HYDRAULICS OF TILE DRAINS IN PEAT AND MUCK SOILS

BY

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THESIS

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REQUIREMENT FOR THE DEGREE

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Kelappaji College of Agricultural Engineering and Technology
TAVANUR — MALAPPURAM

1989

DECLARATION

I hereby declare that this thesis entitled "Hydraulics of tile drains in peat and muck soils" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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Thavanur

April, 1989

CERTIFICATE

Certified that this thesis, entitled "Hydraulics of tile drains in peat and muck soils" is a record of research work done independently by Sri.T.D. Raju, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

SYMBOLS AND ABBREVIATIONS USED

cm	:	Centimetre(s)
cm/year	:	Centimetre per year
$D_{15}F$	:	Size of particle in filter, 15% passing sieve
$D_{85}S$	:	Size of particle in soil, 85% passing sieve
dS/m	:	Deci-Seimen per metre
EC	:	Electrical conductivity
Fig	:	Figure
he	:	Entrance head loss
h_{tot}	:	Total head loss
kg/ha/cm	:	Kilogram per hectare per centimetre
m	:	Metre(s)
m^3	:	Metre cube
mm	:	Millimetre(s)
mg/l	:	Milligram per litre
%	:	Percentage
re	:	Entrance resistance
t/ha	:	Tonne per hectare
wt.(g)	:	Weight in grams
$>$	:	Greater than
$<$	:	Less than

Introduction

INTRODUCTION

Land drainage is an age old practice. Agricultural land drainage is the establishment and operation of a system by which the flow of water from the soil is enhanced so that agriculture can benefit from the subsequently reduced or controlled water level on or in the soil.

Adequate drainage of crop producing lands requires a general lowering of shallow water tables. The reclamation of saline and alkali soils has many important phases, but adequate lowering of water table by drainage is the first and basic necessity.

Kuttanad is a unique agro-climatic zone comprising of 55000 ha lying 1 to 1.2 m below sea level. The cropping pattern is primarily of monoculture of high yielding varieties of paddy during the puncha season (October to February). In some of the areas of Kuttanad an additional crop is also raised during June to September. It is believed that this soil was formed and developed in the distant geologic past when the area was covered by dense forest vegetation. In the succeeding geological ages, the sea advanced and engulfed many places. After thousands of years, the sea receded exposing the coastal region and part of the present mid-lands. During the geological upheavals, the entire forest area was submerged far below the ground and thereafter silted upto varying levels.

The profile of Kuttanad alluvium consists essentially of alternating layers of clay and sand, admixed with varying proportions of organic matter. The clay is usually a grey dark or bluish black in colour. These alluvial formations exist in layers varying upto 30 metres in depth underlain by sand and mottled clay of tertiary formation. The top soil is admixed with well decomposed organic matter to the tune of 10 to 30%. But, underneath the top layer, is the partially decomposed, fibrous plant residues containing less than 50% mineral matter. In some places, large logs of wood locally known as "Kandamaram" occur embedded in the sub-soil. Beneath this layer, the soil is an admixture of sand, organic matter and clay and still deeper it becomes river sand. Presently the grain yield of rice is on an average 2.5 t/ha even after adoption of 100% high yielding varieties.

Preliminary studies conducted in such areas reveal that the soils of this region are acid saline in nature during summer season, the pH ranging between 3 to 5 and EC as high as 6 dS/m. It is also noted that these soils are high in iron, sulphate, aluminium etc. which affect the crop growth resulting in poor paddy yield.

Kuttand is a unique agro-climatic zone comprising of 55000 ha out of this Kari lands occupy an area of 7000 ha which lie 1 - 1.2 m below sea level. "Kari" soils contain large amount of organic matter at various stages of decomposition and they are basically peat and muck soils. Peat and muck soils which have unique physical, chemical and biological properties. The ordinary drainage practices that are used in mineral soils are not suitable here. As the field level is below the surrounding water level in the lake, there is always an upward movement of water from the subsoil to the surface. These soils are highly acidic, pH in many cases is as low las 3. The peat and muck soils which have been developed from the residue of trees and shrubs deposited. there thousands of years back contain organic matter in various stages of decomposition in the subsoil. The upward movement of water from the subsoil brings along with it harmful byproducts of decomposition of organic matter which when come into contact with roots of plant adversely affect them. Yield has been consistantly poor in this area.

The present methods practiced by farmers for removing the harmful effects are:

1) Keeping the water table down by pumping the water from open drains.
2) Washing the surface soil with fresh water intermittantly.
3) Application of soil ammendments like lime and dolomite.

These methods are inadequate to produce high yields, which the new varieties are capable of giving.

The surface drains are widely spaced and their effects are only felt in the nearly areas. Closely spaced surface drains will not only be a hinderance to all farm operations, but also will occupy too much land. Their maintenance will be not economical.

Top soil is made free of toxic salts by surface washing but in the deeper root zone the harmful effects continue. The upward movement of salt into the root zone also cannot be checked.

The adverse effects are only reduced by adding soil ammendments and not eliminated.

It is felt that tile drains can be very effective under such conditions. The advantages of tile drains are:

1) The drain embedded below 60 cm depth will not cause any hinderance to farm operations and hence there is no restriction for closer spacing of tile drains other than cost.

2) Tile drains can effectively check the upward movement of water and toxic salts into the root zone.

3) By letting in fresh water on the surface and by allowing it to seep down into the tile drains, the toxic salts can be removed from the root zone.

4) Tile drains once laid can give trouble free service for a long time.

In order to ascertain the effectiveness and economic viability of the subsurface drainage experiment, a field study was undertaken in the farmers' fields at Kavil Thekkumpuram Padasekharam, Karumady, Alleppey District, Kerala. The main objectives of the study were:

1) to determine the suitable filter material
2) to evaluate and select suitable material of tile drains
3) to determine spacing of tiles.

Review of Literature

2. REVIEW OF LITERATURE

The works related to different types and effects of agricultural drainage, purpose, design and functioning of envelope material, selection criteria for determination of suitable envelope material and field experimental studies on subsurface drainage are reviewed in this chapter. The review is presented under following headings.

1) Different types and effects of agricultural drainage
2) Purpose, design and functioning of envelope material
3) Selection criteria for determination of suitable envelope material
4) Field experimental studies on subsurface drainage system.

2.1. Different types and effects of agricultural drainage

Different types and effects of drainage on agriculture as reported by Oosterbaan (1988) are:

Internal and external drainage

To enhance the flow of water from the soil, one must perform internal and external drainage for respectively dewatering of the soil and disposal of the water. This leads to the establishment and operation of field drainage and collector or main drainage system.

Surface and subsurface field drainage

A field drainage system is a drainage system made to enhance the flow of water over or though the soil, giving respectively a surface and a subsurface field-drainage system.

Preventive and occasional field drainage

In field-drainage, it is important to discern preventive drainage from occasional drainage. The first type of drainage system serves to prevent water-logging or high water tables. It is the most common type of field drainage. Occasional drainage is not practiced to prevent water-logging, but to remove water from the field on certain occasions only. In irrigated rice basins, drainage can be required to make the fields dry only for harvest operations or salinity control. Otherwise, drainage would mean a waste of water and hence it needs to be checked. Occasional field drainage, therefore, can also be called check drainage. If, on the other hand, rice basins need drainage during periods of high rainfall, a preventive rather than an occasional field drainage system is required.

Surface relief and interception drainage

Surface interception drainage is meant to intercept the runoff from a field before it reaches the next field whereas relief drainage is meant to remove water from the field that would otherwise remain stagnant on the soil.

Surface interception drainage occur mainly in slopping land and mostly serves the purpose of erosion and flood control.

Surface relief drainage

Surface relief drainage is done by land shaping. In slopping land, the soil surface is given a regular gradient to avoid stagnation of water on the surface. The grade should not be so steep to cause erosion. Shallow collector (intercepter) drains must be made at regular intervals to avoid large flow of water over the soil down slope and also to transport the water elsewhere. These drains do not belong to the field drainage system, but to the collector drainage system.

Subsurface relief drainage

Subsurface relief drainage is meant to get rid of water that infiltrates into the soil and raises the water table.

Horizontal subsurface drainage system

Drainage by mole channels, tiles, pipes or ditches is often called horizontal subsurface drainage, because these drains are laid (almost) horizontal and the flow of water in the drain is (almost) horizontal. The flow of ground water to the drain is not necessarily horizontal. This type of subsurface drainage is called gravity subsurface drainage because the flow in the drains occurs by gravity; suction is not applied.

Vertical drainage

Drainage by wells is often called vertical drainage because the water moves vertically in the wells. The flow of ground water to the well is not necessarily vertical. Vertical drainage is done mostly by pumping or lifting the water, which occurs against the force of gravity.

Subsurface interception drainage

Subsurface interception drainage is designed to intercept upward seepage of ground water before it reaches the rootzone. Subsurface field drainage systems can fulfill relief and interception function at the same time but normally one of the functions dominates over the other.

External drainage

The external drainage system consists of pipes or canals (the collector drains) that receive the water from the internal system and pipes or canals (the main drain) that transport the water to the outlet of the area.

Deep and shallow collectors

In subsurface field drainage by gravity, one needs deeper collector drains (i.e., drain with a normal water level below the soil surface) to facilitate the outflow of water from the internal drains into the collectors.

Cutoff drains or catch canals

Cutoff drains or catch canals are surface interceptor drains that are made to receive laterally and runoff water from the higher areas surrounding the drained land. These canals belong to a flood protection rather than a drainage scheme.

2.1.1. Analysis of effects of drainage on agriculture

The objectives of land drainage are to reclaim and conserve land for agriculture, to increase crop yield, to permit the cultivation of more valuable crops, to allow the cultivation of more than one crop a year, and/or to reduce costs of production. These objectives are obtained through direct and indirect drainage effects.

The direct effects of the installation of a subsurface drainage system in water-logged lands are:

i) A lower average water level on or in the soil.

ii) A discharge of water from the system.

The direct effect of the installation of a subsurface drainage system in water-logged lands is a lower average water level on or in the soil and a discharge of water from the system. The direct effects are determined mainly by hydrological conditions, the hydraulic properties of the soil and design characteristics of the drainage system. The indirect effect, in addition, is determined by climate, soil, crop, agricultural practices and the social or natural environment. The indirect effect can be divided into positive effects (benefits) and negative effects (damages)

i) Positive effect owing to discharge: are removal of salts or other harmful substances from the soil; (re)use of drainage water.

ii) Negative effects owing to discharge: are down stream environmental damage by salt or otherwise polluted drainage water; and the presence of ditches and canals interfering with other infrastructure of the land.

iii) Positive effects owing to lowered water levels are: increased aeration of the soil; improved soil structure; better nitrogen balance in the soil; higher or more varied crop production; better workability of the land; earlier planting possibility; reduction of peak discharges by increased storage capacity of the soil.

iv) Negative effects due to lowered water levels are: decomposition of peat soils; soil subsidence; acidification of cat clays; increased risk of drought; ecological damage.

2.2. Purpose, design and functioning of envelope material as reported by Stuijit *et al.* (1986).

2.2.1 General

The reasons for placing an envelope material around subsurface drain pipes are to prevent the movement into the drains of soil particles which may settle and clog the drains; to provide material in the immediate vicinity of the drain openings that is more permeable than the surrounding soil, leading to lower drain entrance resistances; to provide suitable bedding for the drain and to stabilize the soil material on which the drain is being laid.

The materials are called 'envelopes' rather than 'filters', because a filter is by definition a porous mass through which fluid passes in order to separate it from matter held in suspension. A drain wrapped with a filter would be self-defeating, because soil particle and aggregates would be deposited on or in such a filter, reducing its hydraulic conductivity. Suspended clay particles should pass through the envelope. The relatively coarse envelope material should stabilise the soil material mechanically and hydraulically but it should not act as a filter.

A variety of materials have been placed around subsurface drains as envelopes: almost all permeable porous materials that are available economically in large quantities are suitable envelope material for subsurface drainage.

They can be divided into three general categories: organic, inorganic and synthetic. On the other hand, many thousands of kilometers of subsurface drains have been installed without the use of any kind of envelope material and are working satisfactorily. The soil in which these drains are installed is stable and presents no problems.

In irrigated areas the soils can be quite unstable especially at the greater depths of installation used in irrigated areas and where the soil contains appreciable amounts of sodium on the base exchange complex. Under these conditions it is essential to use some means of preventing the movement of soil into the drain pipe. For this purpose, an envelope can be placed around the pipe. The envelope should be designed in such a way that it will permit fine clay particles to move through the envelope but will prevent the larger particles of sand from moving along with the clay. If the envelope is too effective as a filter, clay particles will collect on the outside of the envelope and will cause it to become impermeable.

2.2.2. Hydraulic aspects of envelopes

If a very permeable envelope is applied to the pipe it can lead to a lower flow resistance for two reasons:

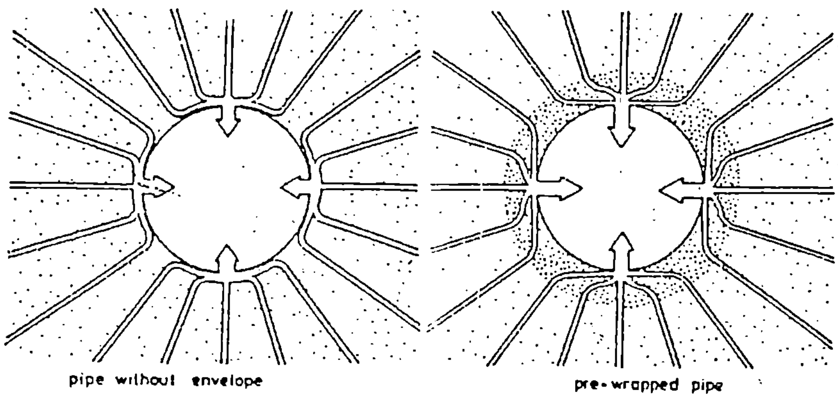

Fig.1. Schematic representation of the flow pattern for a completely submerged drain

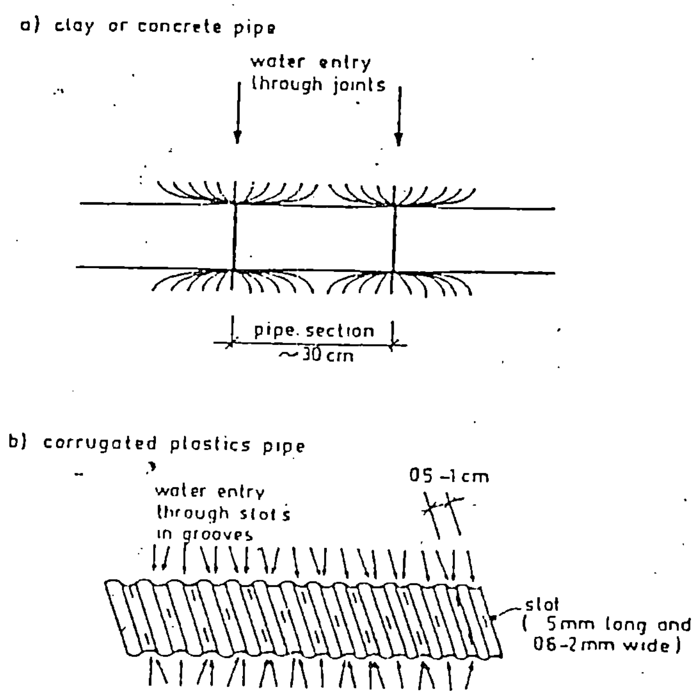

Fig.1(a) Schematic representation of entry flow patterns for clay/concrete pipe and for corrugated plastic pipe (after Smedema and Rycroft, 1983).

i) the external radius, the effective radius is increased and, thus, the contact area between the bed material and the drain is in turn increased

ii) the flow towards the perforations is eased.

Both these effects, for a voluminous envelope material, assuming that the drain is completely below groundwater level and the representation of entry flow patterns for clay/concrete pipes are shown schematically in Fig. 1 & 2.

It is obvious that, in this respect, a voluminous material, which has a thickness exceeding 5 mm, has a lower entrance resistance than a thin material (Nieuwenhuis and Wesseling, 1979). The effects of an envelope however should not be exaggerated, while a good voluminous envelope cannot compensate for the structural deterioration of the bed around the pipe drain. As already stated, more can be expected from a voluminous envelope than from a thin one.

2.2.3. The mineral clogging mechanism

Due to the drag force of the water at the interface between the soil and a drain pipe, soil particles may be carried into the pipe via its perforations. This process can never be prevented completely, but can be counteracted by installing an envelope material, often a geotextile, around the drain.

Generally, two sequential types of mineral clogging can be detected after installation of a drainage system. These are referred to as primary and secondary mineral clogging. Primary clogging is a consequence of the sudden drastic changes in the soil/water boundary conditions, caused by the very installation of the subsurface drainage system, and the resulting water flow, including particle transport due to the high hydraulic gradients towards the newly installed pipes. Secondary clogging is defined as particle transport into envelopes and/or pipes, in the long run: a yearly mineral clogging 'cycle' can, in fact, be detected in some soil types. Mineral clogging starts to develope at the interface between the geotextile (or pipe wall) and the adjacent soil. It is therefore defined as a contact process.

The mineral clogging risk is determined primarily by (relations between) envelope and soil properties. Regardless of time, two clogging mechanisms can be distinguished: contact erosion which occurs when particles of nearly all sizes are washed out locally and contact suffosion when only the fine particles are washed out leaving a skeleton, consisting of coarser particles, behind.

In subsurface drainage systems, contact erosion should be restricted. Contact suffosion is allowed, provided however that the envelope does not clog. It should, in fact, be stimulated to a certain extent because it leads to the development of a natural soil filter since the fine particles are removed from the soil adjacent to the geotextile and washed into the drain. The development of such a natural soil filter enhances the efficiency of the drainage system due to its increased hydraulic conductivity leading to a lower radial and entrance resistance.

In the case of subsurface land drainage systems, however, geotextiles are becoming more and more preferred rather than granular envelopes, mainly for economical reasons and because of the fact that appropriate granular materials are often not available locally. A number of filter criteria has been proposed for fibrous envelopes, made of organic materials as well as geotextiles, but generally these are not universally applicable. (Knops etal., 1979; Dierickx,1980; Irwin and Hore, 1979; and Eggelsmann, 1980).

2.2.4. Chemical and microbiological aspects of the soil

Generally, drainage systems constructed from geotextiles have a service life expectancy of, as a rule, 30 years. Synthetic materials should have a very long service life and should be inert to normal concentrations of the chemicals which occur in the soil and ground water. Usually this can be achieved by using the correct raw materials in the manufacturing process. The raw materials most commonly used for envelopes are polypropylene, polyamide and polystyrene and polyster ('nylon').

The functioning of the geotextile can be endangered by deterioration or clogging due to chemical, microbiological and/or mechanical processes. The risk of clogging due to iron, lime and sulphate compounds is dependent on the chemical composition of the soil and the ground water, the microbiological activity in the soil, the environmental conditions (aerobic/ anaerobic) and the structure and the surface character of the geotextile.

The chemical composition of the soil and the ground water

The iron compounds in the soil and ground water, in practice, cause the maximum problem. Data, published by Kuntze and Eggelsmann (1974) indicate how the danger of iron deposition can be determined. A method, developed by Ford (1983) makes it possible to establish the danger to a higher degree of accuracy. It is important to know whether or not the source of clogging is permanent. This is the case, for example, with seepage containing iron compounds. In such cases, it is necessary to counteract from clogging at regular intervals. In the Netherlands this is achieved by jetting the pipe drains.

Microbiological activity in the soil

Microbiological activity plays a decisive role in the development of iron compound clogging. Certain kinds of bacteria convert iron compounds into slimy products which can clog the pipe and the filter material. This happens particularly when there is ample oxygen available. The most recent studies carried out on this subject are in France (Houot, 1985) but conclusive solutions are still to be found.

Environmental conditions (aerobic/anaerobic)

Iron compound clogging seems to occur mainly in oxygen-rich environments. This has occurred on many occasions in the Netherlands where open collectors (ditches) are used almost exclusively. As a result oxygen can enter the drains via outlets in the trenches; iron compound clogging is the strongest where the drain section has its outlet into the ditches.

The structure and surface character of the geotextile

Too little is known about this aspect. Experiments have shown that some geotextiles, especially thin ones, are clogged more quickly than others by (bio) chemical causes. Ultimately all materials will be clogged and its is recommended that whenever danger of clogg ing exists, for the reasons mentioned above, in any case thin materials should not be applied. This is because they will be clogged quickly and cannot be cleaned very effectively by jetting. With voluminous materials this is often still possible.

2.2.5. Characteristics of organic, inorganic and synthetic envelopes

Organic materials that are sometimes byproducts of agricultural production are often used as envelope materials. Two common materials are coconut fibres and straw, but organic materials are sawdust, widely used in Denmark, peat fibres and litter, used on reduced scale in the Netherlands, woodchips, reeds, heather and corncobs. In a laboratory experiment by Cavelaars (1966), all of the various organic envelope materials compared improved drainage. Peat litter was about hydraulically equal to a single thin fiberglass sheet.

Inorganic materials - the practice of blinding or covering subsurface drains with a layer of topsoil before backfilling the trench actually provides many drains with permeable envelope material. In stratified soils, drain pipes are blinded with the coarsest material. In the Netherlands, blinding with top soil is no longer recommended because of its high organic matter content that may result in biochemical clogging. The practice of blinding has developed into the concept of using granular envelope materials. In several countries, blinding is a standard recommended part of drain installation, notably in humid regions (Hore et al., 1960). The most widely used inorganic envelope materials are naturally graded coarse sand and fine gravels. These materials have a long service life expectancy but the availability is sometimes problematic. Granular envelopes are expensive and, as a consequence, incompetitive in most cases.

Synthetic materials: The unavailability of natural sand and gravel for use as envelope material in some areas, e.g., the Netherlands, has prompted the search for synthetic drain envelopes. A mineral, man-made material, that has received mucj attention in the 1060s was fibreglass sheet.

It is relatively cheap and can be manufactured in large quantities of exact specifications. In the Netherlands, this material is still used in a restricted area. In the last decade, synthetic materials, often called geotextiles, are getting increasingly popular. Geotextiles are subjected to field and laboratory testing.

2.2.6. Design of inorganic granular envelopes

The movement of soil particles and aggregates in a man-made soil-hydraulic system has been a problem for many years. Terzaghi (1948) developed a mechanics-based theory on the piping and seepage forces that develop beneath hydraulic structures. He developed 'filter' criteria which have since been tested for applicability for envelopes. He recommended that the 'filter' material be many times more pervious than the soil base material but that it should not be so coarse that the base material would move into and through the 'filter'.

Design criteria for granular drain envelopes have been developed by the British Road Research Laboratory, the U.S. Soil Conservation Service and the U.S. Bureau of Reclamation through careful experimentation. The emphasis is on the filtering function. The USBR criteria allow use of somewhat coarser material but both have important restrictions on the quantity of fine materials permitted in the 'filter'.

The criteria of the U.S.Bureau of Reclamation (1978) are set out in Table-1. They are based upon the analysis of the grain size distribution of the base material, expressed by the D60 value (the sieve aperture which lets 60% of weight of the soil pass through).

2.2.3. Selection criteria for determination of suitable envelope material

The theory postulated by Spalding (1970) was considered for selecting the envelope material. Spalding (1970) suggested that the most reliable criteria for the design of filter are those of the United State Water Ways Experimental Station. These criteria establish the desired range of particle sizes of a granular envelope in relation to the soil, which is to be drained. For stability of the envelope, following criteria have been formulated by Spalding.

1. $D_{15}F \leq 5 \times D_{85}S$

2. $D_{15}F \leq 20 \times D_{15}S$

3. $D_{50}F \leq 25 \times D_{50}S$

4. $D_{85}F \geq 5 \times D_{50}S$

where $D_{15}F$ is the size of particle in filter, 15% passing sieve and $D_{85}S$ is the size of the particle in soil, 85% passing sieve. The first three criteria represent the filtration quality and the last one represents the adequacy of the hydraulic conductivity

Table-1. Gradation relationship between base material and filter (U.S.Bureau of Reclamation 1978).

Base material 60% passing (diameter of particles, mm)	Gradation limits for gravel envelope (particle diameter, mm)					
	Lower limits percentage passing					
	100	60	30	10	5	0
0.02 - 0.05	9.52	2.0	0.81	0.33	0.3	0.074
0.05 - 0.10	9.52	3.0	1.07	0.38	0.3	0.074
0.10 - 0.25	9.52	4.0	1.30	0.40	0.3	0.074
0.25 - 1.00	9.52	5.0	1.45	0.42	0.3	0.074

Base material 60% passing (diameter of particles, mm)	Gradation limits for gravel envelope (particle diameter, mm)					
	Upper limits percentage passing					
	100	60	30	10	5	0
0.02 - 0.05	38.10	10.0	8.7	2.5	..	0.590
0.05 - 0.10	38.10	12.0	10.4	3.0	..	0.590
0.10 - 0.25	38.10	15.0	13.1	3.8	..	0.590
0.25 - 1.00	38.10	20.0	17.3	5.0	..	0.590

2.2.4. Field experimental studies on subsurface drainage system

Wesseling and Van Wijk (1957) analysed eight years of tile flow recorded at Tiffin, Ohio, USA for drains at 60 and 90 cm depth and at spacings of 9.15 and 18.3 m. They concluded that in all combinations, annual tile flow varied considerably from the year to year and the percentage variation was much greater than the annual precipitation. Tile flow at 90 cm depth was greater than the flow from tile at 60 cm depth for four month period. Similarly on the basis of the actual flow per 30 cm length, the 18.3 m spacing gave about 40% more flow than 9.15 cm spacing.

Skaggs (1963) performed an experiment on the relative effectiveness of tile and surface drainage of clay soils near Sandusky, Ohio, USA. The experiment consisted of four replication each of four treatments namely level plots with no drainage alone and combination of tile and surface drainage. The tile depth and spacing were kept as 90 cm and 12.2 m respectively. They arrived at the following conclusions.

i) A combination of tile and surface drainage system gave the best drainage performance.

ii) Tile drainage gave about the same degree of drainage as the surface drainage, except for high antecedent moisture conditions.

iii) Surface drainage reduced the amount of water removed by the tile by 43% and tile drainage reduced the amount of surface runoff by about 40%.

iv) The average rate of drop of the water table for the first three days after irrigation was maximum for the combination of tile and surface drainage.

Monke <u>et al</u> (1967) conducted a field experiment on subsurface drainage on a slowly impermeable soil in Indiana in which 13 cm dia tile lines were installed with spacing at 7.6, 15.2 and 30.4 m on a slope of 0.1% at an average depth of 90 cm. The length of drain was 107 m. Studies on the yield of corn and tile out flow were made. They reported that the corn yield was significally different with respect to the spacing of drains. In general, crop stand for 7.6 m spacing was higher than those at either 15.2 or 30.4 m spacing.

Fausey and Sehwad (1967) reported that the surface drainage system was found to compliment each other where the meadow crop was sprinkled, surface drainage reduced tile flow by 48% and tile drainage reduced surface runoff by 32% for similar moisture conditions. The following years, surface drainage reduced surface runoff by 31% and tile drainage reduced surface runoff by 51%. They provided the following practical recommendations.

i) The design runoff rates for tile or surface drainage channels could be reduced when they are installed in combinations rather than as single practices by themselves.

ii) For low rainfall intensities surface drain runoff rate for relatively flat land was higher for grass covers than for corn while the design rates for tile drains were greater for cultivated conditions (corn or raw crop) than for grass cover.

Hermsmier (1968) conducted experiments on the yield of tiles and surface drains and their effect on water table in a wet soil on a field plot in southwest Minnesota, USA to determine the relative effectiveness of tile drains and surface drains to find what peak flows and total flows can be expected. Four degrees of drainage, subsurface tile drain, surface drain, tile drain and no improved drainage were adopted. The tiles were spaced 30.4 m to a length of 60.5 m and to a depth of 107 cm. The tile diameter was 15.14 cm. These tiles were laid down along contour line to a slope of 0.2 to 0.1%. The tile drainage was installed 1.54 m offset from the centre of the surface drain. They derived following conclusions:

i) Water could enter tile lines installed at 107 cm depth in a typical depressional 'wet' soil at a rate equivalent to a drainage coefficient upto 10 cm when the water table every where in the test area was at the surface. The rate of inflow decreased rapidly as the water table in the immediate vicinity of the tile approached tile depth.

ii) With tile spaced at 30.4 m and the flow capacity based on 5.65 cm drainage coefficient, the rate of drainage was limited by the capacity until the water table midway between tile lines reached to a depth of 19.3 m.

iii) After the soil got saturated, one day was required for the water table to be lowered to 60 cm in plots with tile drains, two days were required in plots with surface drains and five days with no improved drainage.

iv) With higher intensity of rainfall, surface drains in combination with tile drainage system would result considerable reduction in peak tile flows. Surface drains were very effective in removing excess water from the soils and surface drains should be incorporated in most tile drainage system.

Hoover and Sehwab (1969) studied the effect of tile depth, spacing and cropping practices and drain discharge from their field experiment at North Central Ohio, USA. Drains were located at 60 and 90 cm at 9.15 and 18.3 m spacings. They concluded that narrow drain spacing resulted in a higher discharge than the wider spacing.

Luthin and Robinson (1969) analysed eight years of field measurements of water table and soil salinity at the University of California field station in the Imperial Valley and concluded that the depth of drainage was related to factors besides capillary rise from the water table. In soils of low to moderate hydraulic conductivity, capillary rise might only be a minor factor in salt accumulation in root zone. The major problem there was that the low soil hydraulic conductivity made it impossible or difficult to apply irrigation water to satisfy the leaching requirements. In sandy soils, of high hydraulic conductivity, normal irrigation practices easily satisfied the leaching requirements. In these soils, water movement by capillary action was sufficient for salts to accumulate in the root zone, if the soil was left fallow. Under such conditions, capillary rise from water table was probably a major source of soil salinization.

Hermsmeir (1973) performed an experiment on shallow drain performance in heavy soils. The test site was located near California in the north end of the Imperial Valley. The drains were installed at 1.22 m depth and 60 and 90 m spacing in a clay and loamy soil. The drainage removed only from 12% to 7.2% of salt added by irrigation water during four cropping seasons over a two year period. The small amount of salt removed by natural drainage was sufficient to maintain a favourable salt balance. However, during sugarbeet cropping, only 7.2% of salt added by irrigation water was removed by drains and there was an unfavourable salt balance in the field. A relatively high water table in the field was not a problem with subsurface drains and water table was seldom more than 0.25 m higher at 22.86 m from the drains. He observed that maintaining a favourable salt balance in clay and clay loam soil while using irrigation water containing 1000 ppm of dissolved salts was difficult and required good water management as well as good drainage. Subsurface drains could provide the means for removing sufficient salt from the soil to maintain a favourable salt balance when combined with natural drainage and good irrigation practice.

Yadav (1973) reported a study on subsurface drainage system in a salt affected heavy clay soils at Sirugappa in Tungabhadra project area in Karnataka. The crop yield and total quantity of salt removed were highest under the treatment where tile was placed at 1.2 m depth and at a spacing of 12 m. There was improvement with wider spacing of 36 m but it was slow.

Sehwab _et al_. (1975) studied the effect of tile spacing on crop yield and water level in a clay soil. Tile spacings were kept at 4.56, 9.15 and 18.3 m. These were installed at 75 to 90 cm depth. They concluded the following points after six years of field study.

i) Corn and oat yields were higher in the 4.56 m and 9.15 m tile drain spacing respectively than 18.3 m spacing. A little evidence of any difference in yields between the 4.56 m and 9.15 m spacing was achieved by variance analysis.

Narayana and Kamva (1980) conducted a field study of subsurface at the Bidag Farm of the National Dairy Development Board, Anand, in Gujarat State which has a problem of inland salinity and low productivity. In one of the worst affected soils, an experiment with closely spaced open drains at 15, 20 and 25 m spacing at an average depth of 1.5 m was initiated in June, 1978. They concluded their field study as follows:

i) The soil salinity (EC) was reduced from 3.85 dS/m in November, 1976 to 0.325 dS/m in November, 1977 in 15 m and 20 m spacings. In 25 m spaced plots, the corresponding EC value was 0.9 dS/m.

ii) The water table levels were lowered in the study area from the near surface levels in November, 1976 to a depth of 90 cm. The lowest water table depth recorded in November, 1979 was 120 cm in the 15 m spacing drainage plot.

Pandey and Gupta (1981) conducted an experiment on evaluation of drainage methods and leaching criteria for saline soils in Rohtak region, Hariyana. They found that, on an average, about 0.77 t/ha of bajra yield was obtained from the drained plots whereas there was complete failure of crops in the undrained plots. The salt content during first wheat crop was substantially high because of which, poor yields were recorded. During monsoon season because of enough underground drainage, salts were almost drained from the root zone of bajra crop and a good crop yield was recorded. During this crop, undrained plots also gave an average yield of 0.75 t/ha on bajra. This was because of leaching of salts from soil due to water accumulation in the monsoon period.

Fausey (1984) from his field study of subsurface drainage installed at 45 to 50 cm depth in silt loam soil with good surface drainage, measured water table fluctuations, drain flow rates, drain water quality and corn yield for a period of three years. Water table draw down from datum line was detected to around 6 m. The drain showed minimum sediment accumulation, no structure deterioration and good quality outflow water.

Gupta (1984) studied evaluation of drainage and leaching criteria for saline soils in Rohtak region. Tile drainage system was installed at Sampla in 1979-80. Two spacings 20 m and 50 m were practised. Cropping was started from Kharif 1980 and continued for four years. He observed water table draw down rate for four years, which indicated that tile drains at 50 m spacing could lower the water table to 1 m from an initial water level of 65 m within a period of 2-3 days. He also concluded that natural drainage rate in the area could be substantially improved by providing subsurface drainage. The soil salinity was found to drastically decline. There was no non-uniformity of leaching through the soil profile in 20 m spacing (open drain) while in 50 m spacing (tile drain) as on moved away from the tile line, tendency of non-uniformity in leaching below root zone (60 cm) was observed but these differences were small, crop yield improved considerably in the drained plots over the undrained control and continued to be higher inspite of the stoppage of pumping during the last two years.

Singh and Pandey (1985) studied the effect of subsurface drainage on hydrological aspects of saline soil reclamation and crop performance in Sonepat district of Hariyana State. They concluded that:

i) In the case of undrained area, maximum possible evaporation rate was 115.5 cm/year which was reduced to 64.5 cm/year in drained area, which in turn reduced the secondary salinization.

ii) The observed recession of water table was slower compared to the theoretically calculated values. Drains lowered the water table upto 90 cm depth very effectively.

Materials and Methods

3. MATERIALS AND METHODS

3.1. Site of the experiment

The experiment was conducted in the farmers' fields of Kavil Thekkumpuram Padasekharam, a kari soil in Karumady village of Alleppey District, during the puncha seasons of 1984-85 to 1987-88.

The kari soils which lie below 1 to 1.5 m below sea level can be readily discerned by the deep black charcoal colour, due to high organic matter content. The top soil is admixed with well decomposed organic matter to the tune of 10-30%. But, underneath the top layer is the partially decomposed, fibrous plant residues containing less than 50% mineral matter. Hence these soils are both mucky and peaty in nature. In some places, large logs of wood locally known as 'Kandamaram' occur embedded in the sub-soil. Beneath this layer, the soil is an admixture of sand, organic matter and clay and to still deeper it becomes river sand. Kari soils are extremely acidic in reaction (pH 3 - 4.5) and the pH reduces further when the soils gets dried up. The fertility status of the soil is very poor. Besides these, the soil contains toxic concentrations of Fe, Al and some toxic organic products.

In these areas monoculture of paddy is only practised. Rest of the period the field is left as water fallow.

3.2. Climate

The project site is situated in tropical region with 7.6° 23' east longitude 9° 30' north latitude. This area receives a mean annual rainfall of 313 cm and most of the showers are received during the months of June, July and August (53% the total rainfall). Seventy three percent of the total rainfall is received during the period May to September. This area has a fairly uniform temperature throughout the year, comparatively hot weather is experienced from March to May.

3.3. Details of experiment

3.3.1 Determination of suitable filter material

In this experiment suitability of different filter materials were determined by sieve analysis grading curve.

River sand (big size) and sea sand were selected as envelope materials. Laboratory tests were conducted to find out the performance of these materials as mentioned hereunder.

Four samples of river sand and three samples of sea sand were tested in the laboratory. For this, sieve analyses were carried out in six different sieve sizes viz., 5.6 mm, 2 mm, 1 mm, 0.5 mm, 0.106 mm, 0.045 mm and less than 0.045 mm. River sand was tested first by putting the soil samples one by one in the top sieve and shaking for half an hour. After this, weight of the particles retained in each sieve was taken. The same procedure was followed for sea sand envelope material also.

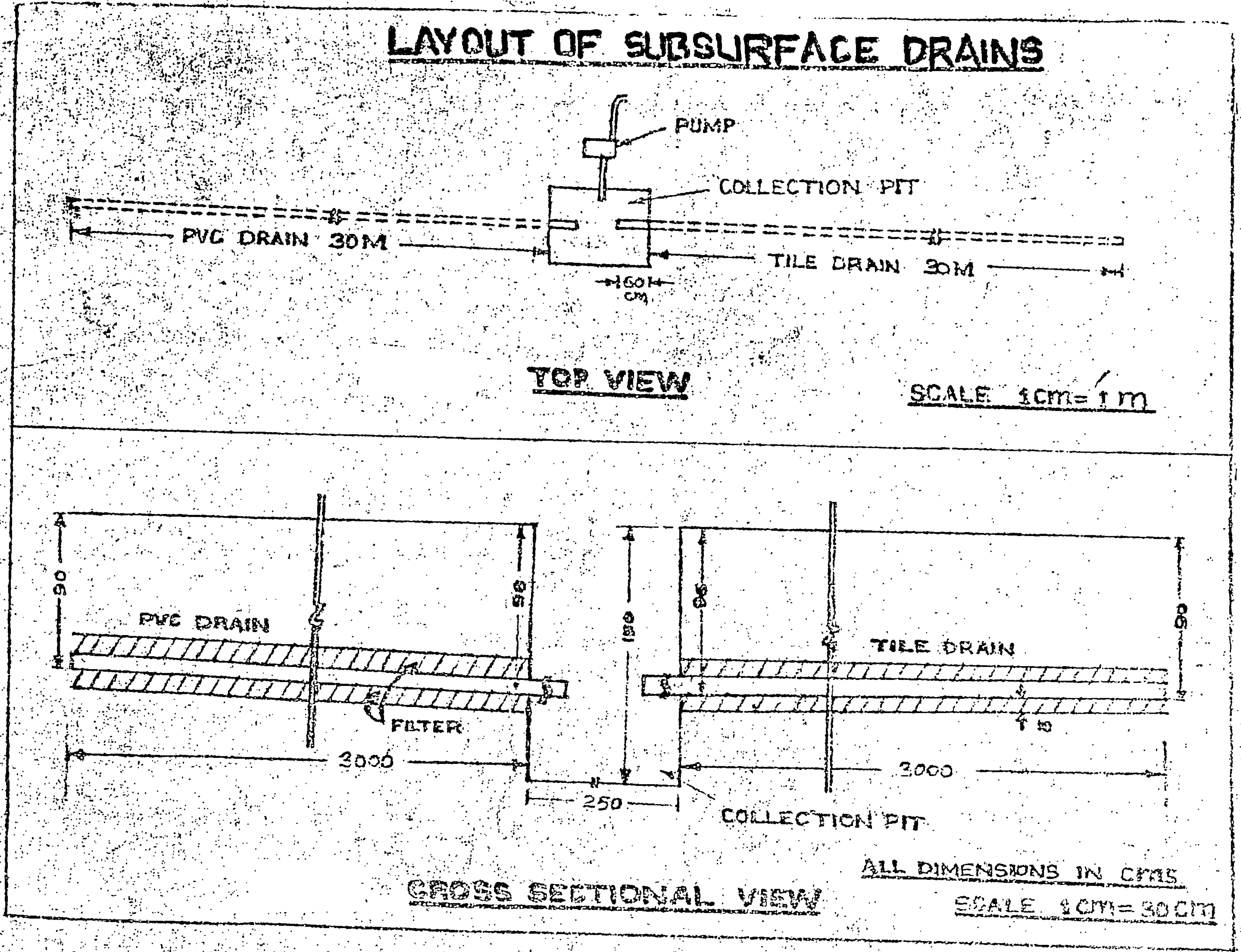

Fig.2. CROSS SECTIONAL VIEW OF THE TRENCH

For testing the base material (soil) three samples were taken from different locations of the experimental area and sieve analysis was carried out as described above. After the collection of data, graphs were drawn with cumulative % retained (y-axis) against the sieve size (x-axis).

3.3.2. Determination of suitable materials for the drains viz., PVC and baked clay pipe

In this experiment, the study was envisaged for understanding whether subsurface drains viz., PVC and baked clay pipe will function normally as desired in this particular type of soil.

Plain PVC drains were made by slotting the PVC pipe radially, with hacksaw at its 1/3rd circumferential area in two bands. The arrangement of the slots on pipe with technical details are given in Fig.2. The length and diameter of a single PVC pipe is 5 m and 100 mm respectively. Tile drains used were of 0.6 m length baked clay pipes of 125 mm outer diameter and 100 mm inner diameter with bell mouth at one end.

In the experimental area a trench was excavated with a top width of 75 cm and the bottom width of 30 cm and length 30 m. The cross sectional view of the trench is given in Fig.2. The trench was given a slope of 0.2%. The depth at the upstream end of the trench was 0.90 + 0.1 m and depth at the downstream (outlet) end was 0.96 + 0.1 m. The drain was laid at the upstream at a depth of 0.90 m and 0.10 m additional

depth was given to the trench to provide a bedding of 0.10 m of river sand as envelope. After the trench was excavated the envelope material was spread all along the trench to a thickness of 0.10 m and exact gradient of 0.2% was given to the envelope bedding. At this stage the depth of the trench was 0.90 m and 0.96 m respectively at the up and down stream. Then the drains were laid, sides were covered with envelope material to a 0.10 m thickness on each side. The top was also covered with 10 cm thick river sand. Finally trench was back-filled with the excavated earth.

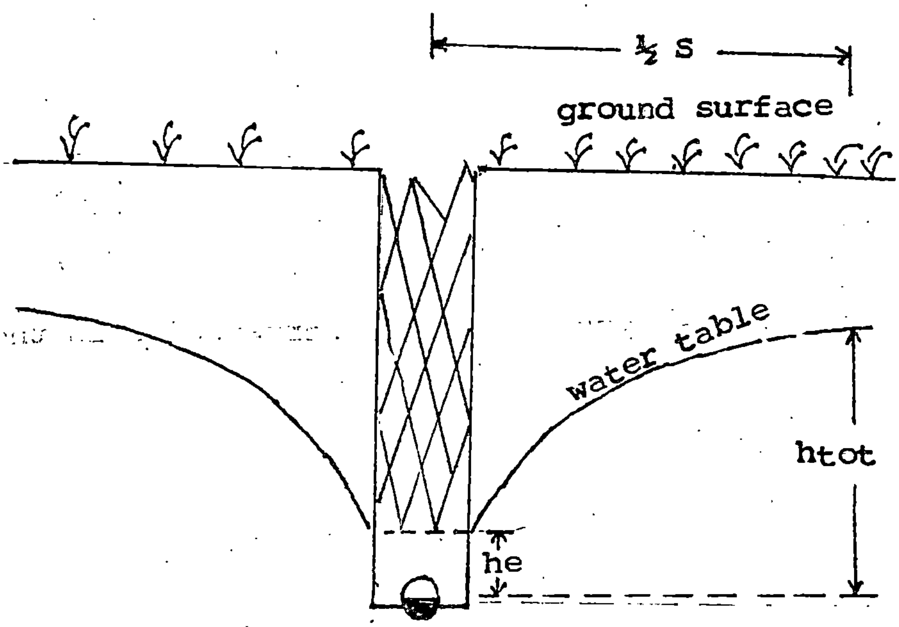

Fig.3. Entrance head loss 'he' and total head loss 'h_{tot}'

The entrance resistance (r_e) provides a suitable parameter for the examination of drain line performance. It is the entrance head loss per unit flow rate, where the outflow (Q) is measured at the end of the drain line and the head loss (he) is measured as the vertical difference between the centre of the drain pipe and the water level in a piezometer at a distance of a 40 cm away ie. just beyond the trench wall.

So head loss fraction means the ratio of 'he' to the h_{tot} (he/h_{tot}) where 'he' is the entrance head loss and 'h_{tot}' is the total head at mid-spacing ie. ½ S.

Entrance resistance

Entrance resistance is given by the formula

$$re = \frac{he}{qu} \quad \text{or} \quad re = \frac{heL}{Q}$$

where re = entrance resistance in days/metre

he = entrance head loss in metres

L = length of the drain in metre

qu = flow rate in m^3 per day and per metre length of drain

Q = QuL = total drain discharge over the length L.

The groundwater flow towards and into a drain pipe is subjected to radial and entrance resistance. These resistance depend among other things on the type of pipe and the corresponding water flow pattern in the vicinity of the pipe.

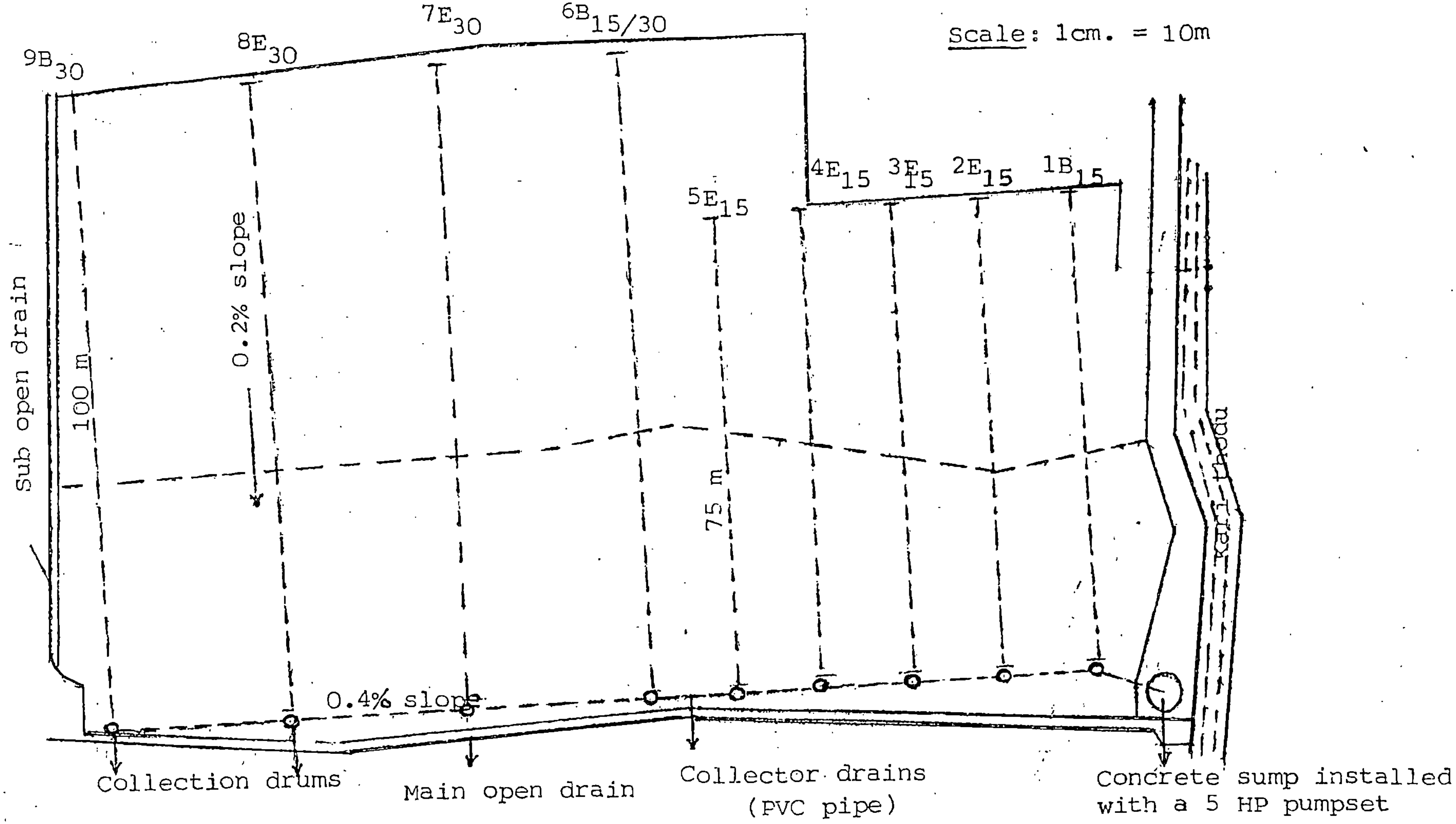

Fig.4. Layout of Tile Drains

3.3.3. Determination of spacing in peat and muck soils

In this experiment two spacing of 15 and 30 m were evaluated and compared with the control for the parallel subsurface drainage system. To conduct the study, the lines already laid out by AICRP on Agricultural Drainage, Karumady was considered. A total of nine lines were installed. Out of these lines 6 lines were of 15 m spacing and 3 lines were of 30 m spacing. The 15 m spacing lines stretched over a length of 75 m where as for 30 m spacing it was of 100 m length. For both the spacings there were buffer lines to nullify the external inflow of subsurface water. Two lines each from 15 m spacing and 30 m spacing were considered for evaluation of the hydraulic parameters. To evaluate the performance of the paddy crop the treatments were fixed as following during the puncha season of 1987-88.

The standing crop was divided into different strips of 2.5 m width along the drain line. The first strip was designated as T1 which fell within 2.5 m on either side of the centre of the drain line. The second strip T2 fell between 2.5 to 5 m on either side and T3 between 5 to 7.5 m from the drain line on either side. Hence lateral drains of 15 m spacing ahd four treatments including control with eight replications. In the same manner the drain lines with 30 m spacing had seven treatments including control with four replications. The plots were fixed in randomized manner by giving random numbers to undertake statistical analysis. The layout has been given in the Fig.4.

The methodology and experiment techniques were followed as per the "Techniques for field experiments with Rice" by Kwachai A. Gomez (1972). The paddy variety selected was "KARTHIKA" - a short duration high yielding, red kernelled variety evolved at the Rice Research Station, Moncompu of Kerala Agricultural University. The crop was sown on 25.11.'87 and harvested on 1.3.1988. All the other practices with reference to seed rate, fertilizer application, use of insecticides/pesticides etc. were followed as per the recommended package of practices for rice cultivation in Kuttanad. The pumping out of subsurface drained water was continued day and night till the harvest.

The effect of subsurface drainage on crop performance was studied and observations on the growth and yield parameters recorded vide table 7 and 8. The control was accounted from the adjacent fields where there was only surface drainage and no subsurface drainage existed. A weekly comparison of pH and EC of irrigation and subsurface drainage water was carried out during the puncha season of 1986-87. The results obtained are tabulated and discussed in detail, in the next chapter.

Results and Discussion

4. RESULTS AND DISCUSSION

The results related to selection of an envelope material, determination of suitable material of the drains (PVC & baked clay pipe) and spacing of tile in peat and muck soils are separately discussed in three stages in this chapter.

4.1. Determination of suitable envelope material

The results of the sieve analysis of river sand, sea sand and soil are given in the Tables 2, 3 & 4 and graphically represented in the Fig.4 and 5.

Table-2. Sieve analysis data of river sand envelope material

Sieve size/ wt.retained (g)	5.6 mm	2 mm	1 mm	0.5 mm	0.106 mm	0.045 mm	<0.045 mm	Total
Sample 1	121.00	207.50	380.50	245.50	457.50	4.25	13.50	1429.75
Sample 2	72.50	214.50	357.00	199.00	295.50	2.42	10.58	1151.50
Sample 3	99.00	229.00	412.50	265.50	413.50	3.83	18.17	1441.50
Sample 4	69.50	209.75	308.50	231.50	377.50	2.92	12.83	1284.50
Total	362.00	860.75	1530.50	941.50	1544.00	13.42	55.08	5307.25
% retained	6.82	16.22	28.84	17.74	29.09	0.25	1.04	
Cumulative % retained	6.82	23.04	51.88	69.62	98.71	98.96	100.00	

Table-3. Sieve analysis data of sea sand envelope material

Sieve size/ wt.retained (g)	5.6 mm	2 mm	1 mm	0.5 mm	0.106 mm	0.045 mm	<0.045 mm	Total
Sample 1	2.52	1.185	12.39	145.00	1309.00	19.50	0.370	1489.97
Sample 2	0.28	0.655	3.56	67.00	679.00	9.15	0.202	759.85
Sample 3	0.75	0.520	7.22	93.50	772.50	0.395	1.070	875.96
Total	3.55	2.360	23.17	305.50	2760.50	29.05	1.642	3125.78
% retained	0.12	0.08	0.74	9.77	88.31	0.93	0.05	
Cumulative % retained	0.12	0.20	0.94	10.51	99.02	99.95	100.0	

Table-4. Sieve analysis of base material (soil)

Sieve size/ wt.retained (g)	5.6 mm	2 mm	1 mm	0.5 mm	0.106 mm	0.045 mm	<0.045 mm	Total
Sample 1	0	0	0.045	1.875	18.116	0.597	1.681	22.314
Sample 2	0	0	0.066	1.654	19.770	1.519	1.673	24.682
Sample 3	0	0	0.555	1.410	18.871	1.540	1.719	23.595
Total	0	0	0.166	4.939	56.757	3.656	5.073	70.591
% retained	0	0	0.23	7.000	80.400	5.18	7.19	
Cumulative % retained	0	0	0.23	7.23	87.63	92.81	100.00	

The first three criteria related to the theory postulated by Spalding (1970) represents the filtration quality and the last one represents the adequacy of the hydraulic conductivity. The different particle size as per the above criteria computed from the sieve analysis grading curve Fig.5 is given below:

$D_{15}F$	=	0.25 mm	$D_{15}S$	=	0.125 mm
$D_{50}F$	=	1.00 mm	$D_{50}S$	=	0.250 mm
$D_{85}F$	=	2.50 mm	$D_{85}S$	=	0.400 mm

The design criteria are as follows:

i) $D_{15}F \leqslant 5\ D_{85}S$: 0.25 mm $<$ 2.00 mm

ii) $D_{15}F \leqslant 20\ D_{15}S$: 0.25 mm $<$ 2.50 mm

iii) $D_{50}F \leqslant 25\ D_{50}S$: 1.00 mm $<$ 6.25 mm

iv) $D_{85}F \geqslant 5\ D_{50}S$: 2.50 mm $>$ 1.25 mm

Particle size of the sea sand envelope material computed from the sieve analysis grading curve Fig.6 are as follows:

$D_{15}F$	=	0.15 mm	$D_{15}S$	=	0.125 mm
$D_{50}F$	=	0.30 mm	$D_{50}S$	=	0.250 mm
$D_{85}F$	=	0.45 mm	$D_{85}S$	=	0.400 mm

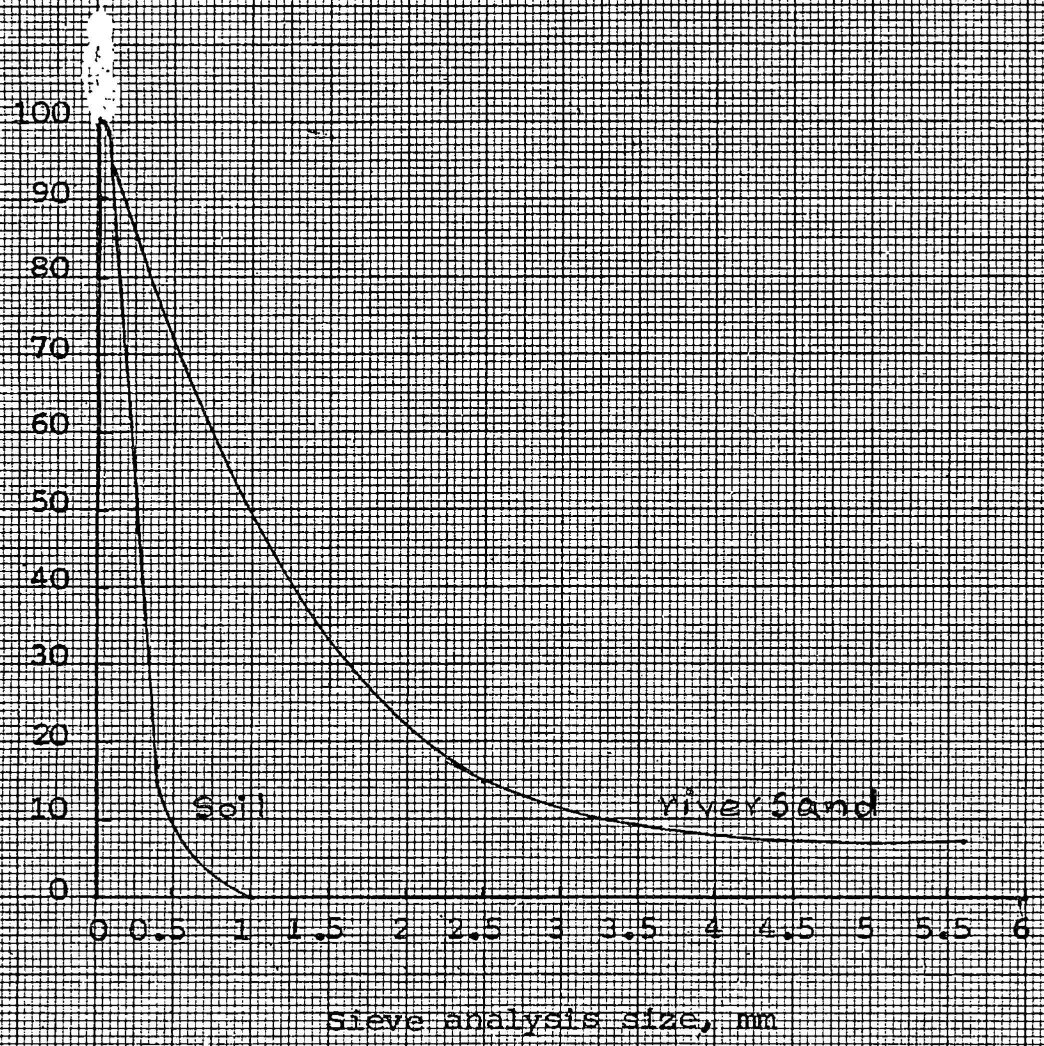

Fig. 5. Sieve analysis grading curve of soil & river sand

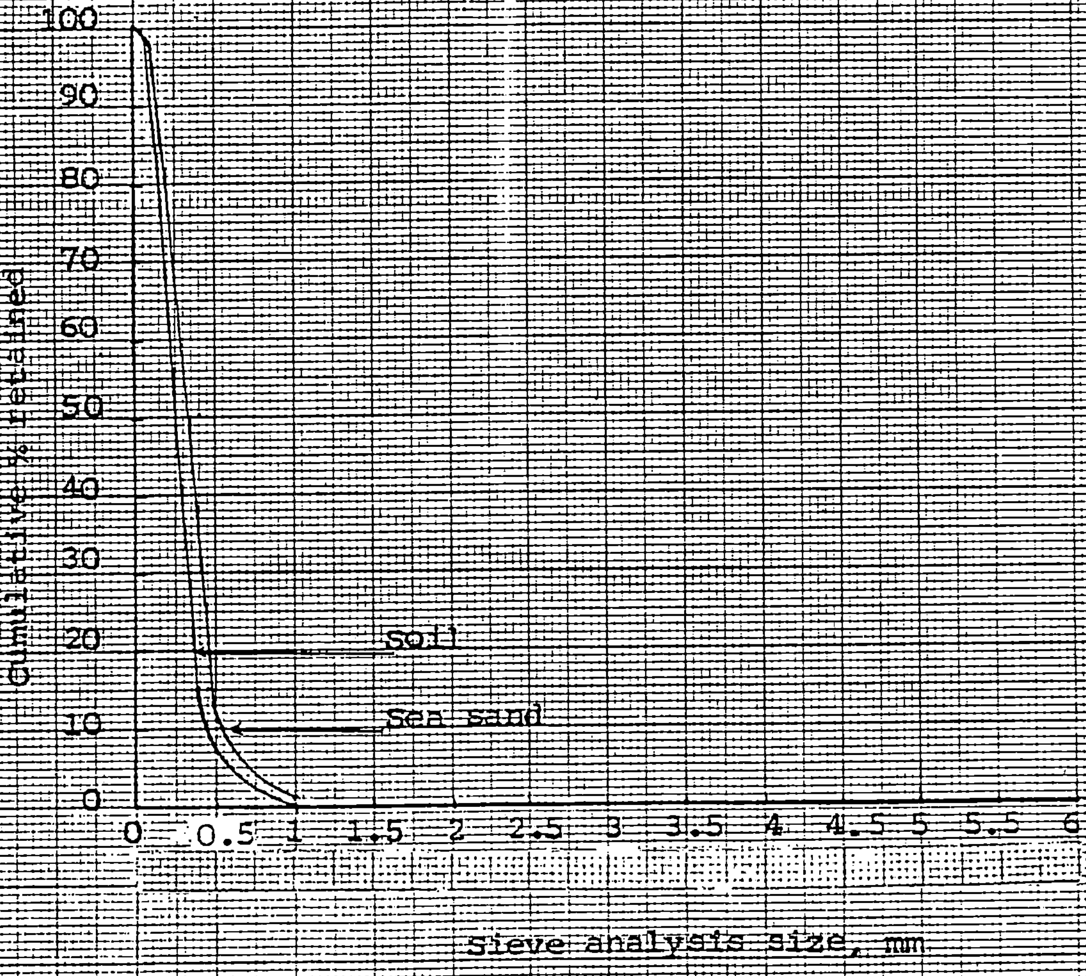

Fig.6. Sieve analysis grading curve of soil & sea sand

The design criteria of sea sand envelope material are as follows:

i)	$D_{15}F \leq 5\ D_{85}S$	:	0.15 mm	$<$ 2.00 mm
ii)	$D_{15}F \leq 20\ D_{15}S$	:	0.15 mm	$<$ 2.50 mm
iii)	$D_{50}F \leq 25\ D_{50}S$	:	0.30 mm	$<$ 6.25 mm
iv)	$D\ F \geq 5\ D\ S$	:	0.45 mm	$<$ 1.25 mm

From the above it can be seen that the last criterion which represents the adequacy of hydraulic conductivity is not satisfied in the case of sea sand. Last criterion stipulates that $D_{85}F$ should be greater than 5 $D_{50}S$.

From the above it can be seen that in the case of river sand all the above criteria have been satisfied and its quality was adequate in terms of filtration and hydraulic conductivity. Thus river sand was selected as envelope material for the rest of the experiments.

4.2 Determination of the suitable materials of the drains viz. PVC and baked clay pipes

The data collected for computation of head loss fraction is given in the table-5 and the entrance resistance in table-6.

Table-5. Comparison of head loss fraction between PVC and tile drain

hours after drainage	PVC drain			Tile drain		
	he cm	htot cm	he/ h_{tot}	he cm	h_{tot} cm	he/ h_{tot}
1	20.10	23.2	0.87	4.60	18.00	0.255
6	18.10	22.6	0.80	4.60	17.00	0.270
12	18.10	22.6	0.80	4.50	17.00	0.265
24	17.10	20.7	0.83	4.00	16.00	0.250
48	16.00	18.1	0.88	3.50	14.00	0.250
72	16.10	17.2	0.94	3.50	14.00	0.250

The general criteria recommended for assessing the drain line performance based on head loss fraction is given below:

Head loss fraction he/h_{tot}	Drain line performance
Smaller than 0.20	Good
0.20 - 0.40	Moderate
0.40 - 0.60	Poor
Larger than 0.60	Very poor

(after drainage testing FAO, Rome, 1976)

By comparing the head loss fraction of PVC and tile drain, it can be seen that the fraction is lower in the case of tile drain as per the above criteria.

As read from the table-5 the head loss fraction for the tile drain is very low and ie below 0.30 where as in the case of PVC drain it is around 0.80 for the period upto 72 hrs. of continuous drainage. Hence it is inferred from the general criteria that the performance of clay tile drain are good in the project area whereas the performance of PVC drain is very poor.

The value of entrance head loss (he) total discharge over length (Q) for the period of 72 hours of continuous pumping is given below:

Table-6. Comparison of entrance resistance between PVC and tile drain.

hours after drainage	PVC drain			Tile drain		
	he in m	Q m^3/day	re = heL/Q days/m	he in m	Q m^3/day	re = heL/Q days/m
1	0.20	2.88	2.0908	0.05	6.856	0.22
6	0.18	0.72	7.50	0.05	3.086	0.49
12	0.18	0.475	11.39	0.05	3.086	0.49
24	0.17	0.389	13.11	0.05	2.595	0.58
48	0.16	0.302	15.89	0.04	2.152	0.56
72	0.16	0.173	27.74	0.04	1.652	0.74

L = 30 m

The criteria for evaluating drain line performance based on "Entrance resistance" is given below:

Entrance resistance re - days/m	Entrance head loss (m) ie he	Drain line Performance
smaller than 0.75	smaller than 0.15	Good
0.75 - 1.50	0.15 - 0.3	Moderate
1.50 - 2.25	0.30 - 0.45	Poor
larger than 2.25	larger than 0.45	Very poor

(after drainage testing FAO, Rome, 1976)

The values given in the table-6 show very low entrance resistance for tile drains. As read from the above table the entrance resistance of PVC drain is very high from the starting of continuous drainage and stands above 2.00. From the criteria already established by F.A.O. it can be seen that the performance of PVC drain is very poor compared to the tile drains.

In the case of tile drain, the entrance resistance value is below 0.75 upto 72 hours of continuous drainage. The low value of resistance that stands below 0.75 in the case of tile drain indicate the good performance of tile drain in the project area.

From the above discussion it is evident that very high resistance is offered to the intake of water into PVC drains. This may be because the slots of the PVC drain get clogged due to iron precipitation.

4.3 Determination of spacing of tiles in peat and muck soils (15 and 30 m spacing)

The results obtained with regard to crop growth parameters, yield and yield attributing characters are given in table-7 and 8.

a) No.of plants/m^2

There was no significant difference between the treatments in the case of number of plants per unit area. This may be due to the long period of water submergence in the field, preceeding the crop which lowered the ill-effects of both acidity and salinity.

b) Height at maturity (cm)

In the case of 15 m spacing the height did not differ significantly between the treatments. But in the case of 30 m the data in table-8 clearly indicate that there is significant difference and all the treatments with subsurface drainage were on par and significantly superior to the control.

c) Panicle length (cm)

The panicle length both in the case of 15 m and 30 m spacings the drained plots were significantly superior to control plot.

d) No.of grains/panicle

The data in the table-7 show that there is a significant difference in the number of grains/panicle between the treatments in the case of 15 m spacing. The treatments with the subsurface drainage were found to be significantly superior to control. There was no significant difference between treatments in the case of 30 m spacing.

Table-7. Mean values of plant growth and yield attributing characters (15 m)

Treatment No.	Treatment	No. of plants/ m^2	Ht. at maturity cm	Panicle length cm	No. of grains/ panicle	100 grain weight g	Chaff %	Grain yield t/ha	Straw yield t/ha
1.	2.5 m from drain line to either side.	137.50	97.16	20.56	105.73	2.57	15.50	5.46	5.99
2.	2.5 m to 5 m on either side.	143.75	89.25	19.72	93.44	2.67	20.25	4.59	4.86
3.	5 m to 7.5 m on either side.	126.25	95.26	20.42	96.14	2.60	20.50	4.88	5.28
4.	Control (No drainage)	107.50	83.16	18.32	69.88	2.34	25.25	2.69	3.48
	C.D	N.S	N.S	1.42	15.58	0.11	6.09	0.4	1.35

Table-8. Mean values of plant growth and yield attributing characters (30 m)

Treat-ment No.	Treatment	No.of plants/ m^2	Ht. at maturity cm	Panicle length cm	No.of grains/ panicle	100 grain weight g	Chaff %	Grain yield t/ha	Straw yield t/ha
1.	2.5 m from drain line to either side	152.5	92.24	20.46	100.05	2.587	16.75	5.68	5.18
2.	2.5 m to 5 m on either side	135.0	91.16	20.42	101.05	2.565	25.75	4.72	5.20
3.	5 m to 7.5 m on either side	160.0	90.18	20.78	105.20	2.563	27.00	4.22	4.15
4.	7.5 m to 10 m on either side	165.0	88.90	19.64	95.07	2.398	25.50	4.27	4.03
5.	10 m to 12.5 m on either side	132.5	90.45	19.72	90.65	2.649	19.25	3.93	5.53
6.	12.5 m to 15 m on either side	125.0	91.51	20.59	108.40	2.565	21.75	4.71	5.20
7.	Control (No drainage)	87.5	76.55	18.25	76.98	2.464	23.75	2.61	3.33
	C.D.	N.S	9.93	0.90	N.S	0.11	N.S	0.64	N.S

e) 100 grain weight (g)

The table-7 and 8 clearly show that the 100 grain weight is significantly superior to control in the case of 15 m spacing and in the case of 30 m spacing the superiority over control is seen only in the cases of T1 and T5.

f) Chaff percentage

Although this character was not significant for 30 m spacing, the data for 15 m spacing show that T1 is superior to control.

g) Grain yield (t/ha)

A study of the grain yield data in both 15 m and 30 m spacings conclusively prove that the areas where maximum drainage took place could yield significantly higher than other treatments. In the case of 15 m spacing all treatments were superior to control. Among treatments T1 was superior to T2 and T3. But T2 and T3 were on par. In the case of 30 m spacing also all the treatments were significantly superior to control. Among the treatments T1 was superior to T2 - T6. But T2, T3, T4 and T6 were on par except T5. This indicates that the sub-surface drainage can be considered effective upto 30 m spacing. However further spacings could not be evaluated due to financial constraints and non-availability of suitable land.

Table-9. Weekly averages of EC and pH of irrigation and drained water

Week	Date of observation	Irrigation water		Drained water	
		EC	pH	EC	pH
1	26.10.86	1.86	5.79	2.41	6.94
2	3.10.86	1.14	3.86	2.46	7.85
3	6.11.86	0.32	6.63	2.42	7.84
4	13.11.86	0.36	7.61	2.85	6.47
5	20.11.86	0.88	7.60	3.84	7.81
6	28.11.86	1.68	9.23	3.82	7.38
7	6.12.86	2.24	6.35	4.71	7.17
8	11.12.86	2.13	6.54	4.35	6.94
9	18.12.86	2.45	7.00	3.43	6.50
10	27.12.86	1.51	7.38	4.48	6.88
11	1.1.1987	2.45	5.87	3.71	6.87

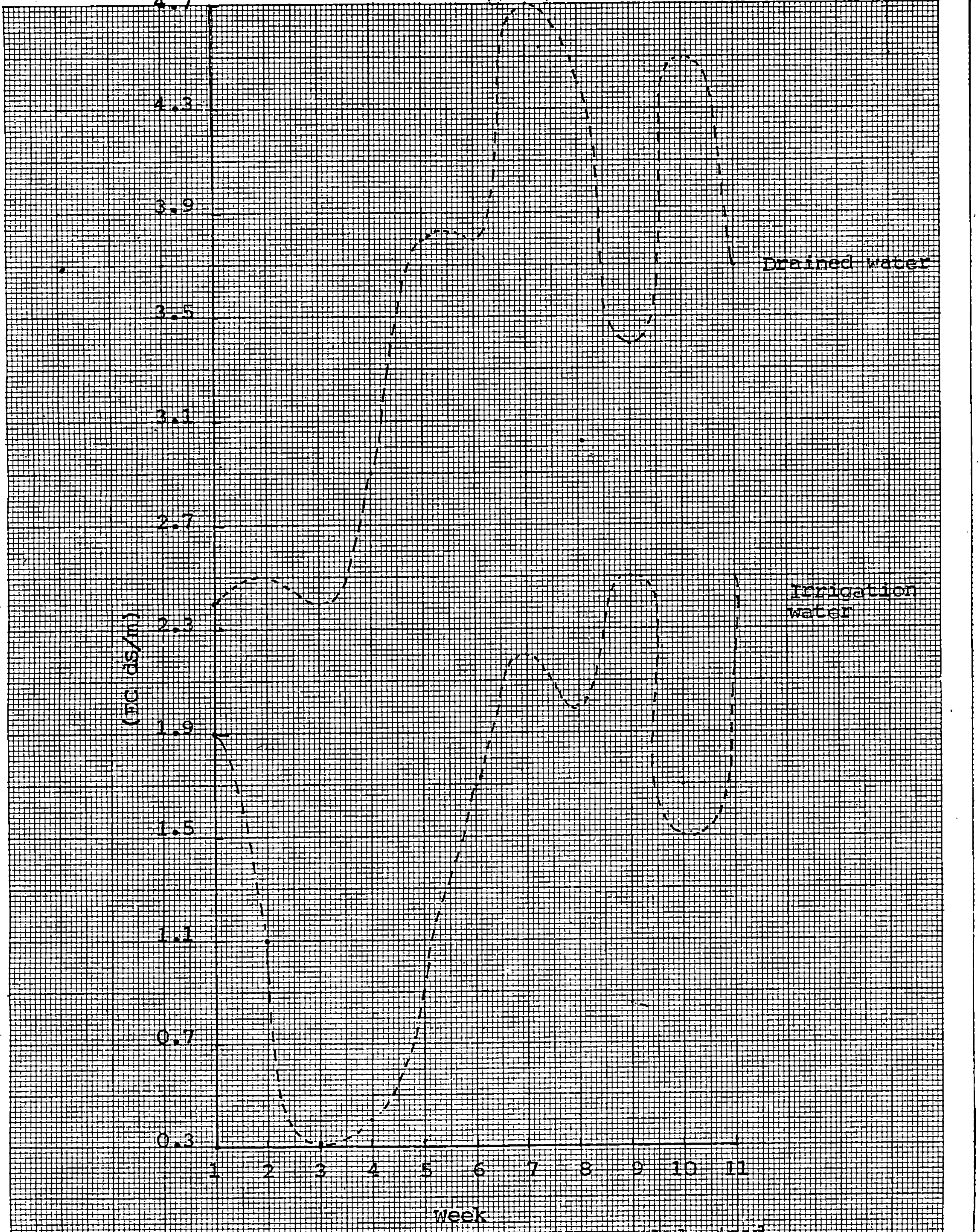

Fig.7. EC of irrigation water and drained water at weekly intervals.

Fig.8. pH of irrigation water and drained water at weekly intervals.

h) Straw yield (t/ha)

This character did not vary significantly for 30 m spacing, the data for 15 m spacing clearly indicates that there is a significant difference and all the treatments with subsurface drainage were on par and they were superior to control.

4.3.1. Weekly monitoring of EC of irrigation water and surface drainage water was recorded during the cropping season (1986-87) as shown in table-9. The comparison of EC showin in Fig.7 has indicated that a substantial amount of salt could be leached through the subsurface drainage. The EC value of irrigation water remained same with respect to time while that the subsurface drainage water has come down which proves a reduction of salt level of the soil after drainage. On an average the difference between the EC of drained water and irrigation water was 1.95 dS/m which quantitatively amounts to 1248 ppm or 1248 mg/l. This is equivalent to 124.8 kg of salt/ha/cm of drained water.

A close study of the weekly values of pH of irrigation water and subsurface drainage water as per Fig.8 leads to the following inferences. The pH value of irrigation and subsurface drainage water remained identical andthe values ranged between 3.85 to 9.2. This conclusively proves that acidity is not the problem in such peat and muck soils.

4.3.2. Economic analysis

One of the main factor which increases the cost/ha of the subsurface tile drainage system is the envelope material. Economic analysis was carried out to find whether river sand used as an envelope material was economically viable or not. The capital cost, operation and maintenance cost and production cost were worked out for an area of 100 ha, on the basis of assumptions and calculations are represented in Appendix-II. The life of the system was taken as 20 years with 5% increase both in operation and maintenance cost as well as in benefits till the end of the 20th year. The internal rate of return was calculated as 34% and the benefit/year/ha was Rs.2590.00. The internal rate of return clearly indicates that subsurface drainage using river sand as an envelope material is economically viable and financially sound.

Summary

5. SUMMARY

Kuttanad is a unique agro-climatic zone comprising of 55000 ha, out of this kari lands cover an area of 7000 ha which lie 1 to 1.2 m below sea level where monoculture of paddy is followed, in polders. This soil is characterised by the black charcoal colour with high organic matter content. It is believed that such lands are formed by some upheavals in the geological past. Presence of large logs underneath the soil with intermittent layers of sant indicate that there was dense forest, which due to some havoc was buried down and later engulfed by sea resulting the typical acid saline kari soils. The peat and muck soils have organic matter at various stages of decomposition in the subsoil. The toxic byproducts of decomposition when come into contact with the plant root zone adversely affect them.

An experiment was carried out at Kavil Thekkumpuram Padasekharam, a kari land, during the years from 1984-85 to 1987-88 to find out an effective measure to leach out the toxic salts from the crop root zone and to bring the soil environment suitable for good crop growth by adopting subsurface drainage system. The whole experiment was subdivided into four steps as follows:

1. Determination of suitable filter material

Considering the easy vailability of filter material, river sand (big grain size) and sea sand were selected as envelope materials. The theory postulated by Spalding (1970) was considered for selecting the envelope materia. Accordingly sieve analysis was carried out for both envelope materials and base material (soil) and the sieve analysis grading curve was drawn for envelope and base material. The different particle sizes as per the above criteria computed from the sieve analysis grading curve satisfied the quality of river sand envelope material in terms of filtration quality and hydraulic conductivity.

2. Determination of suitable material of the drains viz. PVC and baked clay pipe

The performance of PVC and baked clay pipe were assessed during the course of the experiment. From the information gathered the following inferences were drawn. The head loss fraction and the entrance resistance are higher in the case of PVC drains. The performance of tile drain is very good in the peat and muck soils whereas the performance of the PVC drain was very poor.

3. Determination of spacing of tiles in peat and muck soils (spacing selected 15 m and 30 m)

In the case of 30 m spacing, the area covered from treatment T2 upto T6 the grain yield show similar effect due to the subsurface drainage and is significantly superior to the control. This indicates that the spacing of subsurface drain could be considered upto 30 m.

The comparison of pH of subsurface drainage water and irrigation water confirm that acidity is not the problem in rice cultivation in peat and muck soils.

A comparison of EC values of irrigation water and the subsurface drained water indicated that a substantial amount of salt could be removed through subsurface drainage system. On an average, the difference between the EC of subsurface drained water and irrigation water was 1.95 dS/m which was quantitatively equivalent to 124.8 kg of salt/ha/cm of drained water. The better crop growth and higher grain yield may be attributed to the washing off the toxic salts from the root zone.

4. Economic analysis

Economic analysis was carried out to find whether river sand used as an envelope material was economically viable. The economic analysis is carried out for a 100 ha unit. The life of this experiment was considered as 20 years. The abstract of the economic analysis is as follows:

i) Internal rate of return	=	34%
ii) Cost/ha/year	=	1260
iii) Benefit/ha/year	=	2590
iv) Net benefit/year/ha	=	1330

From the internal rate of return and net benefit/ha/ year clear that subsurface drainage using tile drain is economically viable.

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Appendices

Appendix - I

No.of plants/m^2 (15 m spacing)

Treat.	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	Mean
T_1	120	110	150	160	170	70	180	140	137.50
T_2	140	120	90	170	180	180	150	120	143.75
T_3	170	160	110	100	80	120	150	120	126.25
T_4 (Control)	110	90	100	120	90	80	140	130	107.50
Total	540	480	450	550	520	450	620	510	

Grand Total = 4120

ANOVA table

	Df	SS	MS	F ratio	F table	Remarks
Block	7	5650	807.14	0.81	2.497	N.S
Treat	3	6075	2025.00	2.04	3.072	NS
Error	21	20825	991.67			
Total	31	32550				

Height at maturity (15 m spacing) (cm)

Treat	R1	R2	R3	R4	R5	R6	R7	R8	Mean
T_1	92.50	104.30	98.91	96.90	90.44	101.10	89.40	103.70	97.16
T_2	86.80	84.67	87.20	92.50	90.40	87.00	101.20	84.20	89.25
T_3	91.50	93.45	90.40	100.30	88.20	99.10	99.90	92.20	95.26
T_4 (control)	88.40	81.60	83.60	83.60	77.00	73.80	87.10	90.20	83.40
Total	359.20	364.02	360.11	373.30	346.04	361.00	377.60	377.30	

Grand Total = 2918.57

ANOVA table

	Df	SS	MS	F ratio	F table	Remarks
Block	7	203.17	29.02	0.95	2.497	N.S.
Treat	3	962.79	320.93	10.50	3.072	Significant
Error	21	641.76	30.56			
Total	31	1807.71				

Length of panicle (cm)

Treat.	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	Mean
T_1	19.77	20.54	21.58	21.13	21.70	21.05	18.30	20.15	20.56
T_2	21.45	18.80	18.50	17.73	20.05	19.50	22.25	19.45	19.72
T_3	22.00	19.13	19.72	19.56	19.50	19.60	22.30	21.40	20.42
T_4 (Control)	17.94	20.00	18.70	18.13	18.60	16.60	18.10	16.52	18.32
Total	81.16	78.47	76.50	76.55	79.95	76.75	81.15	77.52	

Grand total = 681.86

ANOVA table

	Df	SS	MS	F ratio	F table	Remarks
Block	7	8.941	1.277	0.688	2.497	N.S
Treat	3	24.656	8.219	4.428	3.072	Significant
Error	21	38.976	1.856			
Total	31	72.573				

No.of grains/panicle (15 m spacing)

Treat	R1	R2	R3	R4	R5	R6	R7	R8	Mean
T_1	85.20	100.80	107.60	111.70	124.10	120.10	94.30	102.0	105.73
T_2	112.30	73.80	75.60	70.00	105.20	89.90	123.00	97.7	93.44
T_3	106.00	78.00	86.00	99.40	89.50	84.20	110.50	115.5	96.14
T_4 (Control)	66.10	86.00	66.30	65.40	86.30	57.40	71.10	60.4	69.88
Total	369.60	338.60	335.50	346.50	405.10	356.60	398.90	375.6	

Grand Total = 2921.40

ANOVA table

	Df	SS	MS	F ratio	F table	Remarks
Block	7	1244.88	177.84	0.793	2.497	N.S
Treat	3	5560.65	1853.55	8.261	3.072	Significant
Error	21	4711.61	224.36			
Total	31	11517.14				

100 grain weight (15 m spacing) (g)

Treat	R1	R2	R3	R4	R5	R6	R7	R8	Mean
T_1	2.528	2.533	2.495	2.574	2.551	2.532	2.679	2.662	2.570
T_2	2.780	2.637	2.491	2.700	2.639	2.889	2.634	2.593	2.670
T_3	2.843	2.416	2.696	2.590	2.617	2.551	2.505	2.586	2.600
T_4 (Control)	2.382	2.236	2.405	2.361	2.269	2.166	2.483	2.486	2.342
Total	10.533	9.822	10.087	10.225	10.076	10.138	10.301	10.277	

Grand total = 81.459

ANOVA table

	Df	SS	MS	F ratio	F table	Remarks
Block	7	0.08	0.01	0.88	2.88	N.S
Treat	3	0.48	0.16	13.31	3.697	Significant
Error	21	0.25	0.01			
Total	31	0.81				

CD = 0.11

Chaff % (15 m spacing)

Treat	R1	R2	R3	R4	R5	R6	R7	R8	Mean
T_1	14	15	17	25	17	12	14	10	15.50
T_2	24	19	22	26	21	17	11	22	20.25
T_3	29	18	17	25	22	20	20	13	20.50
T_4 (Control)	13	23	24	48	33	66	15	30	20.25
Total	80	75	80	124	93	115	60	75	

ANOVA table

	Df	SS	MS	F ratio	F table	Remarks
Block	7	690.5	98.6	2.88	2.497	
Treat	3	380.5	126.83	3.697	3.072	Significant
Error	21	720.5	34.33			
Total	31	1791.5				

CD = 6.09

Grain yield t/ha (15 m spacing)

Treat	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	Mean
T_1	5.17	5.21	5.97	5.32	5.07	5.70	5.38	5.88	5.46
T_2	4.63	3.59	4.23	4.95	4.08	5.13	5.24	4.88	4.59
T_3	5.02	5.16	4.68	5.09	4.37	4.71	4.88	5.10	4.88
T_4 (Control)	3.07	2.86	2.04	2.96	2.35	2.22	3.17	2.84	2.96
Total	17.89	16.82	16.92	18.32	15.87	17.76	18.67	18.70	

Grand total = 140.95

ANOVA table

	Df	SS	MS	F ratio	F table	Remarks
Block	7	1.76	0.25	1.675	2.497	N.S.
Treat	3	34.57	11.52	76.700	3.072	Significant
Error	21	3.15	0.15			
Total	31	39.48				

CD = 0.40

Straw yield t/ha (15 m spacing)

Treat	R1	R2	R3	R4	R5	R6	R7	R8	Mean
T_1	5.70	4.60	7.60	5.70	3.80	7.30	6.60	6.60	5.99
T_2	5.00	3.30	3.60	5.80	4.70	4.80	8.20	3.50	4.86
T_3	5.10	7.60	5.10	4.40	5.90	4.00	5.60	4.50	5.28
T_4 (Control)	3.20	3.80	3.50	4.20	2.10	1.60	5.40	4.00	3.48
Total	19.00	19.30	19.80	20.10	16.50	17.70	25.80	18.60	

Grand total = 156.80

ANOVA table

	Df	SS	MS	F ratio	F table	Remarks
Block	7	13.35	1.91	1.12	2.497	N.S
Treat	3	26.84	8.95	5.28	3.072	Significant
Error	21	35.61	1.70			
Total	31	75.80				

CD = 1.35

No.of plants/m^2 (30 m spacing)

Treat	R_1	R_2	R_3	R_4	Mean
T1	180	150	140	140	152.50
T_2	130	160	120	130	135.00
T_3	160	150	140	190	160.00
T_4	180	100	160	220	165.00
T_5	150	110	130	140	132.50
T_6	130	90	80	200	125.00
T_7 (Control)	150	40	100	60	87.50
Total	1080	800	870	1080	

Grand total = 3830

ANOVA table

	DF	SS	MS	F ratio	F table	Remarks
Block	3	2925.00	2975.00	2.85	3.160	N.S
Treat	6	16685.71	2780.95	2.60	2.661	N.S
Error	18	18800.00	1044.44			
Total	27	44410.71				

Height at maturity (30 m spacing) (cm)

Treat	R_1	R_2	R_3	R_4	Mean
T_1	100.10	96.20	80.45	92.20	92.24
T_2	94.70	101.00	78.10	90.82	91.16
T_3	88.40	98.90	81.10	92.30	90.18
T_4	75.40	97.80	91.10	91.30	88.90
T_5	96.10	91.50	92.10	92.10	90.45
T_6	84.20	98.55	94.00	89.30	91.51
T_7 (Control)	76.60	78.10	70.60	80.90	76.55
Total	615.00	662.05	587.45	618.92	

Grand total = 2483.92

ANOVA table

	Df	SS	MS	F ratio	F table	Remarks
Block	3	406.47	135.49	3.03	3.160	N.S
Treat	6	717.40	119.57	2.68	2.661	Significant
Error	18	804.52	44.70			
Total	27	1928.40				

CD = 9.93

Length of panicle (30 m spacing (cm)

Treat	R1	R2	R3	R4	Mean
T_1	20.80	20.85	20.25	19.95	20.46
T_2	20.40	21.25	19.59	20.45	20.42
T_3	20.33	20.36	20.78	21.65	20.78
T_4	18.31	20.35	20.15	19.75	19.64
T_5	19.58	19.95	20.10	19.25	19.72
T_6	19.79	20.55	21.58	20.35	20.59
T_7(control)	18.15	18.30	18.11	18.45	18.25
Total	137.36	20.23	140.66	139.85	

Grand total = 559.48

ANOVA table

	Df	SS	MS	F ratio	F table	Remarks
Block	3	1.422	0.474	1.291	3.160	N.S
Treat	6	18.445	3.074	8.375	2.661	Significant
Error	18	6.607	0.367			
Total	27	26.474				

CD = 0.90

No.of grains/panicle (30 m spacing)

Treat	R_1	R_2	R_3	R_4	Mean
T_1	106.20	99.40	93.50	101.10	100.05
T_2	108.50	112.80	92.10	90.80	101.05
T_3	90.90	102.70	105.00	122.20	105.20
T_4	66.70	99.90	108.50	105.20	95.07
T_5	91.50	87.80	101.20	82.10	90.65
T_6	91.90	102.20	139.00	100.50	108.40
T_7	64.10	70.30	82.40	91.10	76.98
Total	619.80	675.10	721.70	693.00	

Grand total =. 2709.60

ANOVA table

	Df	SS	MS	F ratio	F table	Remarks
Block	3	789.84	263.28	2.470	3.160	N.S
Treat	6	2670.27	445.04	2.485	2.661	N.S
Error	18	3224.06	179.12			
Total	27	6684.18				

100 grain weight (30 m spacing) (g)

Treat	R1	R2	R3	R4	Mean
T_1	2.516	2.616	2.707	2.508	2.587
T_2	2.583	2.547	2.516	2.613	2.565
T_3	2.623	2.579	2.568	2.482	2.563
T_4	2.298	2.450	2.370	2.473	2.398
T_5	2.562	2.738	2.683	2.613	2.649
T_6	2.648	2.478	2.644	2.491	2.565
T_7 (Control)	2.392	2.521	2.446	2.498	2.464
Total	17.620	17.929	17.934	17.678	

Grand total = 71.163

ANOVA table

	Df	SS	MS	F ratio	F table	Remarks
Block	3	0.01	0	0.67	3.160	N.S
Treat	6	0.16	0.03	4.83	2.661	Significant.
Error	18	0.10	0.01			
Total	27	0.28				

Chaff % (30 m spacing)

Treat	R1	R2	R3	R4	Total	Mean
T_1	25	13	14	15	67	16.75
T_2	20	30	29	24	103	25.75
T_3	30	31	27	20	108	27.00
T_4	38	16	22	26	102	25.50
T_5	11	20	23	23	77	19.25
T_6	21	25	19	22	87	21.75
T_7	29	24	29	13	95	23.75
Total	174	159	163	143		

ANOVA table

	Df	SS	MS	F ratio	F table	Remarks
Block	3	70.66	23.56	0.601	3.160	N.S.
Treat	6	339.36	56.56	1.442	2.661	N.S.
Error	18	706.07	39.23			
Total	27	1116.11				

Grain yield (30 m spacing) , t/ha)

Treat	R1	R2	R3	R4	Mean
T_1	5.53	5.69	5.39	6.11	5.68
T_2	5.16	5.41	3.50	4.81	4.72
T_3	3.88	4.62	4.16	4.22	4.22
T_4	4.26	4.32	4.34	4.14	4.27
T_5	4.31	4.18	4.01	3.22	3.93
T_6	4.23	4.81	4.80	4.98	4.71
T_7 (Control)	2.43	2.50	2.62	2.90	2.61
Total	29.81	31.53	28.82	30.38	

Grand total = 120.54

ANOVA table

	Df	SS	MS	F ratio	F table	Remarks
Block	3	0.549	0.183	0.974	3.160	N.S
Treat	6	20.947	3.491	18.592	2.661	Significant
Error	18	3.380	0.188			
Total	27	24.875				

CD = 0.64

Straw yield - 30 m spacing (t/ha)

Treat.	R1	R2	R3	R4	Mean
T_1	5.30	6.00	4.80	4.60	5.18
T_2	5.80	7.30	4.10	3.60	5.20
T_3	5.20	3.90	3.90	3.60	4.15
T_4	3.10	3.00	4.10	5.90	4.03
T_5	5.90	6.90	4.70	4.60	5.53
T_6	5.10	6.80	5.00	3.90	5.20
T_7 (Control)	4.30	2.80	3.30	2.90	3.33
Total	34.70	36.70	29.90	29.10	

Grand Total = 130.40

ANOVA table

	DF	SS	MS	F ratio	F table	Remarks
Block	3	5.82	1.94	1.74	3.160	N.S
Treat	6	16.17	2.69	2.41	2.661	N.S
Error	18	20.12	1.12			
Total	27	42.11				

Appendix - II

Economic analysis of subsurface tile drainage system in the peat & muck soils of Kerala.
(100 ha. Unit)

I. Capital cost

a) Excavation charges for laying drains:

Spacing	:	30 m
Length of one line	:	100 m
Area covered by one line	:	3000 m^2
No.of lines required for 100 ha.	:	$\frac{100 \times 10^4}{3000}$
	:	333 lines
Total length of drain lines	:	33300 m.

Gross sectional dimensions of the trench for laying tile drains:

Bottom width	:	0.5 m
Side slope	:	0.5 : 1
Average depth	:	1 m.
Top width	:	1.5 m
Quantity of excavation/m length	:	1 m^3
Total quantity of excavation	:	33300 m^3
Rate of excavation/m^3	:	Rs 15/-
Total cost of excavation	:	Rs. 4,99,500

b) Cost of tile drain:

Length of each tile drain	: 0.6 m
Total length of tile drain	: $\frac{33300}{0.6}$
	: 55500 Nos.
Cost of each pipe including transportation	: Rs 10/pipe
Total cost	: 55500 x 10
	: Rs 5,55,000=00

c) Charges for laying pipes and back filling:

Rate	: Rs.2/m
Total cost	: 33300 x 2
	: Rs.66,600=00

d) Charges for covering filter material:

Rate	: Rs 1/m
Total cost	: 33300 x 1
	: Rs 33,300=00

e) Excavation of open drain to be used as collector drains:

Total length of open drain	: 5000 m

Dimension of the open drain:

Bottom width	: 1 m
Depth	: 1.5 m
Side slope	: 1 : 1
Top width	: 4 m
Quantity of excavation/m length	: 3.75 m^3
Total quantity of excavation	: 3.75 x 5000
	: 18750 m^3
Rate of excavation	: Rs.15/m^3
Total cost	: 18750 x 15
	: Rs 2,81,250=00

f) Cost of construction of 2 pumping system. : Rs 1,00,000

g) Cost of filter materials:

River sand all around the drain:

Average thickness	: 0.2 m
Average width	: 0.3 m
Cross sectional area of filter	: 0.3 x 0.2
	: 0.06 m^2
Total length	: 33300 m
Total quantity required	: 33300 x 0.06
	: 1998 m^3
Rate of river sand including transportation	: Rs 100/m^3
Total cost	: Rs 1998 x 100
	: Rs. 1,99,800=00

II. Operation & Maintenance cost:

a) Periodical maintenance of open drain	:	Rs 25,000
b) Maintenance of pumping system	:	Rs 7,500
Total cost	:	Rs.32,500=oo

III. Production cost:

a) Additional energy requirement	:	400 units/ha
b) Total additional energy	:	40000 unit
Cost per unit	:	Rs.0.35
Total cost	:	Rs.14,000=oo
b) Salary of pump operators	:	Rs 1000/operator/month.
No.of operators	:	4
No.of months per season	:	4
No.of season per year	:	2
Total cost per year	:	1000 x 4 x 4 x 2
	:	Rs.32,000=oo

Capital cost of tile drainage system for 100 ha unit with river sand all around the drain.

1) Excavation charges	:	Rs. 4,99,500=00
2) Cost of tile drain	:	Rs. 5,55,000=00
3) Laying pipe and back filling	:	Rs ,66,600=00
4) Charges for covering filter material.	:	Rs. 33,300=00
5) Excavation of open drain	:	Rs. 2,81,250=00
6) Cost of construction of pumping system.	:	Rs 1,00,000=00
7. Charges for filter material	:	Rs 1,99,800=00
8. Total	:	Rs17,35,450=00
9. Contractor's profit	:	Rs 1,73,545=00
10. Total capital cost (rounded)	:	Rs 19,10,000=00

...analysis of tile drainage system using River sand all around the drain as envelope material

Year	Capital cost Rs.	O & M cost Rs.	Production cost Rs.	Total cost Rs.	Discount factor Rs.	Present worth of cost at 12% (5x6) Rs.	Benefits Rs.	Present worth of benefit at 12% (8x6) Rs.	Cash flow Rs.	Present worth of project ... 12% (9-7...) Rs.
1	2	3	4	5	6	7	8	9	10	11
1	1910000	32500	46000	1988500	0.893	1775731	500000	446500	-1488500	-1329231
2	0	34125	48300	82425	0.797	65693	525000	418425	442575	352732
3	0	35831	50715	86546	0.712	61621	551250	392490	464704	330869
4	0	37623	53251	90874	0.636	57796	578813	368125	487939	310329
5	0	39504	55913	95417	0.567	54101	607753	344596	512336	290495
6	0	41479	58709	100188	0.507	50795	638141	323537	537953	272742
7	0	43553	61644	105197	0.452	47549	670048	302862	564851	255313
8	0	45730	64727	110457	0.404	44625	703550	284234	593093	239610
9	0	48017	67963	115980	0.361	41869	738728	266681	622748	224812
10	0	50418	71361	121779	0.322	39213	775664	249764	653885	210551
11	0	52939	74929	127868	0.287	36698	814447	233746	686579	197048
12	0	55586	78676	134262	0.257	34505	855170	219779	720908	185273
13	0	58365	82609	140974	0.229	32283	897928	205626	756954	173342
14	0	61284	86740	148024	0.205	30345	942825	193279	794801	162934
15	0	64348	91077	155425	0.183	28443	989966	181164	834541	152721
16	0	67565	95631	163196	0.163	26601	1089464	169433	876268	142832
17	0	70943	100412	171355	0.146	25018	1091437	159350	920082	134332
18	0	74491	105433	179924	0.130	23390	1146009	148981	966085	125591
19	0	78215	110704	188919	0.116	21915	1203310	139584	1014391	117669
20	0	82123	116240	198363	0.104	20630	1263475	131401	1065112	110772
Total	1910000	1074639	1521034	4505673	7.471	2518821	16532978	5179557	12027305	2660736

Benefit cost ratio : 2.06
Net present worth : 2660736
Internal rate of return : 34%

Present worth of cost/year/ha : Rs.1260=00
Present worth benefit/year/ha : Rs.2590=00
Net benefit : Rs.1330=00

Abstract of the economic analysis of subsurface tile drainage system using river sand all around the drain

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1)	Benefit cost ratio	:	2.06
2)	Net present worth of project	:	2660736=00
3)	Internal rate of return (%)	:	34
4)	Cost/year/ha	:	1260 =00
5)	Benefit/ha/year	:	2590 =00
6)	Net benefit/year/ha	:	1330=00

HYDRAULICS OF TILE DRAINS IN PEAT AND MUCK SOILS

BY

T. D. RAJU

ABSTRACT OF A THESIS

SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE DEGREE

MASTER OF SCIENCE IN AGRICULTURAL ENGINEERING

FACULTY OF AGRICULTURAL ENGINEERING & TECHNOLOGY
KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF LAND AND WATER RESOURCES AND CONSERVATION ENGINEERING

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ABSTRACT

Agricultural drainage is the removal of excess water, known as free water or gravitational water, from the surface or below the surface of farm land so as to create a favourable soil conditions for crop growth. The process of removing the excess water from land surface is called surface drainage. The excess water saturates the pore space of the soil, the process of its removal by downward flow through the soil is known as subsurface drainage or internal drainage. In the case of kari land of Kuttanad the field level is below the surrounding waterbodies, there is always an upward movement of water from the subsoil to the surface. The upward movement of water from the subsoil brings along with it harmful byproducts of decomposition of organic matter which when come into contact with roots of plant adversely affect the gorwth and yield.

With regard to the experiment on finding the suitable envelope material for subsurface drainage system in peat and muck soils revealed that the river sand (big size) was adequate in terms of filtration quality and hydraulic conductivity. Thus river sand (big size) could be considered as a suitable envelope material for subsurface drainage experiments.

In the second experiment the performance of tile drains viz. PVC and baked clay pipe were assessed.

From the comparison of head loss fraction and entrance resistance between PVC and baked clay pipe showed that the performance of baked clay pipe was good compared to PVC pipe. Considering the performance and economical reasons related to cost of baked clay pipe and its local availability, the use of the same as tile drains in peat and muck soils was confirmed.

A close study of weekly values of EC of irrigation and subsurface drainage water revealed that a quantity of 124.80 kg of salts/ha/cm drop of drained water, could be washed off from the experimental area.

From the observations on the growth and yield attributing characters it could be concluded that subsurface drainage was effective upto 30 m spacing. However, further studies are to be carried out for finding out a higher spacing.

Economic analysis related to subsurface drainage using tile drains and envelope material (river sand) for a 100 ha area revealed that this project is economically and financially viable.