EFFECT OF WATER MANAGEMENT ON FIELD PERFORMANCE OF OIL PALMS ON ACID SULPHATE SOILS IN PENINSULAR MALAYSIA

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1 Summary

The yield performance of oil palms in fields with various acid sulphate soil conditions is examined in relation to changes in water management. In the severely and moderately acid areas, yields improved appreciably when after a period of deep drainage, the watertable was raised, with increases of 36.3% and 17.6% being recorded respectively in the first consecutive four year period after raising the watertable. These yield improvements were maintained thereafter.
Practical recommendations are given for maintaining a high watertable with provision for periodic flushing of the drains in oil palm plantations.

2 Introduction

In Peninsular Malaysia, it has been estimated that there are about 110,000 ha of acid sulphate soils (Kanapathy 1973). These soils are mostly interspersed amongst fertile marine alluvia along the west coast, where oil palm is an important perennial crop.
The adverse effects of acid sulphate soils on oil palm growth were first highlighted during the 1960's when in a series of investigations on amelioration of such soils, intensive drainage was carried out in an attempt to remove the source of their potential acidity, viz., pyrite, through oxidation and leaching of the resultant sulphates. This proved

disastrous as yields in the field under investigation plunged from an average of 15.17 tonnes fresh fruit bunches (ffb) per ha in the years preceding the intensive drainage to 6.03 tonnes ffb/ha within four years. Subsequent examination showed that even after this period of intensive leaching, reserves of unoxidized pyrite remained very large and the soil was still very acid (Bloomfield et al. 1968).

The next phase of investigation involved inhibition of further pyrite oxidation by flooding the pyritic horizon. This treatment led to progressive improvements in palm condition in the following year and, three years after this treatment, yields reached 18.80 tonnes ffb/ha and remained at that level five years later (Poon and Bloomfield 1977).

Since means of resolving the acid sulphate problem were developed, cultivation of oil palms on these soils has expanded considerably. It is presently estimated that the acreage of oil palms grown on acid sulphate soils in Peninsular Malaysia amounts to about 40,000 ha (Paramananthan 1980).

Acid sulphate soils too often are being considered collectively, without taking into account existing variations in acid severity associated with depth of acidic layers. This may have led to misleading impressions on the general performance of oil palms on acid sulphate soils. It is therefore proposed to examine in greater detail, the yields of oil palms on acid sulphate soils in relation to these variations in severity.

3 Identification of acid sulphate soils and classification of fields with acid sulphate soil conditions

Acid sulphate soils in Peninsular Malaysia are characterized by an organic layer in the topsoil overlying a clay subsoil in which the acidic horizon occurs. Typically, pale yellow deposits of jarosite occur as large blotches on ped faces and around old root channels in this acidic horizon.

The criteria suggested by Coulter (1967) as standards for the identification of the acidic horizon, viz., air dried, soil pH less than 3.3 and water soluble sulphate content more than 0.1% have been found practicable for delineation of such soils (Hew and Toh 1973). There is however

considerable variation in the depths at which the acidic horizon occurs in the soil, ranging from less than 30 cm to more than 120 cm from the soil surface. The growth and yield performance of oil palms have been observed to be associated with this variation.
Accordingly, the acid areas have been classified arbitrarily into three categories of acidity depending on the depth at which the acidic layer occurs:

Category of acidity	Depth of acidic layer (cm)
Severe	0 - 60
Moderate	60 - 90
Mild	90 - 120

Within individual fields, there can be a range of depths at which the acidity occurs. Therefore, for the present purpose, a field is classified into the respective category of acidity if more than 70% of the area falls into that category. This definition simplifies interpretation and presentation of data, as available yield data pertain only to entire fields.
The degree of acidity in the various fields that have been selected for the present study, has been determined from soil analyses performed on soil samples collected at an intensity of one point per 10 acres. At each sampling point, soil samples were collected at 15 cm intervals up to a depth of 120 cm. Analyses data accumulated over several years have been used.

4 Yield of oil palms on acid sulphate soils

The yield performance of oil palms in acid sulphate areas, classified into various categories of acidity, is examined in relation to changes in water management. Various periods have been considered, with the period 1964-1967 representing the period prior to the wide-scale introduction of the policy of maintaining a high watertable. Yield performance of palms after the raising of watertables is examined in consecutive periods of four years from 1968 to 1979.
The average yields per annum for four consecutive periods of four years

each, commencing from 1964, for palms under the various categories of acidity are summarized in Table 1. Only the pre-1960 plantings have been included in this compilation so that areas selected have experienced a sufficiently long period of adverse growing conditions prior to the introduction of appropriate ameliorative measures. In addition, yield data have also been provided for comparable age palms growing on non-acid sulphate soil.

Table 1. Yields of pre-1960 oil palm plantings under various categories of acidity

		Yield (tonnes ffb/ha/year)			
Category of acidity	Area (ha)	1964-67	1968-71	1972-75	1976-79
Severe	273	11.44	15.59	17.52	18.06
Moderate	366	16.38	19.27	19.08	18.98
Mild	12	22.81	23.43	22.14	17.32
Non-acid sulphate	888	23.89	24.14	22.44	20.41

The policy to raise watertables was affected in the majority of the acid sulphate areas during 1967. It will be noted (Table 1) that this ameliorative measure resulted in substantial improvements in palm productivity in the severe and moderately severe acid areas.

There are insufficient areas of mild acidity in the same age group for a proper comparison. However, the yield trend in one field indicates that oil palm yields are not adversely affected when the acidity occurs at 90-120 cm. Raising the watertable in that area did not result in dramatic improvement in yield performance. The very satisfactory yields recorded during 1964-1967 in this mildly acid field may also be attributed to the fact that, in normal practice, the depth of internal field drains rarely exceeded 90 cm and the acidic layer was never subjected to very intense drainage.

The growth and productivity of the oil palm is greatly influenced by the soil moisture status and prolonged periods of dry weather can precipitate severe yield declines. Thus, irrespective of the soil acidity level, oil palms will respond to water management practices aimed at avoidance of moisture stress development.

The full impact of altering the watertable by drainage in acid sulphate

soils becomes apparent from the yield trends in an area over which soils were completely acid sulphate (severe). Figure 1 illustrates the yield trends in such a 1952 planting (121 ha) during the period 1960-1979. Drains in the area under consideration were deepened in 1961/1962 to 120 cm and their frequency increased to one per 4 palm rows in an effort to leach out the oxidized sulphates.

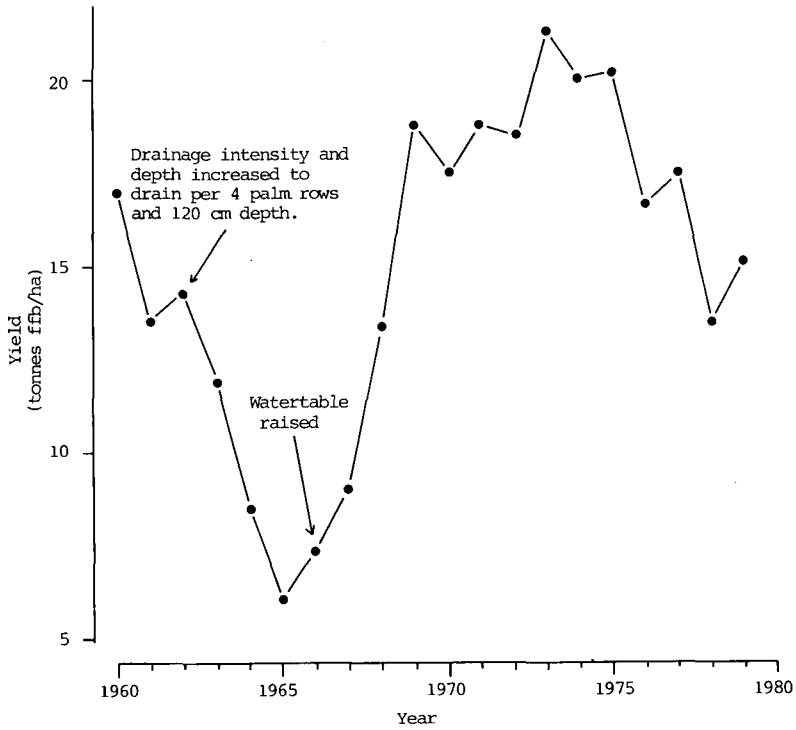

Figure 1. Effect of increased drainage and subsequent raising of watertable on yield of oil palms on severe acid sulphate soils

This intensified drainage caused a steep yield decline from 14.31 tonnes ffb/ha to 6.03 tonnes ffb/ha three years later (Poon and Bloomfield 1977). Raising of the watertable by strategic placement of water retention blocks along the drains produced highly economic yield responses. Though significant yield improvements were recorded in the areas where watertables were raised after a period of free drainage conditions, the yield levels in these areas did not reach those obtainable on non-acid sulphate soils.

Table 2 summarizes the yield performance of 1966-1973 oil palm plantings on moderately acid soils which have not been subjected to intensive free drainage since commencement of planting. Yields of similar age palms on non-acid sulphate soils are included for comparison.

Table 2. Yield comparison of 1966-1973 oil palm plantings on acid sulphate and non-acid sulphate soils

		Mean yield (tonnes ffb/ha)		
Category of acidity	Area (ha)	3-5 yr.	6-8 yr.	9-11 yr.
Moderate	1319	19.94	25.85	26.07
Non-acid sulphate	1051	21.45	28.19	25.75

It is apparent from Table 2 that yields of subsequent oil palm plantings established on acid sulphate soils with appropriate raised watertable policy from commencement of planting have been similar to those of plantings on non-acid sulphate soils. There are no comparative data for plantings on severely acid soils.

5 Current recommendations for water management of acid sulphate soils

The proper management of drainage and irrigation is crucial in relation to oil palm performance in hyperacidic subsoil conditions. The problem of drainage is two-fold. Free drainage conditions will result in the intensification of acidity while inadequate drainage will give rise to flooded conditions, both of which will adversely affect palm performance.

The appropriate drainage intensity within fields depends largely on soil characteristics such as permeability and water retention, which are dependent on soil texture and structure. Acid sulphate soils in Peninsular Malaysia are generally heavy textured and occur in low-lying situations. As such, they require the installation of an extensive drainage system prior to oil palm cultivation.

The drainage system on acid sulphate soils involves a network of field drains running parallel to palm rows which drain into collection drains.

The collection drains are in turn connected to the main drains which lead directly to the tide gate and the outlet drain beyond. This pattern of drainage is illustrated in Figure 2.

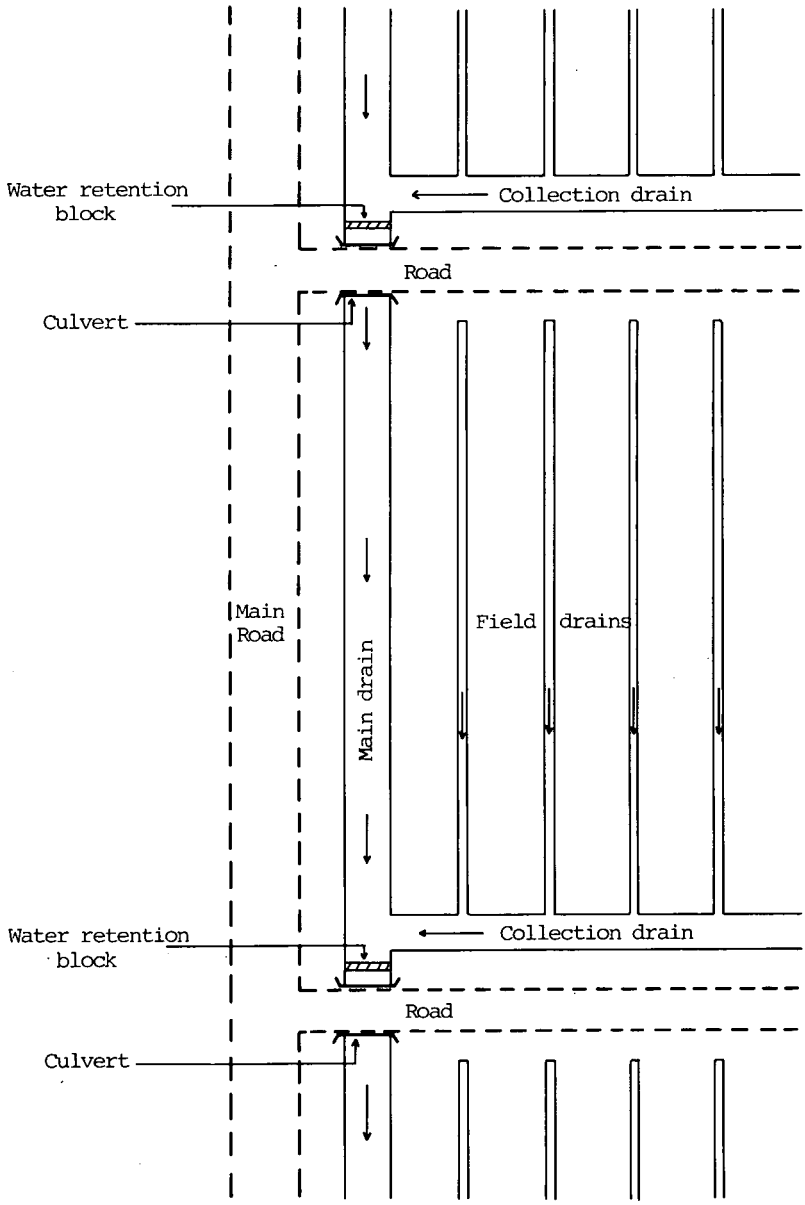

Figure 2. Schematic diagram of drainage system

Typical dimensions for the field, collection and main drains are given below:

Type of drain	Width (m) At top	Width (m) At bottom	Depth (m)
Field	1.00	0.45	0.75
Collection	2.00	0.60	1.50
Main	3.30	1.20	1.80-2.40

The field drains are spaced between 6 rows of palms or 47 m apart while the collection drains are located 396 m apart. The main drains are located 738 m apart. To obviate flooding, the drain dimensions must be varied according to the volume of water offtake necessary during wet weather conditions, as determined by observations in situ.

While the width or intensity of the field drains can be varied according to circumstances, the depth of these drains must not exceed 75 cm, otherwise there is a risk of accelerated oxidation of the pyritic layer during dry weather conditions.

The main requirements in the management of acid sulphate soils is that the watertable should be raised and maintained above the pyritic layer for as long as possible. To achieve this, the main drains must be blocked at various points along their length by weirs. These may be built by using soil bags, i.e. soil packed in used fertilizer bags, or by the construction of sluice gates. From experience, these water retention blocks are best constructed next to the culverts at a point close to where the collection drains meet the main drain. At this location the culvert face will assist in minimizing water leakages through the blocks. Normally the watertable in acid sulphate areas is maintained at about 60 cm from the soil surface.

With the location of the water retention blocks as described, it will usually be unnecessary to place any more blocks in the field drains. However, in situations where the slope of the land is uneven, it may be necessary to place soil bags at various points along the field drains to maintain the watertable.

In many situations, despite placement of water retention blocks, the watertable is not expected to remain at the required level throughout the year because of seasonal dry weather. In practice, the watertable

will fluctuate, though ideally water should be visible in the field drains throughout the year. From observations, the watertable can be maintained at a reasonable level for up to a month into the dry season, but this will largely depend on soil texture and structure.

The fluctuating watertable does not completely prevent oxidation. During the rainy periods, acid accumulation in the ground water is decreased by regular precipitation and removal of acids through the drains. The problem becomes acute during prolonged dry spells when fresh water is not available and the acid concentration increases progressively owing to evapo-transpiration and accentuated oxidation of pyrite.

In practice, the problem of acidity build-up is minimized by periodic flushing of the drains during the wet season, which is achieved by opening up the sluice gates and soil blocks. Well before the end of the wet season, when rainfall is still virtually assured, the sluice gate and blocks are set in place. Fresh water is then allowed to build-up again to the required level, before the dry spell sets in. One to two flushings during the wet season are normally adequate.

6 Discussion

The profound influence of proper water management on the productivity of oil palms grown on acid sulphate soils may be associated with improvements in conditions suitable for root development. With a raised watertable, the secondary and tertiary roots are generally concentrated close to the watertable and primary roots that penetrate to greater depths during the drier periods produce upward-growing secondaries and tertiaries. When the watertable recedes during dry weather, roots are apparently able to proliferate through less toxic areas in the moist acid horizon to reach the watertable below. In contrast, in freely drained acid sulphate soils, few roots can penetrate the apparently less differentiated acid horizon to reach the watertable. Primary roots that happen to penetrate the acidic horizon produce very few secondaries and tertiaries and are usually stunted due to excessive soil acidity. Root spread is also much restricted and the bulk of roots are concentrated close to the bole of the palm. Consequently, oil palms grown in freely drained acid sulphate soils are unthrifty and frequently exhibit symptoms of

moisture stress and multiple deficiencies.

Reservations had previously been expressed on the risk of incurring H_2S toxicity problems owing to anaerobic conditions brought about by maintaining a high watertable over prolonged periods. However, in field practice it is rarely possible to maintain a constant watertable and levels fluctuate throughout the year depending on rainfall distribution. Hence, no problems with H_2S toxicity have been encountered over the last fifteen years and it appears unlikely that such a problem will occur in the foreseeable future.

In addition to proper water management, a rational manuring programme must be implemented if palm yields are to be optimized. Bunch ash, derived from burning empty oil palm fruit bunches, is used almost exclusively as the source of potash in acid sulphate areas. Its highly alkaline reaction contributes to pH improvements in the topsoil. Studies have also shown that bunch ash improved soil moisture retention properties, this being associated with partial destruction of the crumb structure in the topsoil (Yeow et al. 1977).

7 Conclusion

There is a relationship between oil palm yields and the depth at which the acidic horizon occurs. Acidic horizons below 90 cm have virtually no effect on palm yields. On the other hand, where the acidic layers occur within 60 cm of the soil surface, yield levels will be reduced. Fortunately, such areas of severe acidity are usually discontinuous and reclamation of acid sulphate areas as a whole for oil palm cultivation is highly economic.

The recommended drainage pattern, with the location of water retention blocks at strategic points as described, has improved the yield performance of oil palms considerably over many years. It is now envisaged that there are relatively few problems with the growth of oil palms on acid sulphate soils provided that the pyritic horizon is not too shallow and the areas do not experience prolonged dry spells.

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