3/5BG	2.99	Sandy loam	65.1	33.8	1.1	
	45-60	3/5BG	3.22	Sandy loam	59.0	32.5	8.5	

Table 2.1 The pH and electrical conductivity of Shi-an village soils under reduced and oxidized conditions (sampled on July 10)

Pit number	Depth cm	pH			EC, mmhos/cm	
		Freshly sampled soil Paste (reduced)	Air-dried soil satur. paste (partly oxidized)	Soil H_2O_2 1:1 suspen. (completely oxidized)	Freshly sampled soil extract (reduced)	Air-dried soil satur. extract (partly oxidized)
1	0-15	7.4	6.0	3.5	1.5	3.2
	15-30	7.4	3.4	2.7	1.3	4.8
	30-45	7.3	3.5	2.8	1.2	3.9
	45-60	7.2	3.7	2.9	1.0	3.5
2	0-15	7.1	2.7	1.9	1.4	15.7
	15-30	6.9	2.9	2.2	1.1	9.3
	30-45	6.9	3.2	2.5	1.4	4.4
	45-60	6.9	2.9	2.2	1.3	6.9
3	0-15	6.9	2.7	2.0	1.2	12.0
	15-30	7.0	2.8	2.0	1.2	10.1
	30-45	6.7	5.1	2.9	1.4	1.3
	45-60	7.1	3.5	2.7	1.4	4.1

Table 2.2 The pH and electrical conductivity of Fu-ch′u village soils under reduced and oxidized conditions (sampled on July 10)

Pit number	Depth cm	pH			EC, mmhos/cm	
		Freshly sampled soil Paste (reduced)	Air-dried soil satur. paste (partly oxidized)	Soil H_2O_2 1:1 suspen. (completely oxidized)	Freshly sampled soil extract (reduced)	Air-dried soil satur. extract (partly oxidized)
1	0-15	7.5	5.9	5.5	1.7	3.2
	15-30	7.2	3.2	2.5	2.3	8.3
	30-45	7.4	4.6	2.5	2.4	3.2
	45-60	7.4	5.6	2.7	2.4	2.6
2	0-15	7.3	5.6	2.5	1.7	3.0
	15-30	7.3	3.6	2.2	2.1	6.5
	30-45	7.3	3.0	2.1	2.7	7.9
	45-60	7.4	2.9	2.0	2.6	8.1
3	0-15	7.5	2.7	2.1	2.0	10.4
	15-30	7.3	3.0	2.2	2.2	8.2
	30-45	7.4	4.4	2.5	2.3	4.4
	45-60	7.4	6.0	2.6	2.5	2.8

Table 2.3 The pH and electrical conductivity of Yung-an village soils under reduced and oxidized conditions (sampled on July 10)

Pit number	Depth cm	pH			EC, mmhos/cm	
		Freshly sampled soil Paste (reduced)	Air-dried soil satur. paste (partly oxidized)	Soil H_2O_2 1:1 suspen. (completely oxidized)	Freshly sampled soil extract (reduced)	Air-dried soil satur. extract (partly oxidized)
1	0-15	7.3	5.7	3.2	1.6	3.7
	15-30	7.2	3.0	2.2	1.7	9.2
	30-45	7.2	3.2	2.3	1.6	9.7
	45-60	7.1	3.1	2.2	2.1	8.8
2	0-15	7.4	6.3	4.1	1.5	3.2
	15-30	7.4	4.1	2.5	1.6	5.3
	30-45	7.3	3.1	2.3	1.6	6.9
	45-60	7.3	3.1	2.2	1.8	9.4
3	0-15	7.4	6.3	6.2	2.3	3.0
	15-30	7.3	6.6	6.4	2.0	2.8
	30-45	7.4	5.8	3.2	2.4	3.2
	45-60	7.3	6.2	5.2	2.2	2.9

Table 3.1 Soluble ions in the saturation extract of the air-dried soils from Shi-an village (sampled on July 10) m.e./1

Pit number	Depth cm	SO_4	Ca	Mg	Na	K	Fe	Mn	Al
1	0-15	23.4	38.9	16.9	0.2	0.1	0.36	0.6	0.25
	15-30	70.1	29.3	39.5	0.2	0.1	1.79	9.1	1.33
	30-45	43.5	29.3	27.6	0.7	0.1	0.90	3.1	0.45
	45-60	31.8	30.5	19.7	1.0	0.5	0.90	1.9	0.56
2	0-15	355.4	28.7	62.2	0.4	0.2	80.57	2.9	48.92
	15-30	191.9	27.6	47.8	0.1	0.1	19.70	2.3	13.34
	30-45	55.2	29.3	23.7	0.2	0.1	3.76	4.7	2.34
	45-60	99.9	28.7	35.5	0.1	0.1	19.70	3.3	12.23
3	0-15	373.0	27.6	49.9	0.2	0.1	46.55	1.4	28.35
	15-30	216.2	28.7	41.7	0.1	0.1	37.60	2.3	23.35
	30-45	10.6	12.6	7.5	0.6	0.2	0.72	0.1	0.46
	45-60	39.3	29.9	34.4	0.6	0.1	1.43	1.4	0.86

Table 3.2 Soluble ions in the saturation extract of the air-dried soils from Fu-ch'u village (sampled on July 10) m.e./1

Pit number	Depth cm	SO_4	Ca	Mg	Na	K	Fe	Mn	Al
1	0-15	25.2	39.5	17.8	0.7	0.2	0.18	0.1	0.12
	15-30	173.6	28.7	39.5	0.1	0.1	5.37	1.2	3.45
	30-45	23.4	30.5	13.4	0.4	0.2	0.18	0.1	0.10
	45-60	23.4	28.7	9.5	0.5	0.2	0.18	0.1	0.10
2	0-15	33.4	36.5	17.8	0.2	0.1	1.79	0.9	1.22
	15-30	74.8	28.1	26.3	0.1	0.1	17.91	1.8	11.67
	30-45	167.6	28.1	36.2	0.1	0.1	16.12	1.2	9.45
	45-60	181.2	27.2	35.2	0.3	0.2	18.10	1.7	10.35
3	0-15	201.2	37.2	39.2	0.6	0.2	19.10	1.8	11.80
	15-30	172.4	31.1	37.6	0.4	0.2	17.20	1.7	11.50
	30-45	64.0	29.2	26.0	0.2	0.1	16.40	1.2	8.41
	45-60	25.2	28.6	18.1	0.1	0.1	1.60	0.8	1.10

Table 3.3 Soluble ions in the saturation extract of the air-dried soils from Yung-an village (sampled on July 10) m.e./1

Pit number	Depth cm	SO_4	Ca	Mg	Na	K	Fe	Mn	Al
1	0-15	23.4	44.9	16.2	0.3	0.2	2.15	0.2	1.56
	15-30	173.6	26.9	39.5	0.1	0.1	20.02	1.9	12.68
	30-45	228.2	26.4	46.1	0.1	0.1	20.02	1.9	11.67
	45-60	185.6	25.8	46.1	0.1	0.1	12.53	3.0	0.89
2	0-15	19.2	42.5	8.7	0.4	0.2	0.90	0.1	0.67
	15-30	84.6	36.5	19.7	0.1	0.1	0.36	0.9	0.25
	30-45	125.0	27.6	30.3	0.1	0.1	14.32	3.3	9.12
	45-60	204.2	28.7	39.5	0.1	0.1	20.02	2.0	12.90
3	0-15	25.2	40.1	10.3	0.4	0.2	0.36	0.9	0.23
	15-30	20.6	35.9	10.3	0.7	0.2	0.18	0.2	0.10
	30-45	27.1	35.9	20.6	0.1	0.1	0.18	1.4	0.08
	45-60	23.4	35.9	12.7	0.4	0.2	0.36	0.8	0.20

Table 4.1 Exchangeable ions and cation exchange capacity of the air-dried soils from Shi-an village (sampled on July 10)

Pit number	Depth cm	Exchangeable ions, m.e./100g							CEC m.e/100g
		Ca	Mg	Na	K	Fe	Mn	Al	
1	0-15	18.17	3.88	0.09	0.14	0.13	0.12	0.08	4.73
	15-30	7.71	3.26	0.04	0.12	0.93	0.98	1.33	3.69
	30-45	5.00	2.98	0.06	0.12	0.54	0.36	1.22	2.98
	45-60	4.79	2.56	0.05	0.17	0.59	0.26	1.02	3.54
2	0-15	5.31	6.34	0.05	0.09	7.52	0.40	4.67	5.95
	15-30	4.27	4.02	0.01	0.05	2.22	0.33	3.11	3.45
	30-45	4.17	1.94	0.01	0.10	0.43	0.44	1.22	1.84
	45-60	3.65	2.74	0.07	0.06	2.17	0.36	1.78	2.98
3	0-15	5.31	5.14	0.09	0.09	4.30	0.23	2.67	5.47
	15-30	5.00	4.06	0.08	0.05	3.94	0.27	2.22	3.75
	30-45	3.23	1.92	0.12	0.12	0.11	0.04	0.39	1.81
	45-60	3.96	3.10	0.09	0.11	0.22	0.22	1.11	2.77

Table 4.2 Exchangeable ions and cation exchange capacity of the air-dried soils from Fu-ch'u village (sampled on July 10)

Pit number	Depth cm	Exchangeable ions, m.e./100g							CEC m.e/100g
		Ca	Mg	Na	K	Fe	Mn	Al	
1	0-15	20.50	1.22	0.25	0.18	0.43	0.04	0.16	4.46
	15-30	10.83	3.12	0.13	0.10	1.18	0.15	1.78	3.84
	30-45	4.06	1.88	0.07	0.11	0.79	0.04	0.52	1.49
	45-60	3.54	1.64	0.11	0.12	0.65	0.03	0.36	1.73
2	0-15	18.17	3.78	0.14	0.12	0.50	0.12	0.31	7.79
	15-30	14.33	4.38	0.10	0.09	2.51	0.20	1.11	7.32
	30-45	6.15	4.02	0.07	0.06	2.94	0.16	2.11	6.07
	45-60	5.89	3.72	0.12	0.11	3.01	0.18	2.45	6.12
3	0-15	15.30	4.40	0.12	0.14	3.22	0.20	2.67	5.20
	15-30	12.60	3.74	0.11	0.11	3.01	0.18	2.22	5.02
	30-45	6.05	3.24	0.08	0.10	0.72	0.08	0.47	3.96
	45-60	4.26	2.40	0.06	0.07	0.40	0.07	0.18	3.82

Table 4.3 Exchangeable ions and cation exchange capacity of the air-dried soils from Yung-an village (sampled on July 10)

Pit number	Depth cm	Exchangeable ions, m.e./100g							CEC m.e/100g
		Ca	Mg	Na	K	Fe	Mn	Al	
1	0-15	18.17	4.44	0.17	0.14	0.47	0.09	0.30	7.32
	15-30	8.33	5.28	0.07	0.06	2.69	0.22	2.22	6.42
	30-45	5.73	5.60	0.06	0.05	2.65	0.20	1.56	4.22
	45-60	6.46	5.28	0.05	0.09	2.51	0.29	2.11	4.49
2	0-15	16.25	3.34	0.17	0.12	0.40	0.07	0.12	5.77
	15-30	15.17	3.96	0.12	0.23	0.65	0.12	0.47	4.82
	30-45	8.44	4.86	0.07	0.23	2.15	0.34	2.06	5.41
	45-60	6.46	3.76	0.08	0.09	2.29	0.23	2.00	4.88
3	0-15	19.83	3.34	0.18	0.12	0.14	0.12	0.16	5.47
	15-30	19.00	3.20	0.20	0.15	0.13	0.07	0.09	5.30
	30-45	16.67	3.20	0.12	0.14	0.12	0.15	0.27	5.41
	45-60	11.25	4.02	0.10	0.10	0.17	0.10	0.18	4.64

Table 5.1　Changes of the pH of Shi-an soils after treatment with different rates of calcium hydroxide

Pit number	Depth cm	Rates of Ca $(OH)_2$, tons/ha								
		0	1	2	3	4	5	6	7	8
1	0-15	6.0	6.2	6.4	6.6	6.9	7.2	7.4	7.5	7.6
	15-30	3.4	4.5	5.6	6.3	7.1	7.3	7.5	7.6	7.8
	30-45	3.5	4.4	5.1	5.8	6.6	7.0	7.3	7.7	8.0
	45-60	3.7	4.8	5.8	6.3	6.8	7.3	7.5	7.7	7.9
2	0-15	2.7	3.0	3.4	3.6	4.0	4.3	4.5	4.7	5.0
	15-30	2.9	3.2	3.6	4.0	4.9	5.7	6.5	6.9	7.2
	30-45	3.2	4.2	5.2	6.0	6.8	7.1	7.4	7.6	7.8
	45-60	2.9	3.3	3.8	4.8	6.0	6.7	7.5	7.7	7.8
3	0-15	2.7	2.9	3.1	3.4	4.0	4.4	4.8	5.0	5.5
	15-30	2.8	3.0	3.3	3.5	4.0	4.5	5.1	6.0	6.4
	30-45	5.1	5.4	5.8	6.2	6.7	7.0	7.3	7.5	7.7
	45-60	3.5	4.4	5.2	6.2	6.9	7.1	7.3	7.5	7.6

Table 5.2　Changes of the pH of Fu-ch′u soils after treatment with different rates of calcium hydroxide

Pit number	Depth cm	Rates of Ca $(OH)_2$, tons/ha								
		0	1	2	3	4	5	6	7	8
1	0-15	5.9	6.2	6.4	6.6	6.9	7.1	7.4	7.6	7.7
	15-30	3.2	3.6	4.2	4.8	5.8	6.6	6.9	7.2	7.4
	30-45	4.6	4.9	5.4	6.1	6.7	6.9	7.2	7.4	7.7
	45-60	5.6	6.0	6.3	6.7	6.9	7.2	7.5	7.8	8.1
2	0-15	5.6	5.8	6.1	6.5	6.7	7.0	7.3	7.6	7.8
	15-30	3.6	4.2	5.0	5.6	6.2	6.6	7.0	7.3	7.5
	30-45	3.0	3.5	3.9	4.5	5.6	6.3	6.8	7.1	7.6
	45-60	2.9	3.6	4.0	4.6	5.3	6.0	6.7	7.0	7.5
3	0-15	2.7	3.3	3.7	4.0	5.0	5.8	6.4	6.8	7.0
	15-30	3.0	3.7	4.4	5.6	6.6	7.0	7.3	7.5	7.7
	30-45	4.4	4.8	5.4	6.2	6.8	7.0	7.4	7.6	7.8
	45-60	6.0	6.4	6.6	6.9	7.1	7.3	7.4	7.6	7.9

Table 5.3 Changes of the pH of Yung-an soils after treatment with different rates of calcium hydroxide

Pit number	Depth cm	Rates of $Ca(OH)_2$, tons/h[a]								
		0	1	2	3	4	5	6	7	8
1	0-15	5.7	5.9	6.0	6.3	6.6	6.9	7.1	7.3	7.5
	15-30	3.0	3.2	3.6	4.2	5.0	5.6	6.2	6.7	7.2
	30-45	3.2	3.4	4.0	4.8	5.8	6.2	6.6	7.0	7.4
	45-60	3.1	3.6	4.2	4.7	5.5	6.4	6.8	7.2	7.6
2	0-15	6.3	6.4	6.6	6.8	6.9	7.1	7.2	7.3	7.4
	15-30	4.1	4.3	4.6	5.0	5.6	6.5	7.1	7.3	7.5
	30-45	3.1	3.5	4.0	4.8	5.8	6.2	6.7	7.0	7.3
	45-60	3.1	3.3	3.6	4.4	5.5	5.8	6.3	6.7	7.0
3	0-15	6.3	6.5	6.6	6.8	7.5	7.4	7.5	7.6	7.7
	15-30	6.6	6.7	6.8	6.9	7.1	7.3	7.5	7.6	7.7
	30-45	5.8	6.2	6.4	6.6	6.8	7.2	7.4	7.5	7.7
	45-60	6.2	6.3	6.4	6.5	6.7	7.0	7.1	7.3	7.5

Fig 1: Retarded rice growth in a poorly drained acid sulfate soil, showing persistent chlorotic symptoms even nitrogen fertilizers were applied.

Fig 2: (right, 1) Normal rice plant with thrifty root system and normal platn body, and (left, 3) abnormal rice plants in acid sulfate soil showing hurt root systems and stunted plant body.

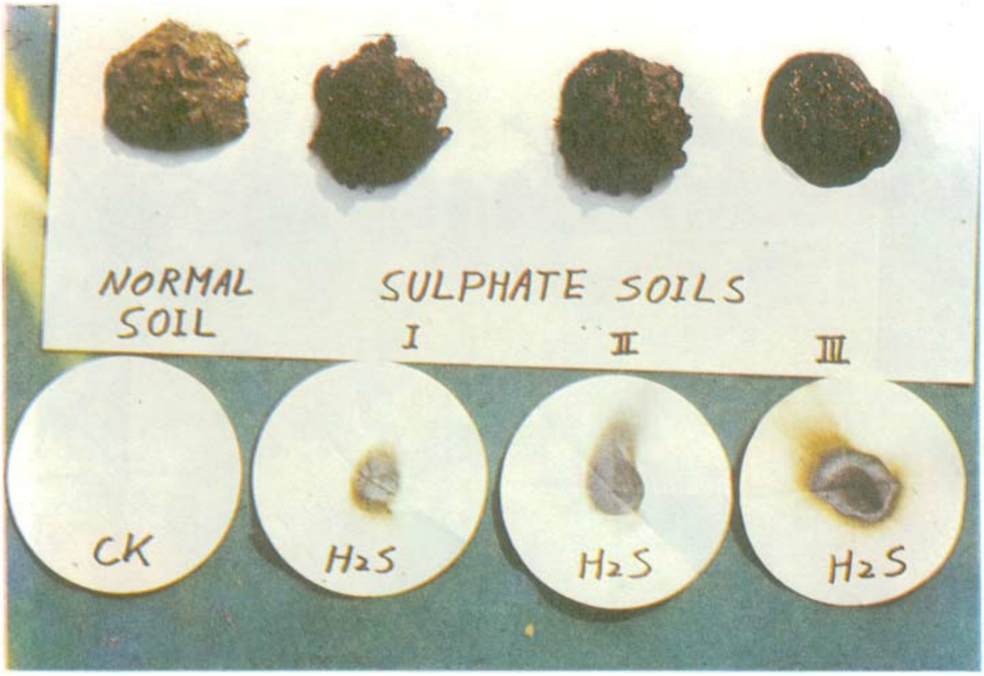

Fig 3: Detection of hydrogen sulfide in some poorly drained acid sulfate soils by lead acetate-treated filter paper in the laboratory.

Fig 4: Detection of hydrogen sulfide in a poorly drained paddy field of an acid sulfate soil by lead acetate-treated filter paper.

Fig 5: Highly reduced soil and very poor growth of rice plants at the harvesting stage in a poorly drained acid sulfate soil.

Fig 6: Rice yield were very low in most poorly drained acid sulfate soils especially in the second crop due to missing hill and low panicle number.

Fig 7: Normal (left), and wilted rice plants (right)from a partly drained and oxidized acid sulfate soil.

Fig 8: (top) Normal, and (bottom) wilted rice plants in a partly drained and oxidized acid sulfate soil.

Fig 9: Seriously wilting and killed rice plants by the heavy salts and strong acids formed in an acid sulfate soil during a spring drought.

Fig 10: Large amount of iron salts appeared in the water of an irrigated acid sulfate soil after a spring drought.

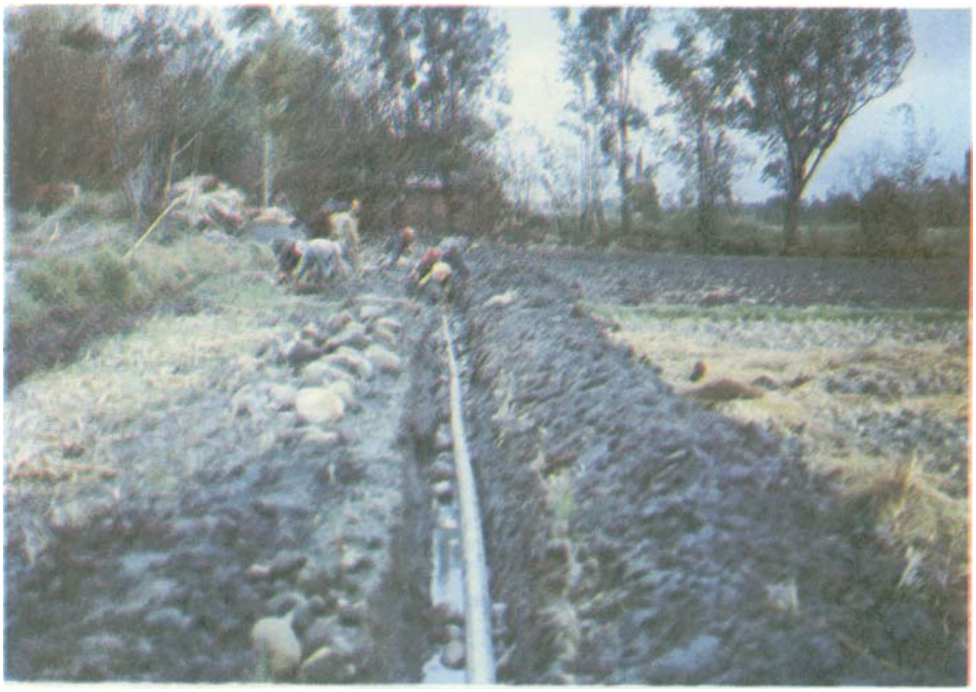

Fig 11: Construction of drainage system is the most effective way for the reclamaton of the sandy acid sulfate soils at Ta-an.

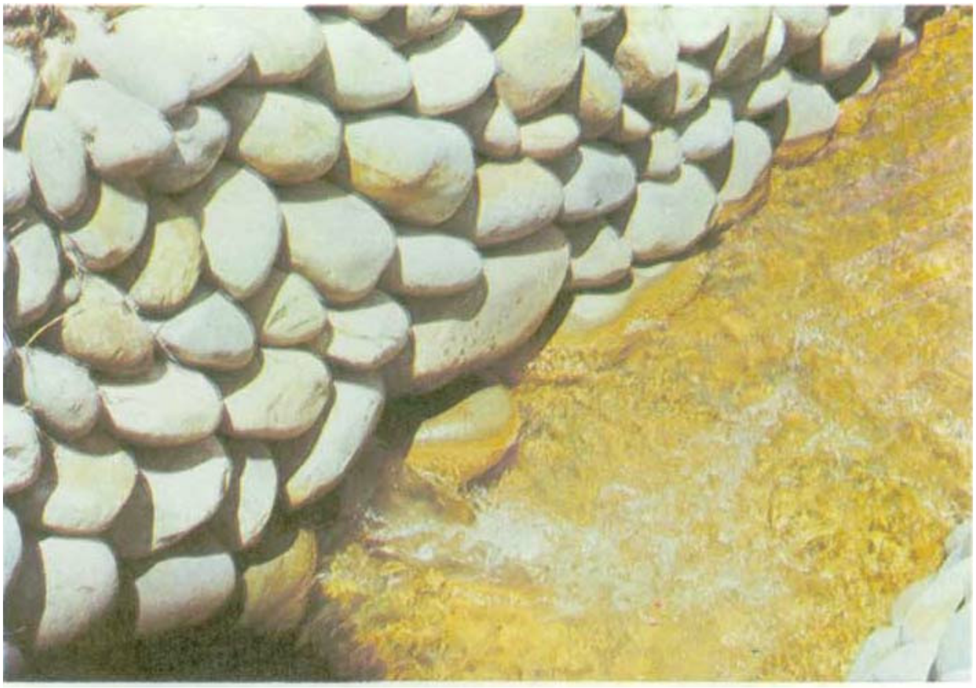

Fig 12: Draining of excessive water from an underground drainage pipe in an acid sulfate soil into a drainage ditch.

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臺灣中部西海岸大安鄉排水不良酸性硫酸鹽土之調查研究

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摘　要

大安鄉排水不良酸性硫酸鹽土，是作者於民國66年春天在一次水稻災害調查之機會發現的。本次調查之目的在研究該酸性硫酸鹽土之分佈情況及其特性，以供進一步改善之參攷。根據本次調查結果，此一海岸鄉鎮之酸性硫酸鹽土分佈異常廣泛，全部面積估計約在500公頃以上，其中有許多整年都在排水不良之狀態，而且多數每20至30公頃成爲一個排水不良之小區域，因此，有許多排水不良之小區域分散在全鄉各村落，成爲一種特殊之低產問題土壤，第一期作稻谷產量每公頃約2000至4000公斤，第二期作約1000至2000公斤。

根據分析結果，多數土壤之硫黃含量都很高，而且都在土壤之淺層，但含量最高者常因地點不同而稍有差異，有些存在於表面第一層，有些則在60公分深之土層，此種硫黃濃度與深度，對根層土壤之化學性質及作物生長均容易發生不良影響。

剛採新鮮土壤之pH多數屬中性而EC也都正常，可是不論在田間或實驗室均可測到硫化氫之產生，此一現象表示在排水不良之情況下，由於土壤高度還元，極易產生硫化氫，這是該地區水稻在排水不良之狀態下容易引起爛根、缺株、持續性黃化以及稻谷產量特別低之主要原因。

土壤經過風乾之後再加分析，發現許多土壤之pH從6.7～7.5下降至2.7～6.6，EC則從1.0～2.7 mmhos/cm上升到1.3～15.7 mmhos/cm，可溶性及交換性陰陽離子包括SO_4, Ca, Mg, Fe, Mn, Al等均達到對作物有害之程度，這些事實告訴我們，在乾燥過程中顯然由於硫化物經過氧化產生硫酸與硫酸鹽類等化合物而使土壤化學性質發生很大的變化，這是本地區水稻在抽穗期經過人工排水或於分蘗期遇到乾旱即大量枯死之主要原因。

由於本地區之土多數屬於粗質地之砂質土壤，排水性良好，而硫化物多數分佈在土壤之淺層，所以只要建立良好之排水系統，硫化物即容易陸續氧化成爲硫酸鹽類隨著多餘的積水排掉。施用石灰似乎也有幫助，在實驗室舉行石灰需要量試驗結果，每公頃約使用4公噸之石灰即可使土壤之pH上升至適合於一般作物生長之程度，過量之石灰不太適宜。根據初步之排水試驗結果，稻谷產量可以增加二至三倍。

這是本省第一次發現酸性硫酸鹽土，本省其他沿海地區可能仍有一些酸性硫酸鹽土之存在，希望本報告可供爲改良本省其他酸性硫酸鹽土之參考。

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