NAME OF THE PROJECT

ALL INDIA CO-ORDINATED RESEARCH PROJECT ON AGRICULTURAL DRAINAGE UNDER ACTUAL FARMING CONDITIONS ON WATER-SHED BASIS, KARUMADY

....

(I.C.A.R)

1987-88

Centre:

AICRP ON AGRICULTURAL DRAINAGE

KARUMADY 688 564

KERALA AGRICULTURAL UNIVERSITY

CONTENTS

ANNUAL REPORT FOR THE YEAR 1987-88

SECTION - A

1. Title of the Scheme	:	All India Co-ordinated Research Project on Agricultural Drainage under Actual Farming Conditions on Watershed Basis, (ICAR), Regional Centre, (KAU), Karumady P.O., Alleppey District, Kerala State.
2. I.C.A.R. Sanction No. and date.	:	Original sanction No.F.4-5/77/AE dated 20.3.1981 of I.C.A.R.
3. Date of commencement of the project.	:	1.12.1981
4. Date of completion	:	31.3.1990
5. Sanctioned grant for 1985-90.	:	16 lakhs.
6. Sanctioned grant for the year for which the report is prepared.	:	3.2 lakhs vide order No.4-2/85/AE dated 1.8.1986 of ICAR.

7. Staff position during 1987-88.

Sl. No.	Name of post	No.of sanc-tioned post.	No.of posts filled	No.of posts vacant	Name of incumbent	Scale of pay	Date of joining.
1	2	3	4	5	6	7	8
1.	Assoc.Professor (Agrl.Engg.)	1	1	..	Sri.E.K.Mathew	1950-2950	1.10.84 to till date.
2.	Asst.Professor (Agronomy).	1	1	..	Sri.Madhusudan Nair	1500-2685	27.9.86 to ,,
3.	Asst.Professor (Agrl.Engg.)	1	1	..	Sri.T.D.Raju	1500-2685	1.10.84 to ,,
4.	Farm Asst.Sr.Gr.	1	1	..	Sri.R.Madhavan Pillai	975-1720	10.6.85 to ,,
5.	Draughtsman (Civil Gr.II)	1	-	1		700-1140	Vacant - since inception.
6.	Farm Asst.Gr.II.	2	2	-	1) Sri.K.O.Shahul Hameed.	675-1125	12.9.86 to till dt.
					2) I.Krishnakumari	,,	11.7.86 to ,,
7.	Technician Gr.II.	2	2	-	1) Sri.K.P.Sreedharan Nair.	,,	30.5.86 to ,,
					2) Thomas Scaria	,,	5.6.86 to ,,

1	2	3	4	5	5	7	8
8.	Typist Grade-I	1	1	..	Smt.K.K.Mary Smt.H.K.Khadeeja Beevi	780-1320	15.7.85 to 3.6.87 4.6.87 to till date.
9.	Assistant Gr.I.	1	1	..	Sri.K.Govindan Sri.M.Mohammed Bashir	780-1320 ,,	5.9.84 to 3.6.87 4.6.87 to till date.
10.	Lab.Asst.Gr.II.	1	1	..	Sri.K.Kunju Pillai	675-1125	1.1.87 to ,,
11.	Driver LDV Gr.III.	1	1	..	K.V.Kumaran T.M.Francis	640-1000 ,,	8.1.86 to15.6.87 15.6.87 to till date.
12.	Peon.	1	1	..	M.Mohammed Haneef	550-800	7.12.85 to ,,
13.	Watchman	2	2	..	1) N.Raveendran 2) M.G.Thomas 3) C.A.Chacko	,, ,, ,,	16.11.85 to 3.6.87 19.6.87 to till date. 7.12.85 to ,,
14.	Overseer(Civil Gr.I.)	1	-	1	..	825-1430	Vacant - since inception.

... Financial information:

i) Expenditure statement from the year of commencement to 1987-88:

Sl. No.	Year	Sanctioned grant for the year.	University sanction	Expenditure	Expenditure as % of the sanctioned grant.
1.	1981-82	1,28,100/-	36,000/-	7,242.85	5.65
2.	1982-83	4,78,200/-	4,37,000/-	1,26,509.58	26.45
3.	1983-84	3,83,800/-	3,83,800/-	2,44,951.89	63.82
4.	1984-85	3,80,200/-	3,80,200/-	3,38,008.35	88.90
5.	1985-86	2,86,000/-	2,86,000/-	2,61,094.23	91.04
6.	1986-87	3,50,000/-	3,50,000/-	3,23,997.91	95.57
7.	1987-88	3,30,000/-	3,30,000/-	4,08,504.66	123.79

ii) Expenditure statement of the year 1987-88 from 1.4.87 to 31.3.1988.

Sl. No.	Budget head	Sanctioned grant for the year.	ICAR sanction.	University sanction.	Total expenditure.	Expenditure as % of the sanctioned grant
1.	Salary	1,92,000/-	..	1,92,000/-	2,86,649.87	149.30
2.	T.A.	10,000/-	..	10,000/-	9,281.35	92.81
3.	Recurring Contingency	60,000/-	..	60,000/-	59,983.54	99.97
4.	Non-recurring Cont:	68,000/-	..	68,000/-	52,589.90	77.34
Grand Total:		3,30,000/-	..	3,30,000/-	4,08,504.66	123.79

SECTION - B.

PROJECT AREA - A BRIEF DESCRIPTION

B. i) Kuttanad:-

Kuttanad tract is a deltaic alluvium formation of four river systems viz. 'Meenachil', 'Pampa', 'Manimala', and 'Achen Coil' and the low lying areas in and around 'Vembanadu Lake'. The total area of Kuttanad tract is about 870 Sq.Km. out of which 290 Sq. Km. is under garden lands, scattering all over the tract and is lying 1 to 2m above the sea level, used mainly for coconut cultivation and habitation. The remaining portion which was under submergence was progressively reclaimed as polders by constructing ring bunds. These polders lie about 0.5 to 2m below mean sea level and the impounded water is drained out by using locally manufactured axial-flow pumps. The area of each polder unit ranges from 75 to 500 ha. and the total area under polder cultivation is estimated as about 520.89 Sq.Km. The whole area is criss-crossed by rivers, channels, canals and other waterways. The general topography of the area is flat and level.

The total watershed area of the above four rivers is nearly 5,000 Sq.Km. and discharge their water into Kuttanad region. After flowing through a net work of canals and channels, they join the Vembanad Lake. The catchment area has an annual rainfall varying between 280cm to 380cm. A good part of the rains, 60% are received during South West monsoon resulting in floods and most often submerging the low lands. The Kuttanad region experiences fairly uniform temperature throughout the year ranging between 21°C and 36°C. The mean relative humidity is high and is about 70%.

The Vembanad Lake which is the non-reclaimed part of the Kuttanad extends between Alleppey and Cochin with an area of 80 Sq.Km. This lake is connected to Arabian Sea at Cochin. The water in the lake is saline except during the monsoon season when the surface water is sweetened by flood water. When the flow in the rivers dwindles from the month of December, the saline water from the sea intrudes the entire area due to tidal action. The salinity in the northern parts of Kuttanad goes beyond limits of tolerance for rice cultivation from January onwards and it spreads rapidly to the southern parts. The surface water remains saline till the first flood washes it during the succeeding South West Monsoon.

The soil is acid sulphate in nature and is having high acidity. Three major problems encountered during cultivation in this area are:

1) high acidity
2) damage caused by floods and
3) intrusion of saline water during the fag end of crop period.

B. ii) Kari Lands:-

The whole Kuttanad tract is differentiated into three types of lands, namely Karappadam, Kayal lands and Kari lands. The Kari lands occupies an area of nearly 7,000 ha. They are located in the Taluks of Shertallai, Ambalapuzha and Kuttanad of Alleppey District and Vaikom and Kottayam of Kottayam District.

The Kari lands are a unique agricultural tract with Kari soils - black charcol coloured organic soil. These lands are quite similar to that of Kuttanad region with respect of topography, formation, climate and vegetation, but the organic matter content of the soil is very high.

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 midlands. During this 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. This alluvial formations exist in layers varying upto 30 metres in depth underlain by sand stone and mottled clay of tertiary formation. Still distinct, the Kari soils can be readily be 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 still deeper it becomes river sand.

Kari soils are extremely acidic in reaction with pH ranging 3-4.5 and the pH reduces further when the soil gets dried up. It is found that the extremely low pH on drying is due to the production of free sulphuric acid by oxidation of sulphur compounds in the soil. The fertility status of the soil is poor. Besides, the soil contains toxic concentrations of Fe, Al and toxic organic products.

B. iii) <u>The Project Area</u>: Kavil Thekkumpuram Padasekharam.

II.iii(a) Location and Area:-

The project area is a typical representative tract of Kari land with an area of 89.99 ha. The project area comes under Ambalapuzha Village and Taluk of Alleppey District. It lies 4 Kms. east of Ambalapuzha junction on National Highway 47. The padasekharam is encircled by Ambalapuzha Thakazhy road at north, Kalathil thodu at east, Kari thodu at south and Karumady thodu at west.

(b) Physiography and Hydrology:-

The project field is located 1 to 1.5m below mean sea level. The water collected in the project area is drained out by pumping to nearby canals using axial flow pumps (petty and parah). There are two pumping outlets, one with a 30HP and the other with 20HP axial flow pump. The former is installed on the ring bund ofKarumady thodu and the latter on the ring bund of Kari thodu. Two drainage channels, with an average width of 2.5m and a depth of 0.7m, are inter connected and lead water to the pumping bays. There is a net work of small drainage channels which opens out into the main drainage channel.

The land has got almost an even topography.

The water level in the surrounding water ways will be higher by 1 to 1.5m than that in the paddy fields during the season of cultivation. The havoc of flood, over topping and breaching of bunds and flooding of paddy fields are anticipated during the period of SW monsoon. Inundation of salt water and damage of crops are experienced during the period January to March.

B.iii(c) Climate:-

The project area experiences a typical tropical climate. The monthly mean of the weather parameters for the period from 1976 to 1986 and that for the period from 1987 January to March 1988 is given in table-A. The monthly changes in climatic parameters have also been illustrated through fig.A and B.

B.iii(d) Land Holding and Utilization:-

From the survey conducted at this station and from the records available with Revenue Department, it is found that altogether 125 cultivators are there in the project area, farming 75.238 ha of paddy fields. When the tenureship of the land is classified based on the extent of holding, it was seen that a substantial number of holdings fell below 1 acre. Out of 125 Nos.of holdings, 75 holdings were with an average extent of 1 acre or below that and 35 holdings were with an average extent between 1 acre and 2.5 acre. Only 15 holdings were with mean acreage above 2.5 acre. The average size of holding is 0.601 ha (1.49 acres).

The total area of the project field is 88.919ha and actual paddy field is 75.238 ha. The rest of the land is occupied by roads, trenches and reclaimed dry lands. The dry lands are used for human habitation and for the cultivation of perennial crops, mainly coconut.

B.iii(e) Cropping:-

The one and the only crop raised in the wet land is paddy and there is 100% coverage under HYVs.

Table - A.

Monthly variations of weather parameters in the project area

(a) Total Rainfall cm.

	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Total mean.
A	0.93	3.19	4.70	11.52	27.37	64.92	52.13	39.82	29.99	28.76	11.46	6.12	290.81
B.	0	3.05	0	0.54	17.40	3.68	16.34	41.43	13.59	29.44	26.10	4.81	156.38
C.	0	2.48	7.00	..									

(b) Monthly mean maximum Temp. °C.

A.	33.67	33.35	34.34	34.58	33.55	30.54	30.10	30.28	31.41	32.06	31.63	33.51	32.42
B.	32.30	32.80	33.14	33.43	32.00	27.86	30.81	29.77	31.20	31.29	31.67	33.00	31.61
C.	33.21	33.52	34.27	..									

A = Monthly mean for the year 1976 to 1986

B = Monthly mean for the year 1987

C = Monthly mean for the year 1988

(c) Monthly Mean minimum Temp. °C.

	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Total mean.
A.	22.01	23.23	25.01	25.15	25.59	24.43	23.90	24.31	24.68	25.31	24.26	23.31	24.27
B.	22.10	22.60	24.55	26.33	24.75	24.93	25.08	25.84	25.15	25.44	24.27	21.50	24.38
C.	21.62	23.90	25.73	..									

(d) Monthly mean evaporation (mm).

A.	3.74	4.24	4.77	5.02	4.90	4.24	4.36	4.11	4.39	4.21	3.89	3.53	4.28
B.	3.41	4.79	4.86	4.89	5.24	3.99	4.14	0.47	0.54	0.84	0.82	0.86	2.82
C.	0.90	1.02	1.14										

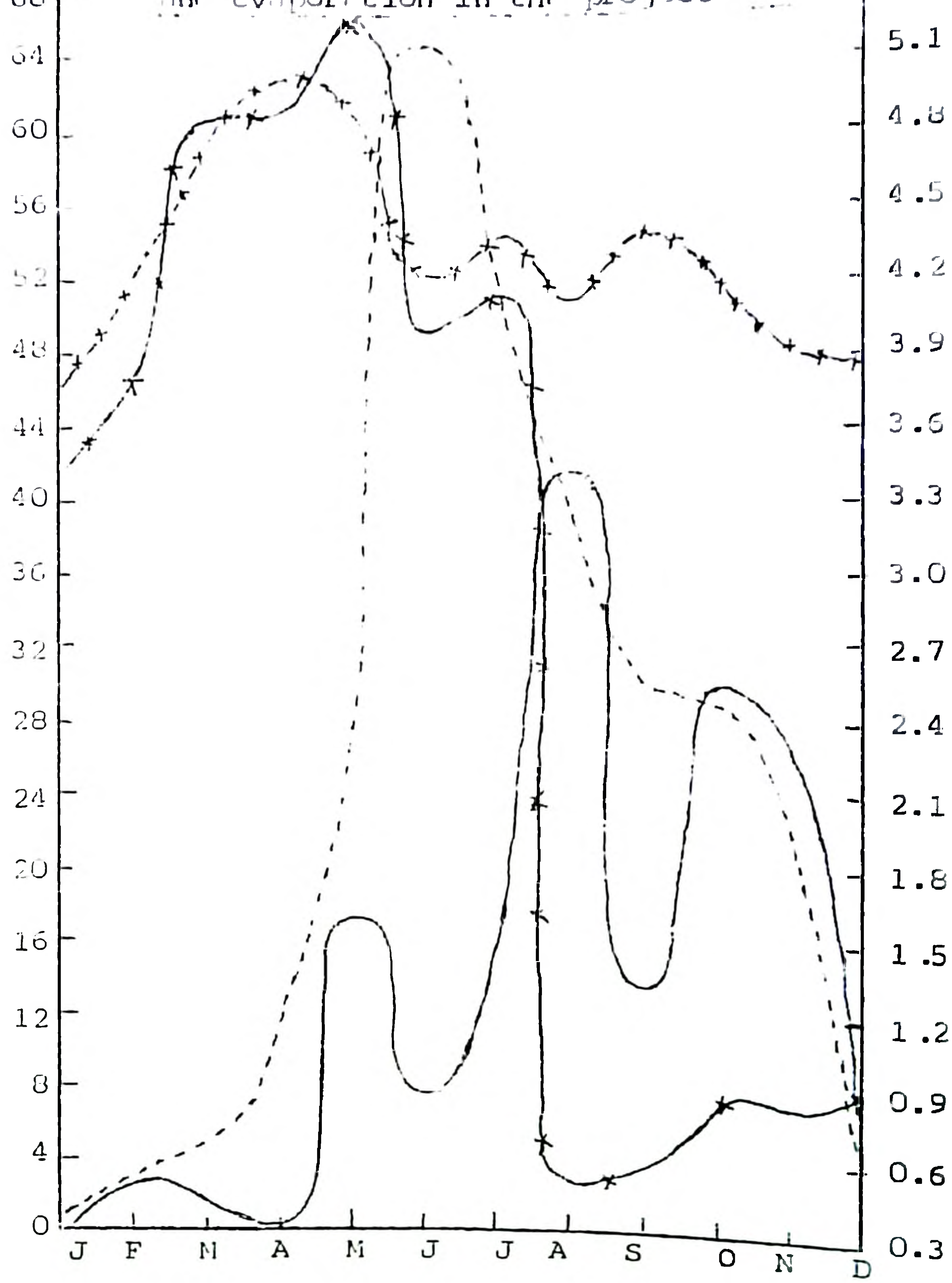
A = Monthly mean for the year 1976 to 1986

B = Monthly mean for the year 1987

C = Monthly mean for the year 1988

Figure - (A)

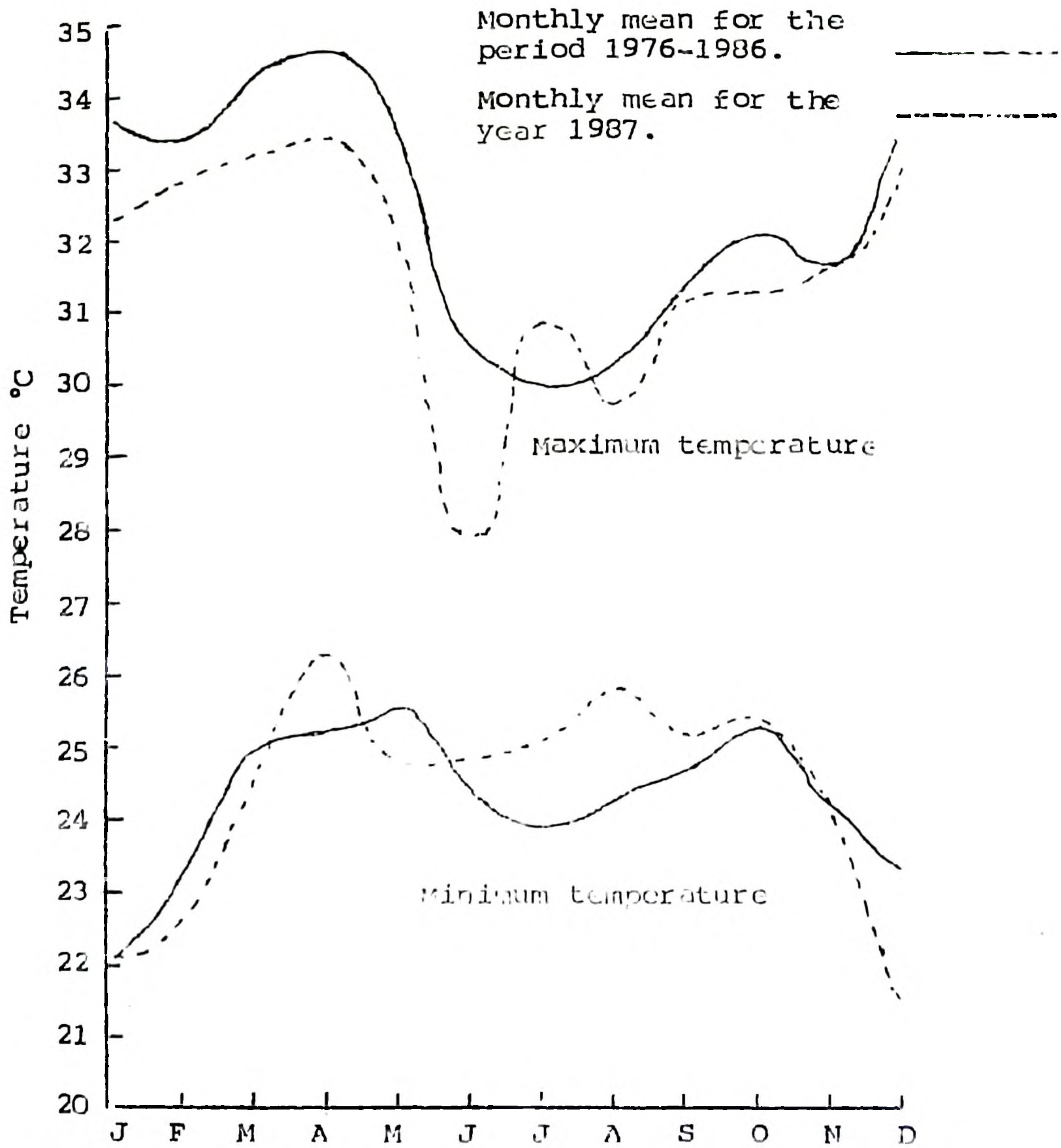
Mean monthly variation in total rainfall and evaporation in the project area



	Total rainfall	Evaporation
Monthly mean for the period 1976 to 1986.	-·-·-·-·-	-x-x-x-x-x-
For the year 1987.	———————	xxxxxxxxxxx

Figure - (3)

Mean monthly variation in maximum and minimum temperature in the project area



B.iii(f) Soil Characteristics:

The soil of the project area is typical Kari soil. A soil monolith from 0-2m depth has been drawn from the project area and has been displayed in a glass box. From the visual observation it is seen that from 0-60cm depth, the soil is clayey and black in colour due to high organic matter content. The clay type is the expanding one and large cracks are formed on drying. From 60-90m depth, lot of wooden debris, undecomposed organic material, are seen embedded. Below that, the soil is an admixture of clay, sand and organic matter. From the depth of 1.5m onwards, the soil is almost of the river sand type.

SECTION - C.

Objectives of the project:

1. To comprehend the effect of a surface and subsurface drainage system on the movement of soil liquids:

   i) To study the effect of surface and subsurface drains in preventing the rise of toxic products from subsurface soil into root zone.

   ii) To study the effect of surface drains in removing the toxic products already present in the root zone.

   iii) To study the influence of sub-surface drains on lowering water table and its effect on growth and development of roots.

2. To study the pattern of hydrological cycle occuring in the watershed area and its importance and influence on the drainage.

3. <u>To develop a feasible technology for the layout of sub-surface drainage system suitable to peat and muck soils:</u>

   i) To develop the criteria for the design of sub-surface drains in peat and muck soils.

   ii) To evaluate the types of drains (such as tile drains, PVC pipes etc.) and size and spacing of slots on drains suitable for the lay out of subsurface drains.

   iii) To evaluate the filter materials to be used for the layout of subsurface drains.

   iv) To decide upon the depth and spacing of the layout of sub-surface drains.

   v) To develop the criteria for the design of auxiliary structures of subsurface drains.

4. <u>To develop criteria for design parameters of surface drainage:</u>

5. <u>To develop the drainage pattern required for different crops:</u>

   i) To determine the drainage requirement of rice crop under static and fluctuating conditions of water levels.

   ii) To study the feasibility of changing monocropping pattern to diversified cropping and to develop agro techniques required for the diversified cropping.

   iii) To fix up the drainage requirements of the compe-tent crops of diversified cropping.

6. To evaluate the feasibility of using the return flow from drainage for irrigation in relation to water quality ratings.

7. To evaluate the socio economic benefits accrued from the drainage projects.

SECTION - D.

I. TECHNICAL PROGRAMME FOR THE YEAR 1987-88.

The following technical programmes were approved in the previous annual workshop.

1. Monitoring of periodical changes in the quality of surface and subsurface water in the project area.

2. Monitoring of seasonal fluctuations of ground water table with reference to surface water level.

3. Assessment of hydraulic properties of the tile drainage system.

4. Effectiveness of the tile drainage system in the performance of paddy crop in the Kari land.

5. Evaluation of different filter materials to find its economic suitability including its design criteria for the subsurface drainage system.

6. Studies on the changes of soil chemical properties with respect of time on sub-surface drainage.

II. Brief technical programme of the projects taken up at the centre during 1987-88.

EXPERIMENT NO.1.

1. Title:-

Monitoring of periodical changes in quality of surface and subsurface water in the project area.

2. Objectives:-

1) To assess the periodic changes in the quality of flowing water, drainage water and ground water.

2) To identify the fluctuation in the quality of water during the periods of fallowing and cultivation.

3. Practical utility:

The study will give useful information on the quality of water moving in the project area and enable to study the impact of quality of water on the ecology of the area. The information thus obtained can serve effectively in the planning of cultivation in the project area.

4. Technical programme:-

Water samples are to be drawn at weekly intervals from the drainage channels and water ways and its quality such as pH and EC assessed.

5. Observations taken:-

pH and EC of the water samples were estimated at weekly intervals.

6. Date of starting : December 1982.

7. Date of completion : Throughout.

8. Progress of work:-

Water samples were collected at weekly intervals from predetermind places for studying the periodic variations in pH and EC. The data has been consolidated and monthly averages are given in the table-1(1) and graphycally represented in the figures 1(1) to 1(2).

A study of the data and graphs shows that the pH ranged from 3.63 to 6.30 in the irrigation water and that of the drained water from 3.4 to 6.11, revealing the fact that the trend is the same. This proves that by adopting only surface drainage the acidity could not be reduced to a considerable extent. However, the favourable period could be arrived at, is from December to March for the year 1987-88. The EC values for irrigation water and drained water were found to be in between 0.5 to 6.8mmhos/cm, the trend being the same for both. The favourable period for optimum growth of paddy in the case above was found to be from December 1987 to March 1988. The high rainfall in the preceeding months from August 1987 to November 1987 could be attributed for keeping the better quality of irrigation water for the months December '87 to March 1988, when the flow of the irrigation water was checked by the closure of spillway near the sea.

The pH and EC values for the five years 1983-84 to 1987-88 are pooled and presented in the tables 1(2) to 1(3) and graphically represented in the figure 1(3). A critical review of the data show that optimum pH of 5.5 to 6.0 required for paddy is available for the months from July to March. The favourable EC range (0.8 to 1.4 mmhos/cm) is also found to be during the same period. It is also evident that the summer months of April to June should be avoided for paddy cultivation. However, the best period for growing paddy can be considered to be from the month of August to November.

Table - 1(1)

Monthly variation of pH and EC (mmhos/cm) for the year 1987-88.

Month	pH		EC (mmhos/cm)	
	Irrigation water.	Surface drained water.	Irrigation water	Surface drained water
April 1987	5.28	6.11	3.87	5.24
May '87	5.01	3.48	5.61	6.76
June '87	4.20	3.74	3.89	3.58
July '87	3.80	3.56	1.63	1.72
August '87	3.63	3.55	0.94	1.17
September	3.80	3.81	1.2[illegible]	1.26
October	3.86	3.69	1.01	1.11
November	3.74	3.50	0.50	0.68
December	4.79	3.71	0.51	0.84
January '88	4.65	4.06	0.74	0.83
February '88	5.23	4.67	0.72	0.79
March '88	6.30	4.15	0.48	0.87

Table - 1(2)

Monthly variation of pH of irrigation water in the project area from 1983-84 to 1987-88.

Month	1983-84	1984-85	1985-86	1986-87	1987-88	Mean
April	5.41	5.25	5.20	5.73	5.28	5.374
May	..	5.57	5.86	5.90	5.01	5.585
June	2.84	5.26	5.26	4.52	4.20	4.416
July	2.91	6.30	7.06	5.83	3.81	5.182
August	3.98	5.92	6.58	6.12	3.63	5.246
September	4.28	5.95	6.11	6.38	3.80	5.304
October	4.48	5.85	6.39	6.37	3.86	5.390
November	3.75	5.07	7.36	6.01	3.74	5.186
December	3.30	4.72	7.08	6.48	4.79	5.274
January	3.16	4.61	6.54	6.91	4.65	5.174
February	5.66	3.21	6.04	6.85	5.23	5.400
March	5.32	6.14	6.53	6.36	6.30	6.130

Table - 1(3)

Monthly variation of EC of irrigation water in the project area from 1983-84 to 1987-88.

EC mmhos/cm.

Month	1983-84	1984-85	1985-86	1986-87	1987-88	Mean
April	..	0.61	2.69	3.81	3.87	2.745
May	..	0.58	1.66	2.27	5.61	2.530
June	2.03.	0 44	1.71	2.94	3.89	2.202
July	1.97	0.16	1.03	1.13	1.63	1.184
August	1.45	0.40	0.87	0.44	0.94	0.820
September	0.96	1.03	0.98	1.00	1.22	1.038
October	0.59	1.21	1.38	0.77	1.01	0.992
November	0.68	2.01	0.53	0.70	0.50	0.884
December	0.77	2.63	1.73	1.92	0.51	1.332
January	0.99	1.95	0.86	0.38	0.74	0.984
February	1.23	0.81	0.38	0.64	0.72	0.756
March	0.31	1.69	0.86	1.36	0.48	0.940

Figure - 1(1)

Monthly variation of pH for the year 1987-88

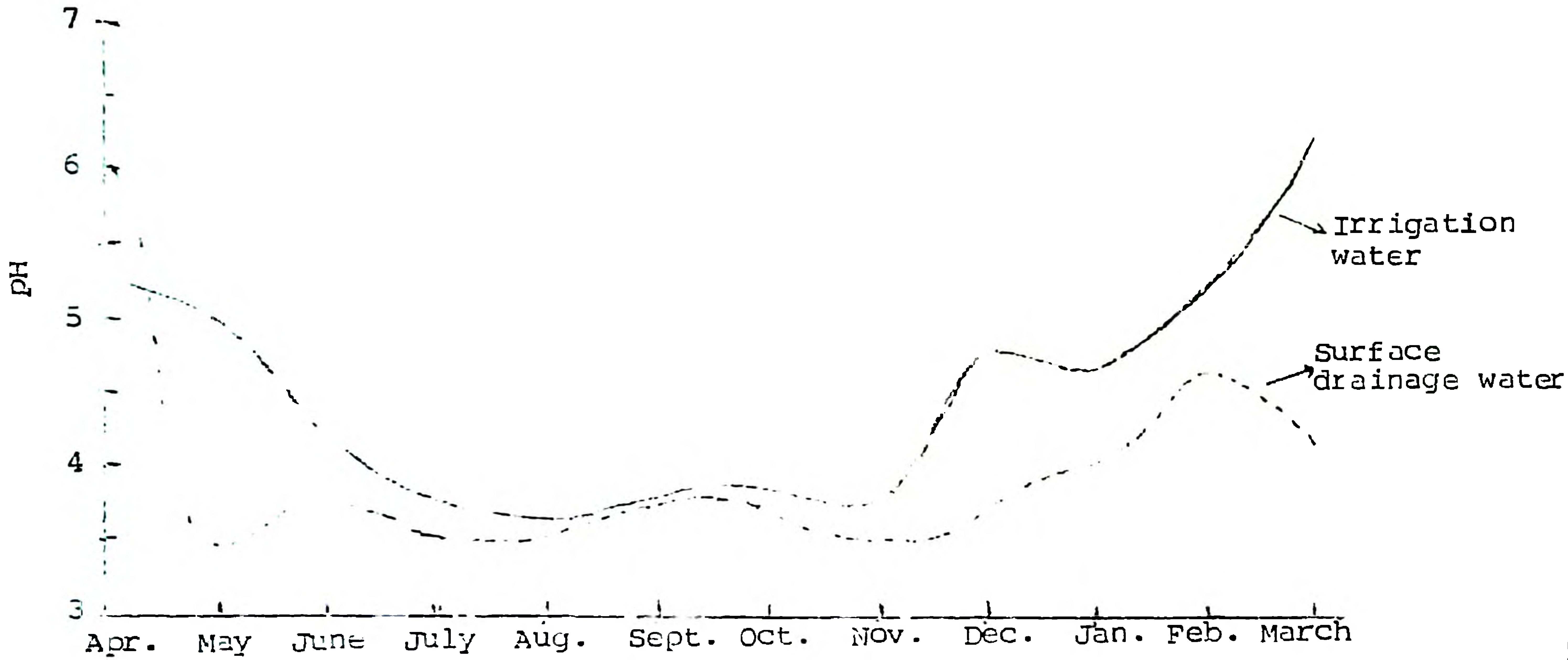


Figure - 1(2)

Monthly variation of EC for the year 1987-88.

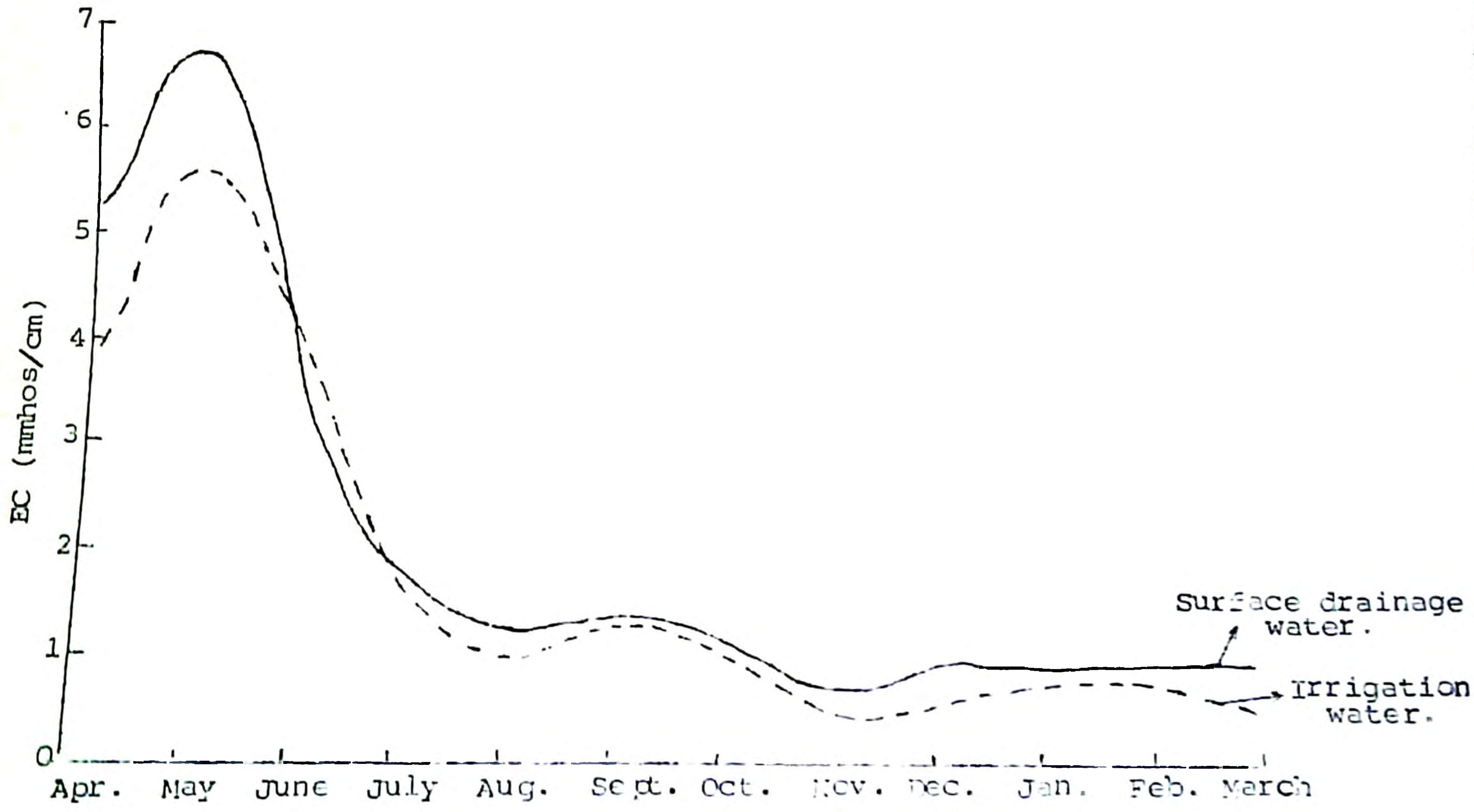
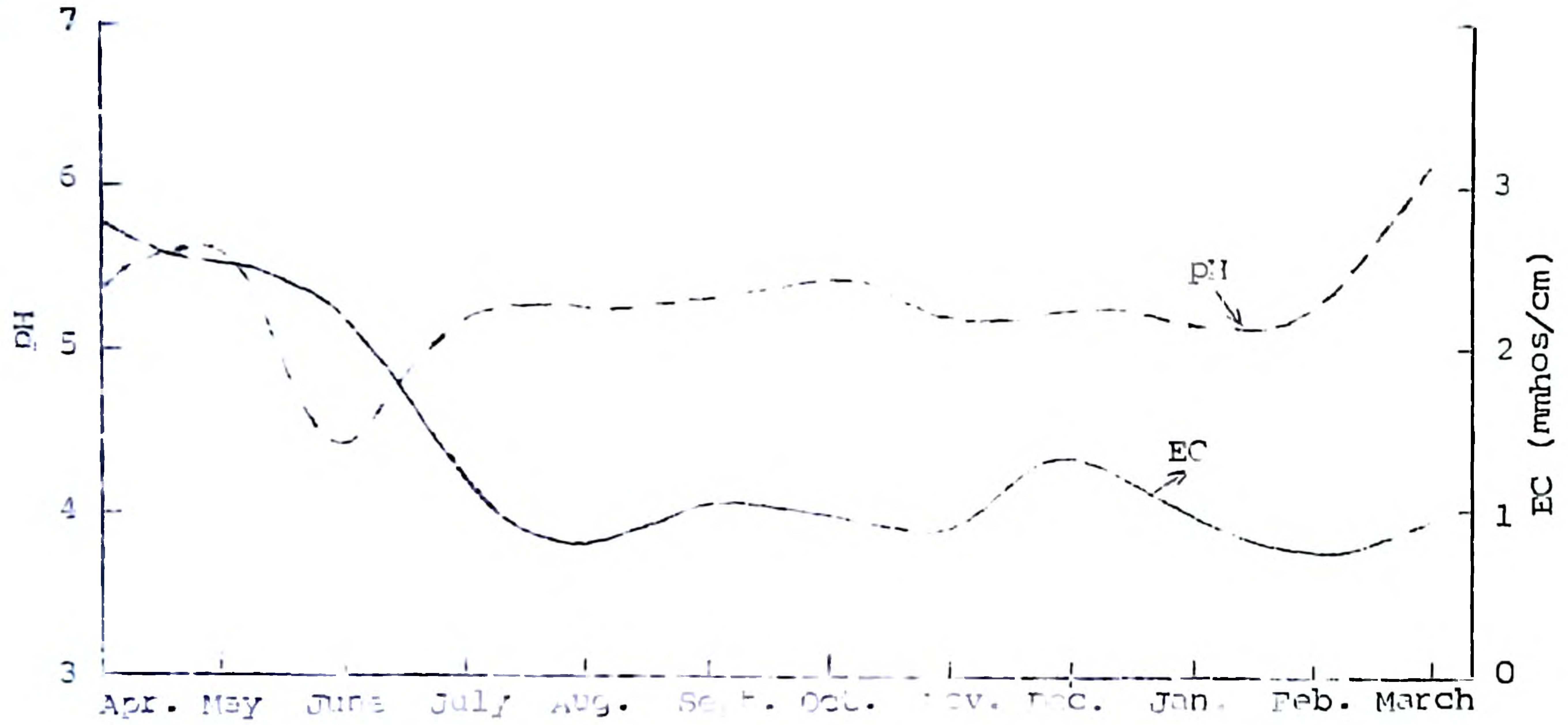


Figure - 1(3)

Monthly variation of pH and EC of irrigation water in the project area - pooled over 5 years from 1983-84 to 1987-88.



EXPERIMENT NO.2.

1. Title:-

Monitoring of seasonal fluctuations of ground water table with reference to surface water level.

2. Objectives:-

   a) Study on the seasonal changes in ground water with reference to surface water movement in water ways outside.

   b) Seasonal changes on the level and movement of water in waterways.

   c) Identification and characterisation of aquifer, if any, existing in the project area.

3. Practical utility:-

This study will enable to understand the changes that take place in ground water after the layout of surface and subsurface drainage system.

4. Technical programme:-

In order to record ground water table fluctuation, observation wells will be installed at a depth of 1m. using 40mm or 50mm of PVC pipes at 100m apart. The pipes will be perforated with 6mm holes at 10 x 5cm spacing and will be wound with nylon ropes/coir to prevent clogging. Water level in these wells will be recorded at weekly intervals.

5. Observations to be taken:-

Water levels in observation wells, waterways and piezometers will be recorded at weekly intervals.

6. Date of starting : June 1982

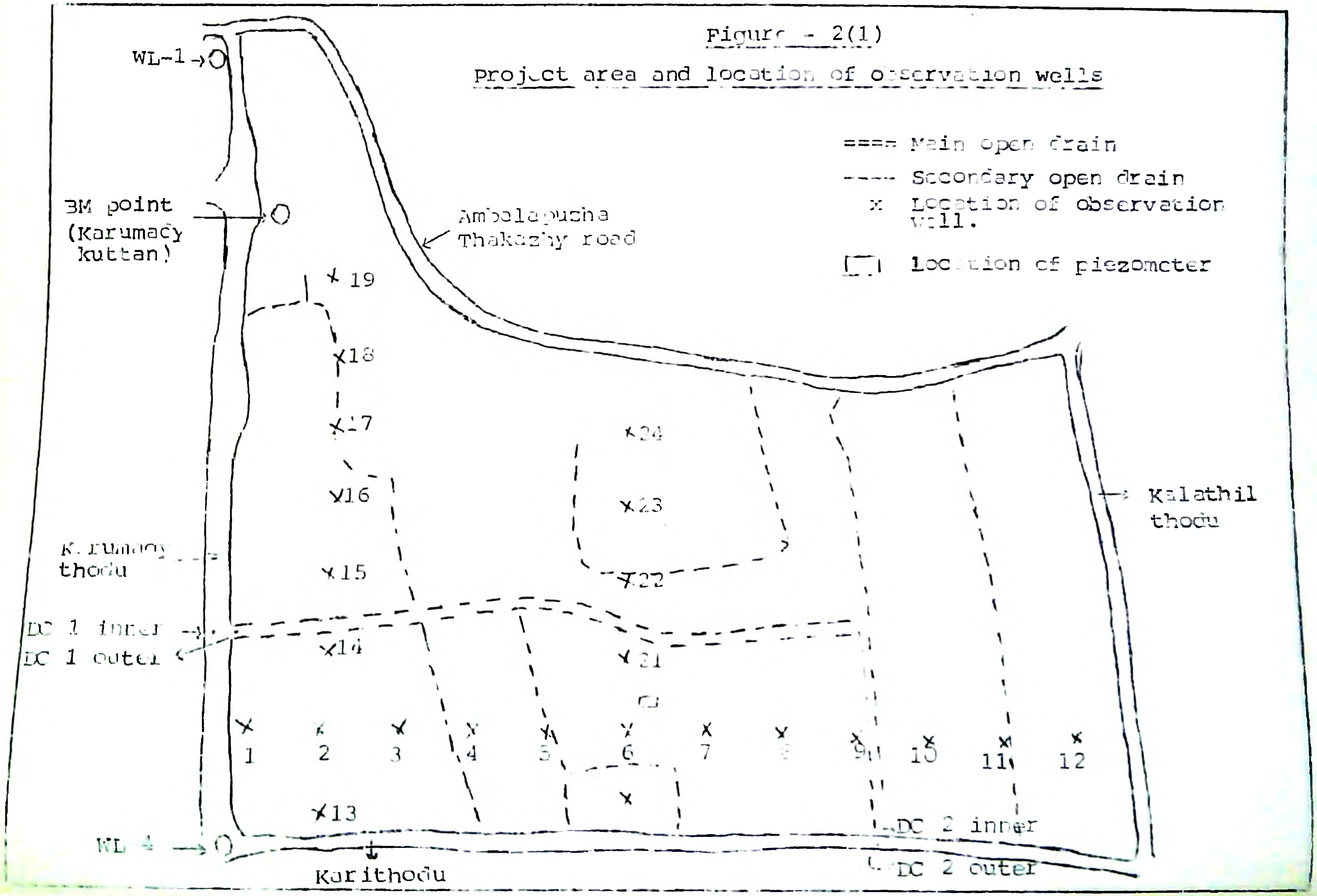
7. Date of completion : Till the scheme work is completed.

8. Progress of work:-

The field is installed with 24 observation wells in 3 bands at 100m apart to record the water table fluctuations. The observation of water levels in these wells had started since its installation. The data generated since 1982 had shown that there is no definite pattern of ground water movement in the soil and is greatly influenced by the outside water level, intermittent flooding and draining. The movement of ground water with reference to the water level of the surrounding waterbody is graphically illustrated in figure 2 (2) and 2(3) for the cropping period. The monthly average values of water table elevation are given in table 2(1) to 2(iii).

Figure - 2(1)

Project area and location of observation wells



5. Observations to be taken:-

Water levels in observation wells, waterways and piezometers will be recorded at weekly intervals.

6. Date of starting : June 1982

7. Date of completion : Till the scheme work is completed.

8. Progress of work:-

The field is installed with 24 observation wells in 3 bands at 100m apart to record the water table fluctuations. The observation of water levels in these wells had started since its installation. The data generated since 1982 had shown that there is no definite pattern of ground water movement in the soil and is greatly influenced by the outside water level, intermittant flooding and draining. The movement of ground water with reference to the water level of the surrounding waterbody is graphically illustrated in figure 2 (2) and 2(3) for the cropping period. The monthly average values of water table elevation are given in table 2(1) to 2(iii).

Figure - 2(1)

Project area and location of observation wells

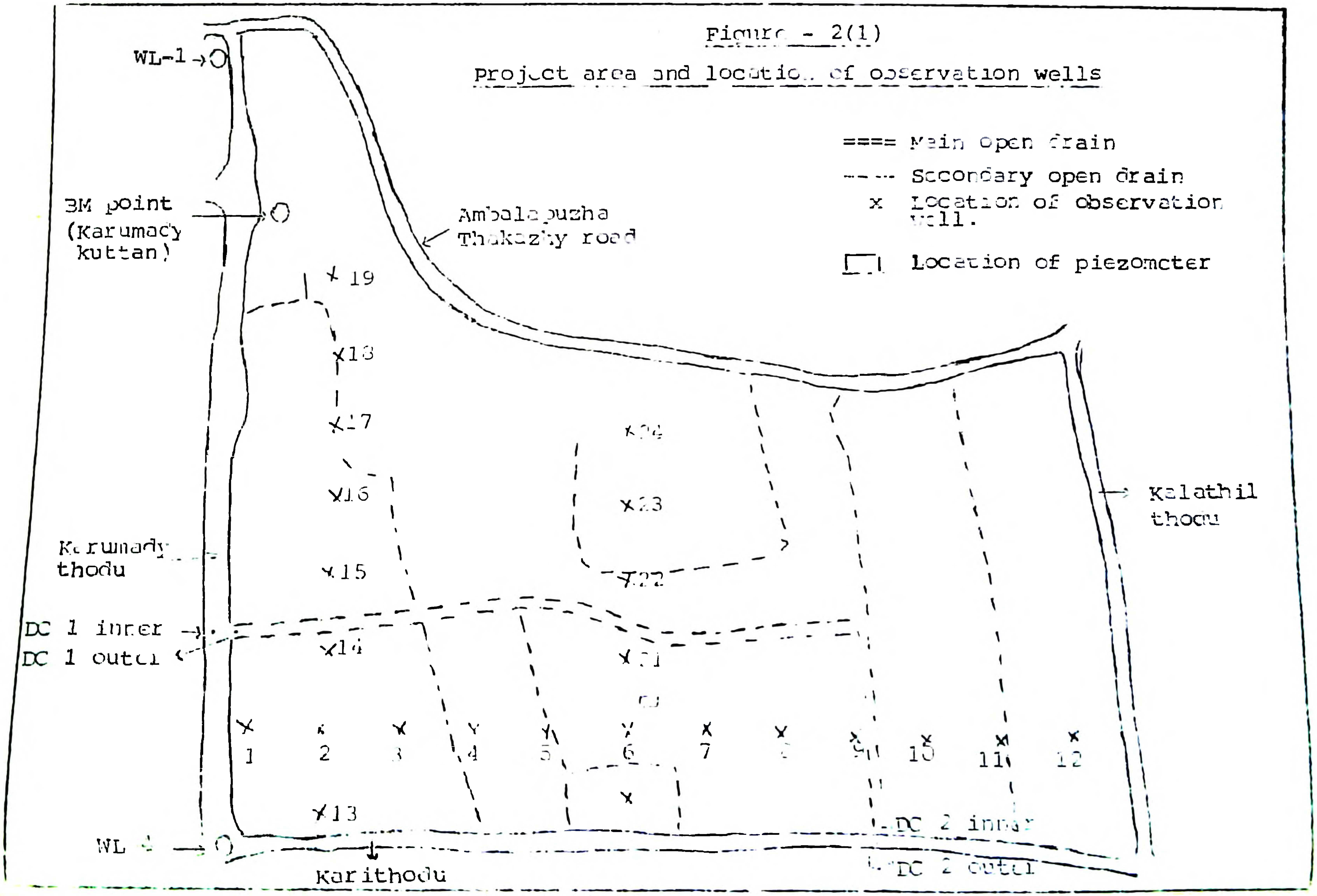


Table - 2(1)

Ground water table in the project area (as read from surface bench mark elevation = 1000 cm.)

Month	OBW1	OBW2	OBW3	OBW4	OBW5	OBW6	OBW7	OBW8	OBW9	10	OBW11	OBW12	Mean
1	2	3	4	5	6	7	8	9	10	11	12	13	14
April '37	80[illegible].0	79[illegible].5	..	..	..	..	..	..	..	..	744.5	768.5	777.38
May "	813.5	814.5	812.[illegible]	822.0	8[illegible]7.75	811.0	815.0	814.5	813.50	..	812.5	815.5	815.20
June "	.... Flood fallowing												
July "							,,						
August "							,,						
Sep. "							,,						
Oct. "							,,						
Nov. "							,,						
Dec. "	824.8	824.5	811.[illegible]	..	815.8	821.5	812.1	819.9	816.0	..	816.1	816.4	817.99
January38	827.8	827.[illegible]	[illegible].7	..	816.7	8[illegible].7	8[illegible]1.7	823.5	820.8	..	824.5	824.3	822.56
Feb. "	[illegible]	[illegible].5	[illegible]	..	816.[illegible]	82[illegible].5	821.4	823.0	819.3	..	824.9	826.0	822.31
March "	818.7	8[illegible]2.[illegible]	812.[illegible]	..	80[illegible].0	803.8	816.7	814.5	796.2	..	807.8	803.8	808.17
Mean	82[illegible].6	813.5	81[illegible]	82[illegible].0	[illegible]	816.1	818.0	819.1	813.2	..	805.1	809.1	

Month	OBW13	OBW-2	OBW14	OBW15	OBW16	OBW17	OBW18	OBW19	Mean
April '67	791.00	790.50	781.50	755.50	797.00	777.00	790.50	779.50	782.61
May "	818.75	814.50	814.50	779.50	820.50	817.75	821.50	835.50	815.31
June "	.... Flood fallowing								
July "	,,								
August "	,,								
September	,,								
October "	,,								
November "	,,								
December "	827.50	824.50	818.88	[illegible]	[illegible]	826.13	837.38	840.75	825.96
January 88	824.50	827.00	[illegible]	817.50	827.50	828.33	841.17	849.17	829.52
February	817.38	822.50	816.75	816.50	[illegible]	831.63	841.50	847.50	827.60
March "	808.00	802.00	811.83	803.17	809.00	811.67	827.67	841.83	814.39
Mean	814.52	813.50	810.58	798.15	817.29	815.42	825.62	832.38	

Month	OBW20	OBW-6	OBW-21	OBW-22	OBW-23	CBW-24	Mean
April '87	..	..	730.50	..	..	..	730.50
May "	813.00	811.00	812.50	812.25	..	813.50	812.45
June "			......	Flood fallowing			
July "				,,			
August "				,,			
Spt. "				,,			
October "				,,			
Nov. "				,,			
Dec. "	822.63	822.50	815.63	819.00	..	816.00	819.15
January '88	829.00	822.67	817.67	821.33	..	820.83	822.30
February "	830.38	820.50	812.38	819.63	..	819.25	820.43
March "	810.[illegible]	803.83	788.50	794.50	..	796.17	798.60
Mean	821.00	816.10	796.19	813.34	..	813.15	

Table - 2(2)

Surface water level in waterways, which surrounds the project area (as read from surface bench mark elevation - 1000 cm).

Table - 2(3)

Surface water level in the drainage channel (as read from Bench mark Elevation - 1000 cm)

Month		WL-1	WL-4	DC-1	DC-2
April	'87	822.00	818.13	741.00	757.75
May	"	832.00	826.50	776.38	793.50
June	"	880.17	879.67	881.35	895.17
July	"	873.50	872.90	875.70	886.80
August	"	882.00	881.88	866.00	880.67
Sept.	"	871.75	869.50	874.13	882.00
Oct.	"	892.80	891.60	892.20	902.40
Nov.	"	894.63	893.13	819.00	831.00
Dec.	"	891.90	890.30	792.90	815.80
Jan.	'88	880.50	877.50	796.75	808.88
Feb.	"	862.25	857.50	784.88	808.50
March	"	867.90	862.90	798.00	808.50
Mean		870.95	868.46	824.86	839.25

Figure 2(1)

Movement of ground water table in the project area wrt time and surrounding waterbody level (Karumady thodu)

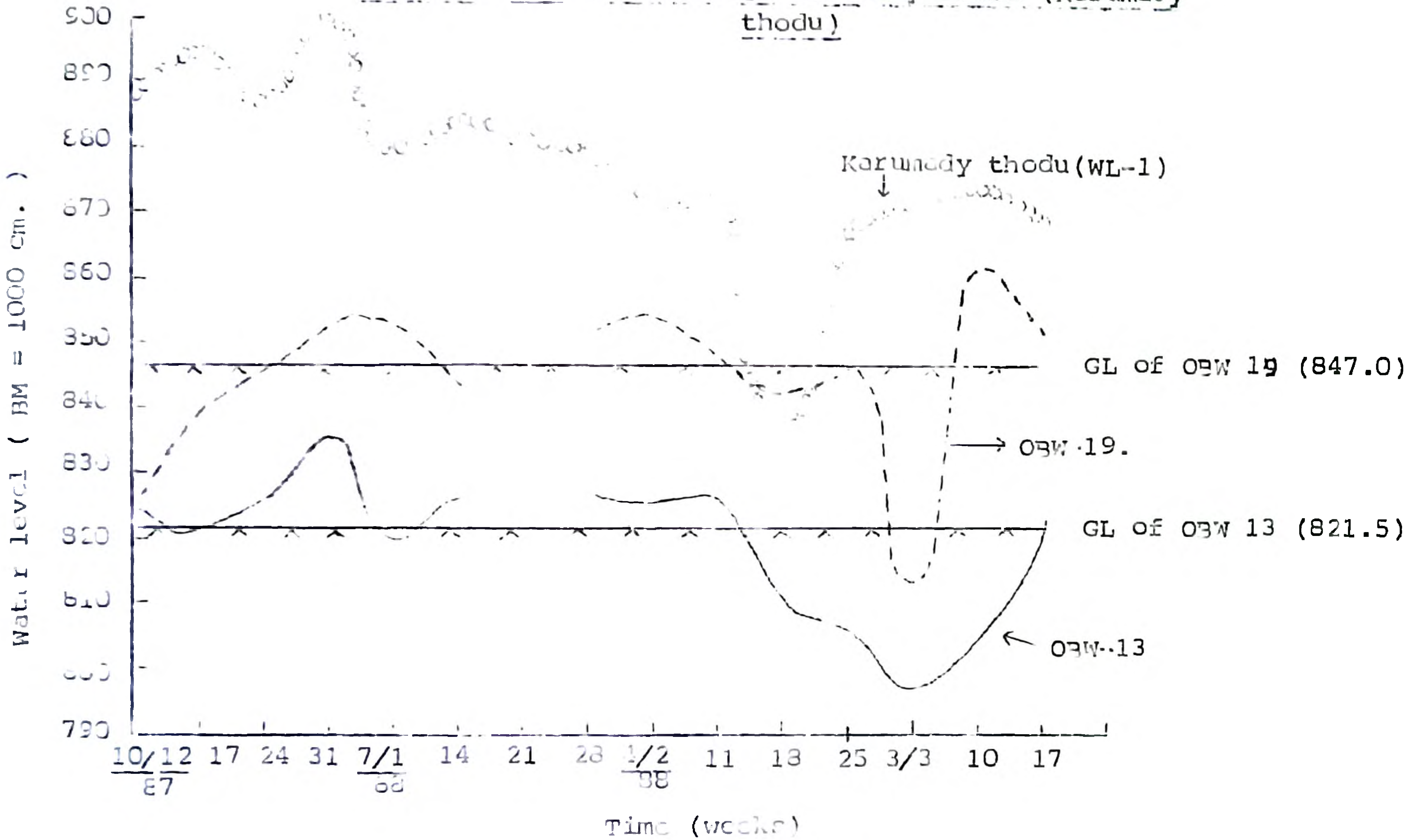


Figure - 2(3)

Movement of ground water table in the project area wrt time and surrounding waterbody level (karithodu)

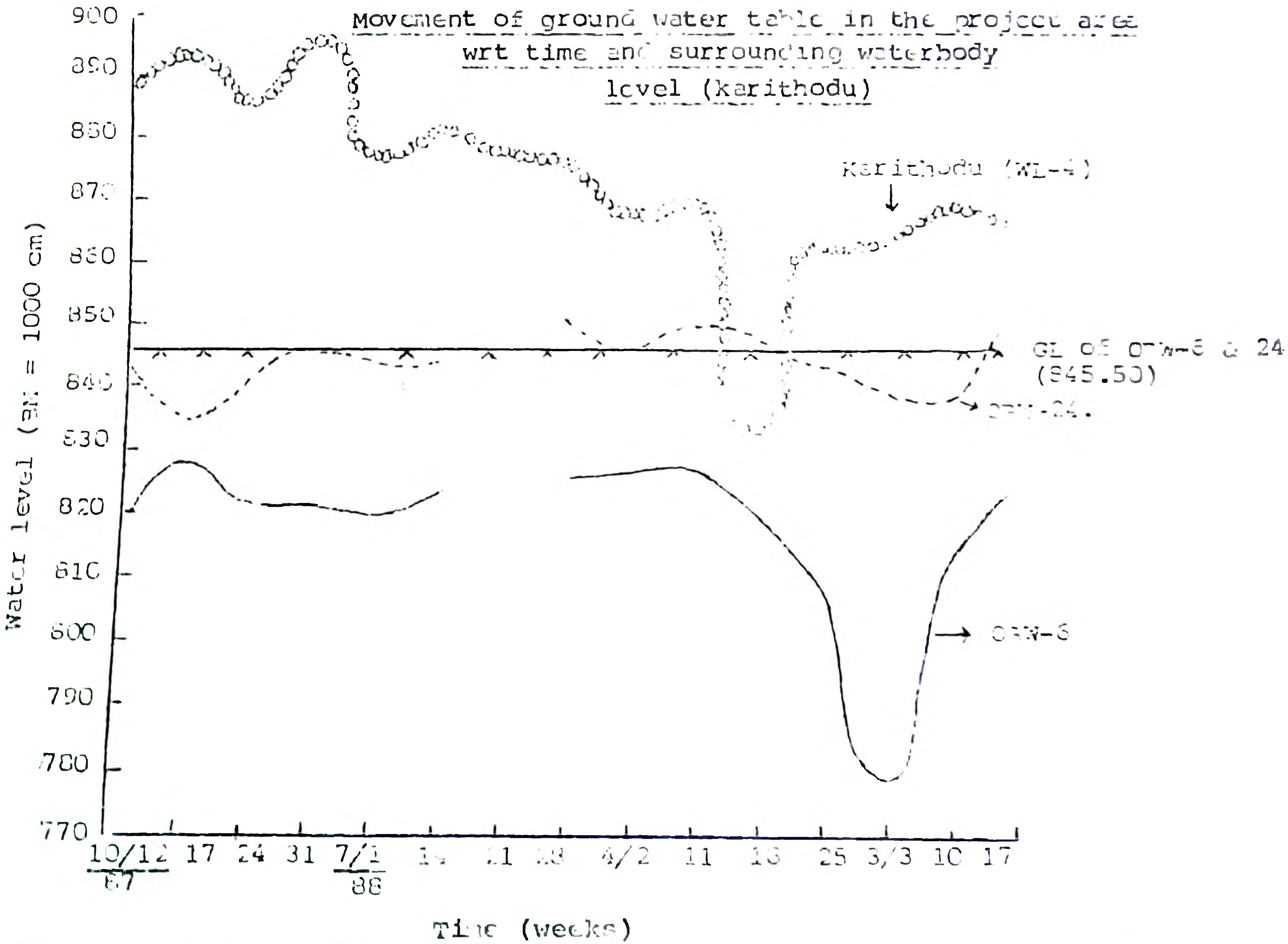
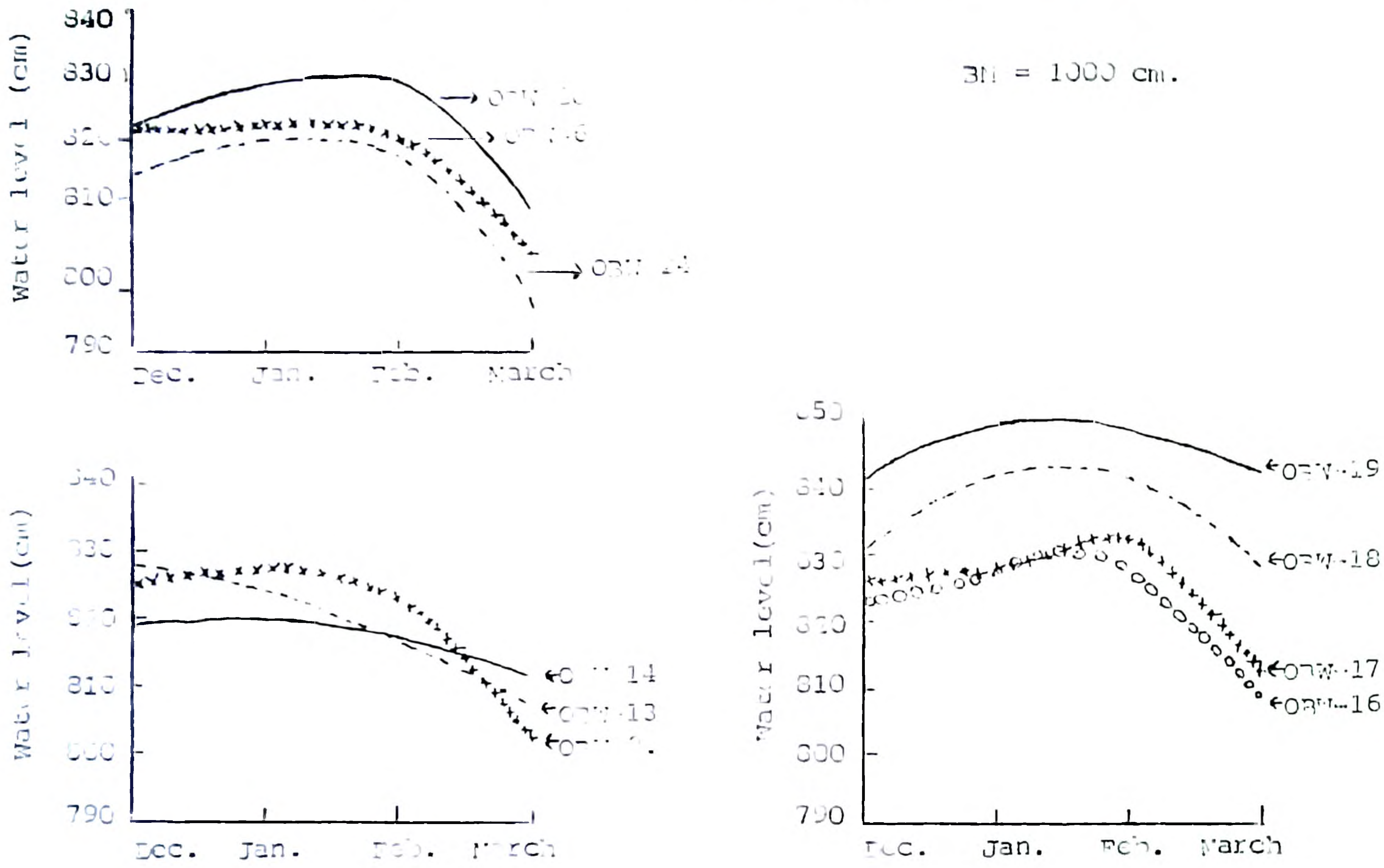


Figure - 2(4)

Relative water table depth in the project area



EXPERIMENT NO.3.

1. Title:-

Assessment of hydraulic properties of the tile drainage system.

2. Objectives:-

a) To estimate different parameters of hydraulics of the tile drainage system in Kari lands.

b) To evaluate the performance of tile drainage system in the project area.

c) To collect information to develop a viable technology for the sub surface drainage system in the project area.

3. Practical utility:-

This is a basic study aimed at gathering valuable parameters of the hydraulics of the tile drainage system. The information collected and compiled can be used for deriving a suitable technology for the design of a sub-surface tile drainage system for the kari lands of Kuttanad.

4. Technical programme:-

Planning was made to lay 9 lines of parallel tile drains. The first six lines were to be spaced at 15m and to have 75m length and the remaining were to be spaced at 30m and to have 100m length. The initial line designated as 1B15, the sixth line designated as 6B15/30 and the last line, 9B30, were laid to function as as buffer lines to minimize the boundary effects. The lines designated as 2E15, 3E15, 4E15 and 5E15 are experimental lines of 15m spacing and the lines 7E30 and 8E30 are experimental lines of 30m spacing.

Further replication of parallel drains of 30m spacing or some other else could not be planned because of the geometry of the location.

All the above drains were to run at a slope of 0.2% and at an average depth of 0.875m. The drains were to be provided with a sand filter of an average thickness of 10-15 cms. all around the drain. All the parallel drains were to open into separate collection sumps where the discharge measurements were to be made. The collection sumps were inter connected by PVC pipes of 110/160mm dia laid at 0.4% slope which drain into a main drainage sump from where the drained water is pumped into the outside waterbody.

The tile drains are of baked clay, 60cm long, with bell mouth at one end (125 mm outer dia and 100mm inner dia). These drains are provided with 15 nos. of 6mm holes in three bands of 5 holes each, on the 1/3rd periphery area.

A series of observation wells were also to be installed in the experimental field to record the subsidence of ground water.

5. Observations to be recorded:

a) Rate of discharge at each collection sump.
b) Water table readings at each observation well.
c) Computation of transmissivity, hydraulic conductivity, drainage intensity factor and effective porosity.

6. Date of start : December 1984

7. Date of completion : Till the end of the scheme.

8. Progress of work:

The installation of the drainage system was completed during 1985-86 and the complete laying procedures are mentioned in the Annual Report 1985-86. The layout of the system is given in figure 3(1).

Figure - 3(1)

Layout of sub-surface tile drain

Data processing:-

The pattern of data collection was the same as that of the preceeding years. Water table recession through observation wells due to the continuous drainage from different tile drains were collected along with the drain discharges. This was continued for 170 hours and the data interpolated for 10 hour interval is given in appendix-1. The graphycal representation of the data drawn for discharge versus head has confirmed the earlier results that there is a continuous recharge towards the drains from the outside water-body and the intensity of this recharge reduces with distance. The drainage flow was analysed using the non-steady state approach which is given in appendix-2.

The parameters found on the basis of the analysis is given in table 3(1) along with the values arrived at the preceeding year.

Table - 3(1)

Hydraulic parameters based on the analysis

Parameters	Values for 87-88	Values for 86-87
K (hydraulic conductivity)	0.2 m/day	0.19 m/day
Kd	0.28 m^2/day	0.4 m^2/day
d (equivalent depth)	1.58 m.	2.1 m.

Values of discharge and average hydraulic head at identical values of elapsed time are given in table 3(2) and their corresponding graphical representations are given in figure 3(2) to 3(4).

Table - 3(2)

Values of discharge and average hydraulic head at identical values of elapsed time

Time	2E15		3E15		4E15		5E15		7E30		8E30	
	q (mm/day)	h (m)	q (mm/day)	h (m)	q (mm/day)	h (m)	q (mm/day)	h (m)	q (mm/day)	h (m)	q (mm/day)	h (m)
0	13.00	0.55	13.40	0.47	12.90	0.47	12.10	0.47	[illegible]	[illegible]	[illegible]	0.28
10	7.50	0.42	7.60	0.39	4.20	0.45	[illegible]	[illegible]	[illegible]	0.31	[illegible]	0.26
20	6.30	0.37	5.70	0.33	3.10	[illegible]	[illegible]	0.43	[illegible]	0.28	0.70	0.25
30	5.50	0.35	4.90	0.30	[illegible]	0.39	[illegible]	0.41	[illegible]	0.27	0.55	0.23
40	5.05	0.33	4.50	0.29	[illegible]	0.37	[illegible]	0.39	[illegible]	[illegible]	0.40	0.21
50	4.85	0.32	4.15	0.27	[illegible]	0.35	1.65	0.37	[illegible]	[illegible]	0.39	0.19
60	4.70	0.31	3.90	0.26	1.90	[illegible]	1.50	0.36	0.20	0.21	0.35	0.18
70	4.60	0.31	3.70	0.25	[illegible]	0.32	[illegible]	0.34	0.18	0.19	0.33	0.16
80	4.55	0.30	3.60	0.24	1.70	0.31	[illegible]	0.33	0.15	[illegible]	0.30	0.15
90	4.50	0.30	3.50	0.24	1.65	0.30	[illegible]	0.31	0.13	0.16	[illegible]	0.13
100	4.40	0.29	3.40	0.23	1.60	[illegible]	1.15	[illegible]	[illegible]	0.15	0.26	0.12
110	4.40	0.29	3.30	[illegible]	1.50	[illegible]	1.10	0.28	[illegible]	0.13	0.25	0.11
120	4.35	0.29	3.20	0.23	1.50	[illegible]	1.10	[illegible]	0.10	[illegible]	0.23	0.10
130	4.30	0.29	3.10	[illegible]	[illegible]	[illegible]	1.05	[illegible]	0.10	0.10	[illegible]	0.09
140	4.30	0.29	3.10	0.22	[illegible]	[illegible]	[illegible]	0.24	0.10	0.09	0.23	0.08
150	4.30	0.29	3.00	[illegible]	1.35	0.26	[illegible]	0.23	[illegible]	0.08	0.21	0.07
160	4.30	0.29	3.00	[illegible]	1.30	0.25	[illegible]	0.22	0.10	0.07	0.20	0.07
170	4.30	0.29	3.00	0.22	1.25	0.25	[illegible]	0.21	[illegible]	0.06	0.20	0.06

Figure - 3(2)

Discharge vs time (2E15 - 8E30)

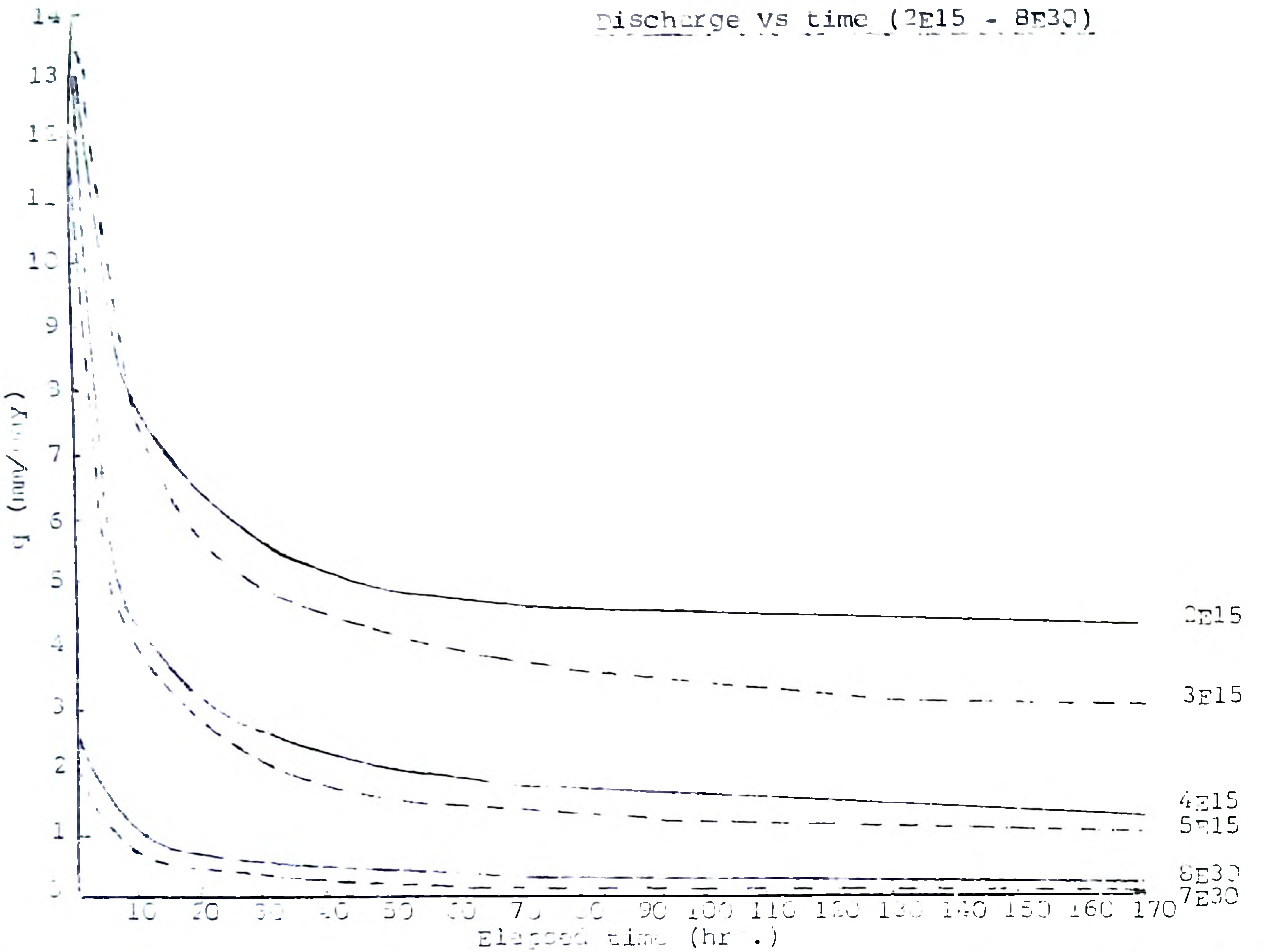


Figure - 3(3)

Hydraulic head vs time (2E15 - 8E30)

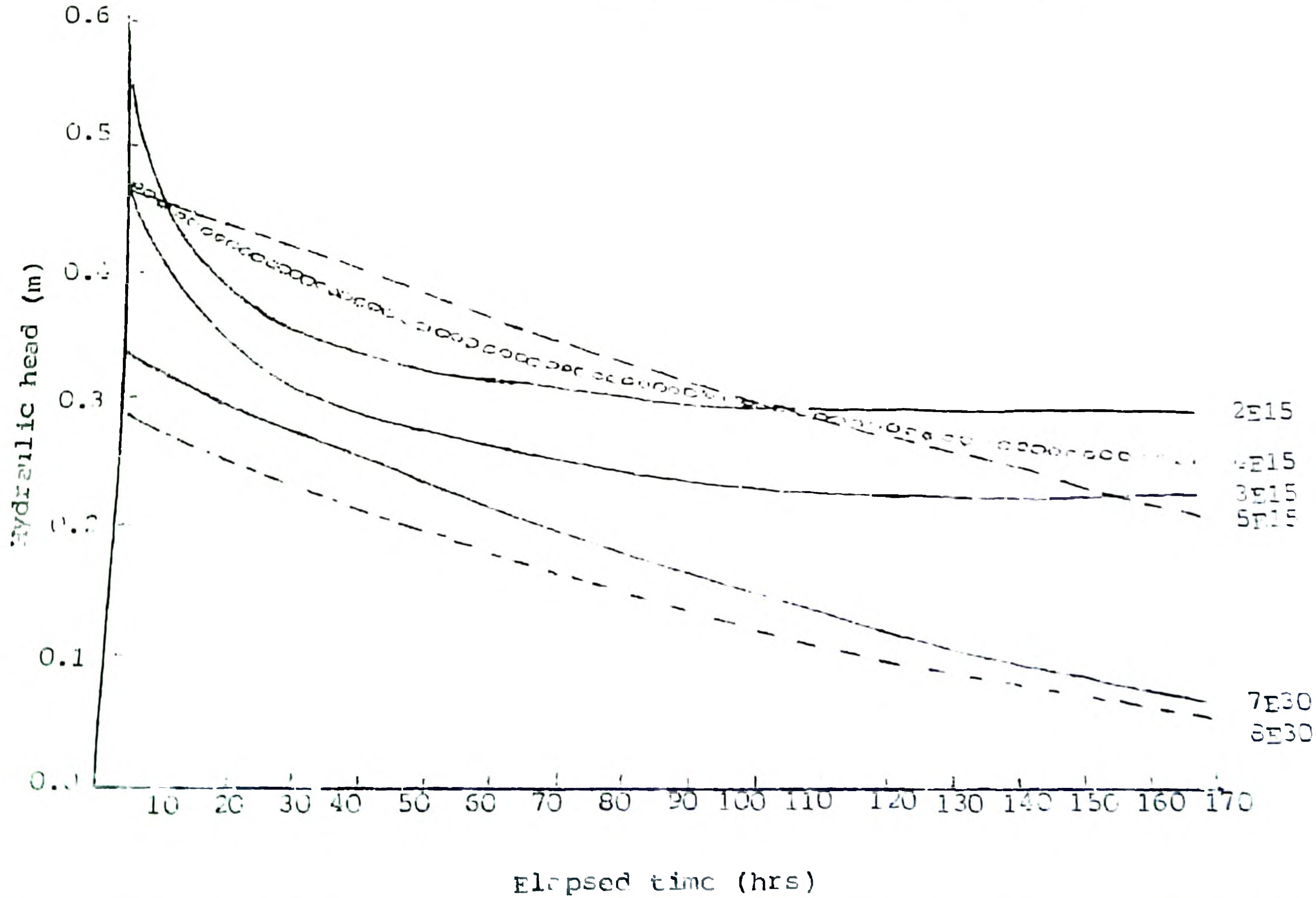
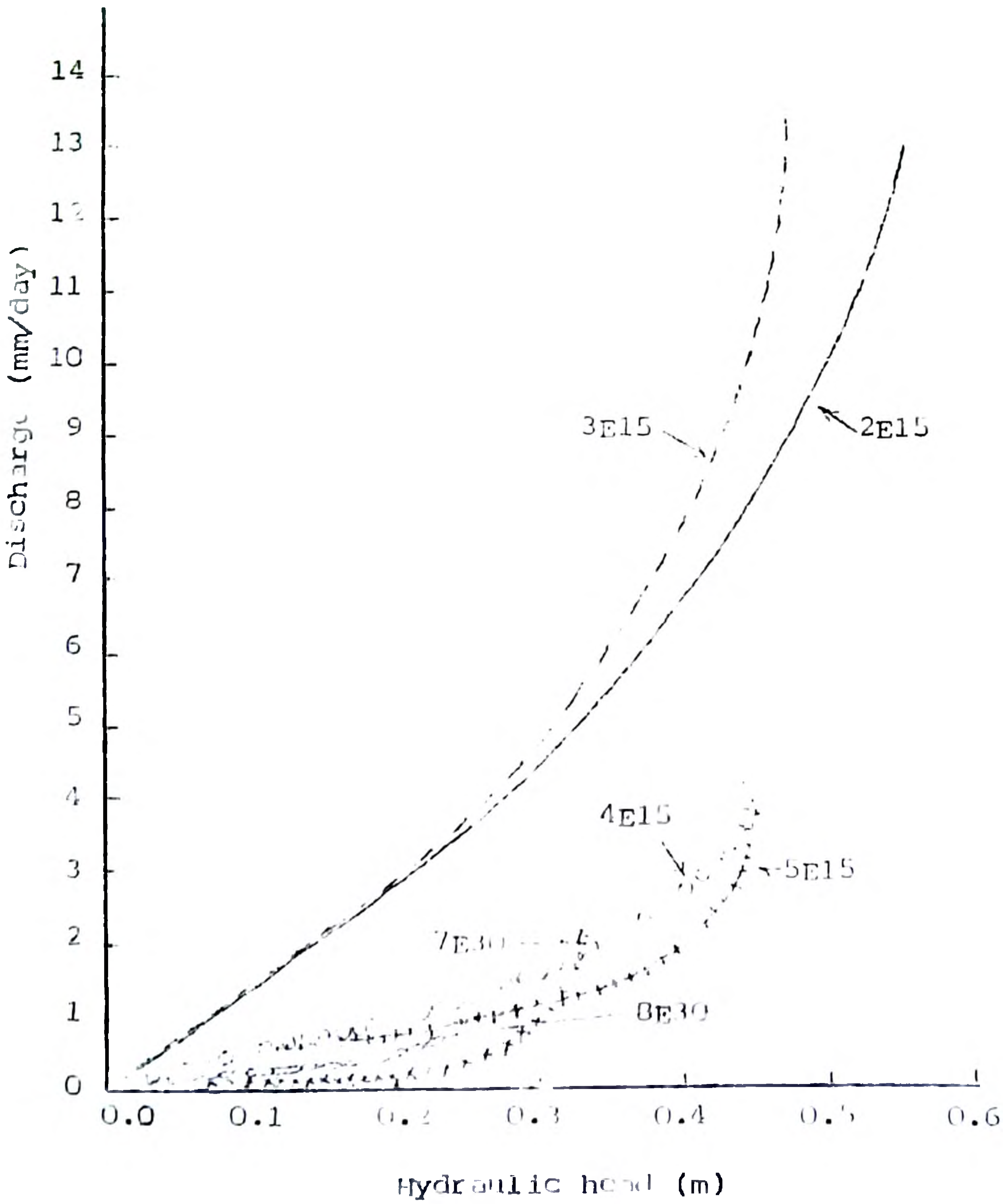


Figure - 3(4)

Discharge versus hydraulic head(2E15 - 8E30)



EXPERIMENT NO.4.

1. Title:

Effectiveness of tile drainage system in the performance of paddy crop in the Kari land.

2. Objectives:

a) To assess the incremental yield of paddy due to tile drainage system.

b) To study the growth pattern of paddy crop under tile drainage system.

c) To study the effect of tile drainage in the improvement of root zone profile of Kari lands.

3. Practical utility:

Earlier studies in this line revealed a remarkable improvement on the growth an yield of paddy crop and also on the fertility of root zone. Hence, this detailed experiment will bring out the magnitude of incremental productivity of kari lands with laying of a suitable drainage system. The study will also help in arriving at an optimum spacing of tile drains.

4. Technical programme:

Paddy crop is to be raised in the field laid out with the lateral drains, giving uniform package of practices in the whole experimental area. The standing crop will be divided into different strips of 5m width along the drain line. The first strip (treatment T1) will fall 2.5m on either side of the centre of the drain line. The second, T2, will fall between 2.5m and 5m from the drain line on either side and T3 will fall between 5m and 7.5m from the drain line on either side.

Hence, lateral drains of 15m spacing will have four treatments T1, T2, T3 and a control and 4 replications (4 experimental lines). The drain lines with 30m spacing will have 7 treatments (T1 to T7) with 2 replications. The different growth parameters will be recorded for each strip and analysed.

5. Observations to be recorded:

   a) Growth and yield parameters of paddy.

   b) Monitoring of quality of drainage and irrigation water.

6. Date of start : December 1984.

7. Date of completion : Till the scheme ends.

8. Progress of work:

   a) Crop performance:-

During the year 1987-88 Puncha season (Rabi 1987) the paddy variety selected was "KARTHIKA" - a short duration high yielding, red kernelled variety evolved from 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 sub-surface drained water was continued day and night till the harvest.

The effect of sub-surface drainage on crop performance was studied and observations on the growth and yield parameters recorded vide table No.4.1 and 4.2. The plant population/m^2 did not vary significantly for the different treatments showing that the

Table - 4.1

Mean values of plant growth and yield attributing characters(15m)

Treatment No.	Treatment	No.of plants/ m^2	Ht. at maturity (cm)	Panicle length (cm)	No.of grains/ panicle	Grain yield mt/ha	Straw yield mt/ha	100grain weight (gm)	Chaff %
1.	2.5m from drain line to either side.	137.50	97.16	20.56	105.73	5.46	5.99	2.57	15.50
2.	2.5m to 5m on either side.	143.75	89.25	19.72	93.44	4.59	4.86	2.67	20.25
3.	5m to 7.5m on either side.	126.25	95.26	[illegible]	96.14	4.88	5.28	2.60	20.50
4.	Control (No drainage).	107.50	83.16	[illegible]	69.03	[illegible]	3.48	2.34	25.25
	CD	N.S	N.S	1.42	15.36	0.4	1.35	0.11	6.09

Table - 4.2

Mean values of plant growth and yield attributing characters(30m)

Treatment No.	Treatment	No.of plants per m^2	Height at maturity (cm)	Panicle length (cm)	Straw yield MT/ha	Grain yield MT/ha	No.of grains/ panicle	100grain weight (gm)	Chaff %
1.	2.5m from drain line to either side.	15[illegible].5	9[illegible].24	20.46	100.05	5.68	5.18	2.587	16.75
2.	2.5m to 5m on either side.	135.0	91.16	20.42	101.05	4.72	5.20	2.565	25.75
3.	5 to 7.5m on either side.	160.0	90.18	20.78	105.20	4.22	4.15	2.563	27.00
4.	7.5 to 10m on either side.	165.0	88.90	19.64	85.07	4.27	4.03	2.398	27.50
5.	10m to 12.5m on either side.	132.5	90.45	19.72	90.65	3.93	5.53	2.649	19.25
6.	12.5m to 15m on either side.	125.0	91.51	20.59	108.40	4.71	5.20	2.565	21.75
7.	Control (No drainage).	87.5	76.55	18.25	76.98	2.61	3.33	2.464	23.75
	CD	N.S	9.93	0.90	N.S	0.64	N.S.	0.11	N.S

the germination percentage was not affected adversely. 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. Afterwards, as the crop growth enhanced, the difference between treatments was found to be conspicuous. The very physical appearance of the crop on the line (0 - 2.5m either side of the drain) was found to be far superior to that in the other treatments (farther from the drains) whereas the control plots resulted very poor growth as evidenced by the height of the crop and other characteristics. The same trend was observed both in the 15m and 30m set of experiments.

A study of the data on grain yield and yield attributing characters clearly revealed that T1, (0 2.5m either side of the drains), where maximum drainage took place, was significantly superior to other treatments. The grain yield recorded was as high as 5.68 t/ha against 1.61 tons/ha in the control. The overall increase in grain yield by the adoption of sub-surface drainage was 2.1 t/ha. The increase can specifically be attributed to the higher panicle length, number of grains/panicle, 100 grain weight and lower chaff percentage in the T1 treatments. During the previous years also the trend was more or less the same viz. T1, T2 ie. those areas lying nearer the lines produced higher grain yield and were on par within themselves.

The grain yield data for the last 3 years are presented in table No.4.3 and expressed in the form of bar diagrams in figure 4(1) and 4(2).

b) <u>Evaluation of water quality of drained out by the tile drains</u>:-

The quality of water drained out from each experimental lines were analysed fortnightly to find out the changes in pH and EC with reference to time.

Table - 4.3

Grain yield for the period from 1985-86 to 1987-88.

(Grain weight tons/ha)

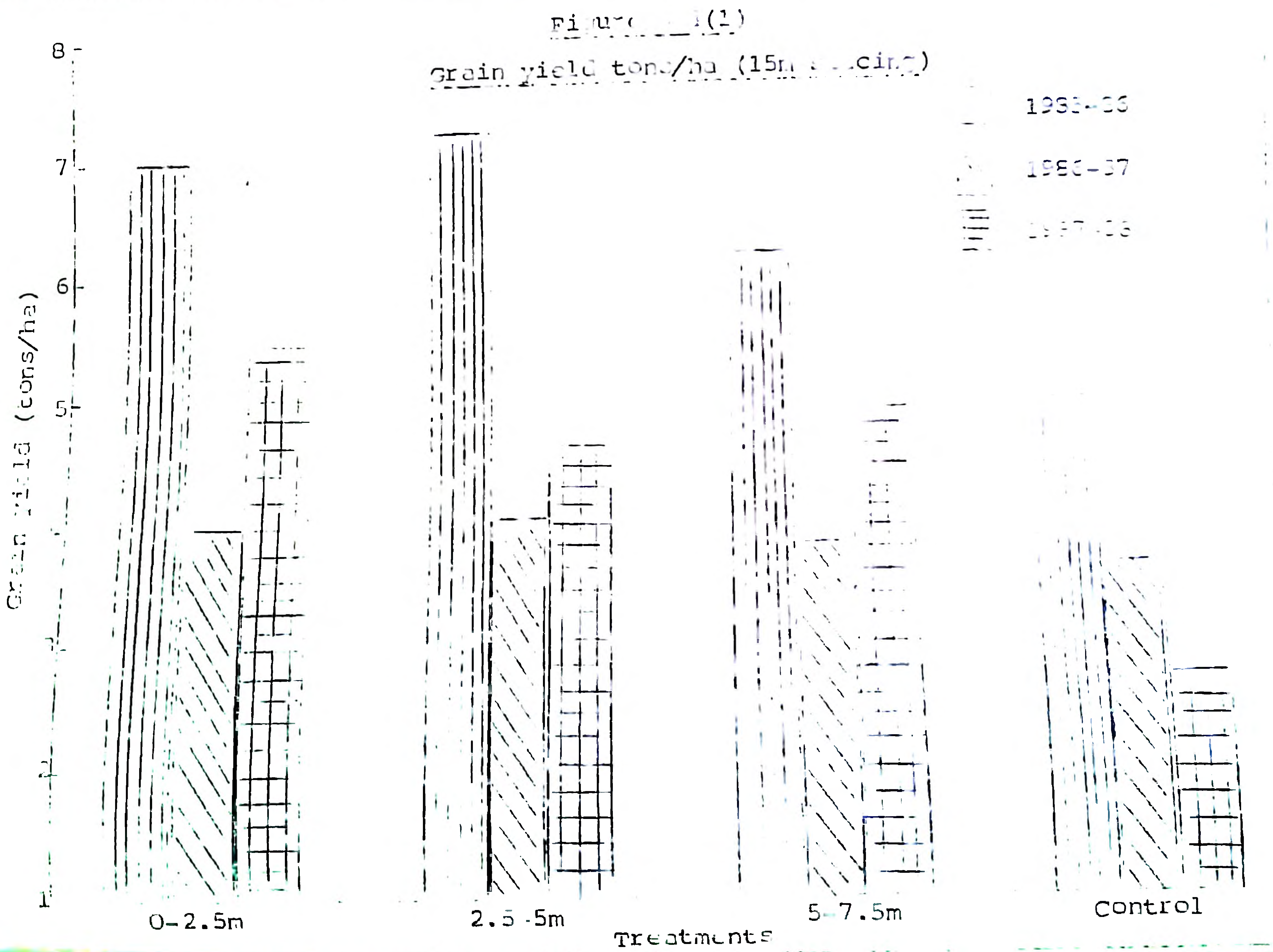
.....

15m spacing

Treatments	1985-86	1986-87	1987-88
0-2.5m, T1	7.01	3.94	5.46
2.5-5m, T2	7.17	3.99	4.59
5-7.5m, T3	6.21	3.77	4.88
Control T4	4.87	3.60	2.96

30m spacing

Treatments	1985-86	1986-87	1987-88
0-2.5m, T1	7.30	4.44	5.68
2.5-5m. T2	8.58	4.35	4.72
5-7.5m, T3	7.11	4.52	4.22
7.5-10m, T4	6.27	4.52	4.27
10-12.5m T5	5.98	4.36	3.93
12.5-15m, T6	8.15	4.34	4.71
Control T7	5.31	3.60	2.61


Grain yield tons/ha (15m spacing)
8
7
6
5
1
Grain yield (tons/ha)
0-2.5m
2.5-5m
5-7.5m
Control
Treatments

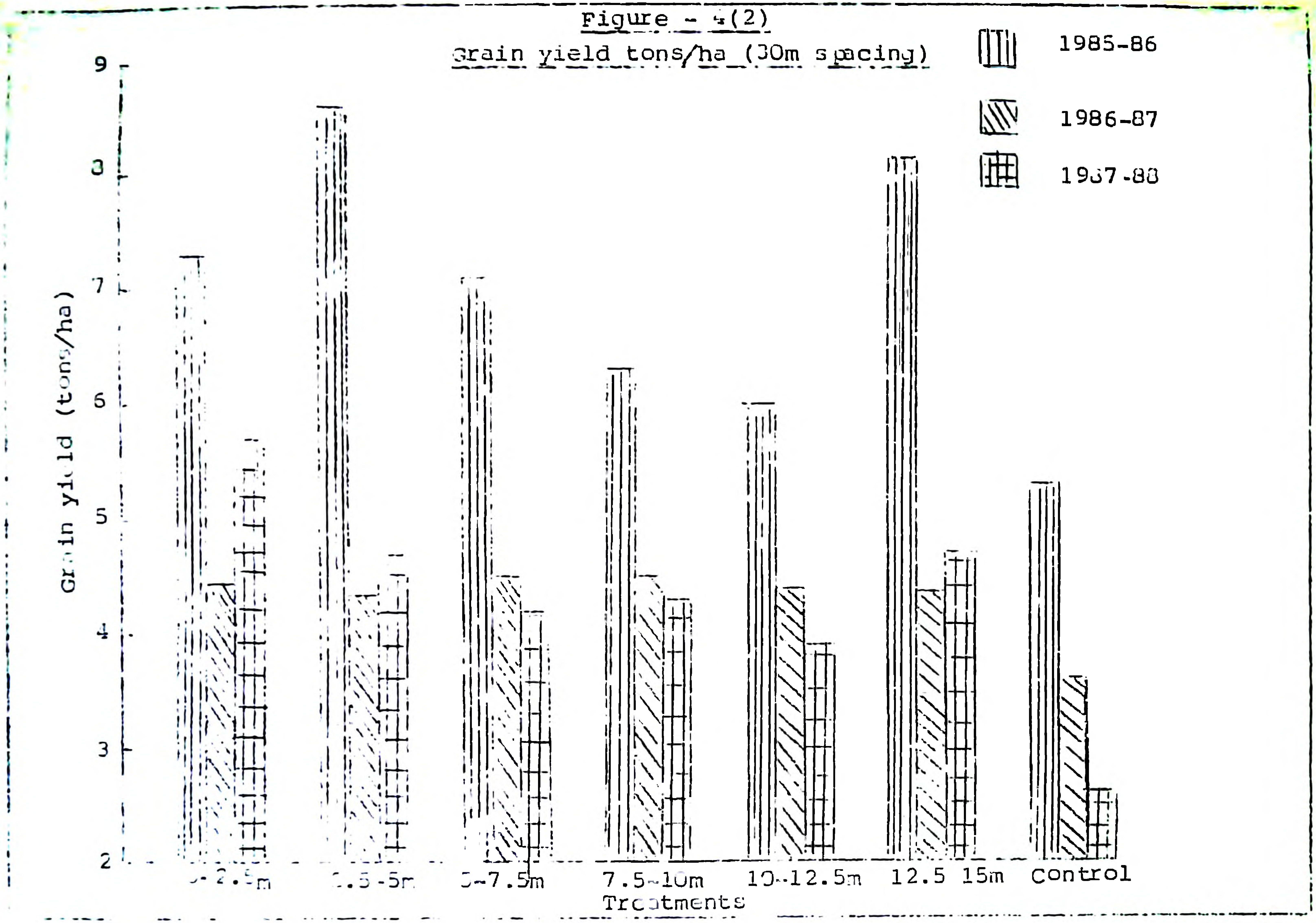


Figure - 4(2)
Grain yield tons/ha (30m spacing)
1985-86
1986-87
1987-88
Grain yield (tons/ha)
9
8
7
6
5
4
3
2
7.5-10m
10-12.5m
12.5 15m
Control
Treatments

The data is presented in Table 4.4 and graphically represented in the figure 4(3), 4(4). The observations on the same characteristics recorded during the previous years viz. 1985-86 and 1986-87 are also presented for comparison in the same figures.

pH: The pH values for the year 1985-86 show that there was a differential washing of acidity with regard to the lines denoting the areas on the lines had a pH difference. It may be noted that the distant line (7E30, 3E30) from the irrigation channel recorded a very low pH 2.5 to 3.5 initially and shot up as the season advanced giving a clear indication that it could wash off acidity to a considerable extent. Other lines behaved more or less in the same pattern remaining in the tolerable limits of paddy crop. In the next year (1986-87) itself all the lines showed uniformity in both the pattern of change in pH and were in the range of 5.5 to 6.8 showing that it could contain the acidity remarkably.

However, in the current season (1987-88) the pH level in the initial period was too low for all the lines, values ranging from 2.5 to 3.5 indicating high acidity. This may be due to severe drought encountered during the early part of 1987 which rendered the top soil acidic by oxidation. It also proves that the nearer area from the irrigation/surface drainage channels represented by the 2E15, 3E15 and 3E30 could attain a higher pH earlier, by washing off the acidity, while all others remaining in the high acidic level of 3 to 3.5 pH.

EC: The pattern of the graph for EC also shows the same trend as in pH with respect to the uniformity of the effect of different lines. It also indicates that the EC values could be lowered considerably in due course of

Table - 4.4 Water sample data taken of fortnightly intervals - collected from tiles.

1985-86

Date	pH						EC					
	2E15	3E15	4E15	5E15	7E30	8E30	2E15	3E15	4E15	5E15	7E30	8E30
21.10	6.10	6.10	7.30	5.9	2.43	3.56	3.30	2.94	2.13	[illegible]	6.06	4.92
5.11.	7.65	7.88	8.49	8.37	2.40	8.80	2.40	3.30	4.20	4.80	6.30	4.80
26.11	7.35	7.30	9.35	8.34	4.60	8.65	2.40	3.00	3.90	4.80	6.30	4.80
10.12	6.40	6.20	6.10	4.10	5.80	5.60	2.50	3.50	6.20	5.70	..	..
6.1.	..	..	..	..	..	..	2.50	2.40	2.4	3.60	4.80	4.40

1986-87

Date	pH						EC					
	2E15	3E15	4E15	5E15	7E30	8E30	2E15	3E15	4E15	5E15	7E30	8E30
23.10	6.10	6.10	6.25	6.20	6.50	6.30	1.90	1.80	1.80	2.10	2.10	2.25
6.11	6.35	6.30	6.20	6.25	6.15	6.25	2.10	2.80	2.80	3.45	3.40	3.90
20.11	6.20	6.20	6.15	6.10	6.05	6.20	2.60	3.30	3.80	4.30	5.30	5.00
4.12.	7.00	6.55	6.60	6.90	5.85	6.45	2.50	3.20	4.00	4.50	4.70	4.70
18.12	6.30	6.30	6.80	6.40	6.75	7.00	[illegible]	3.30	3.90	4.80	5.25	5.44

1987-88

Date	pH						EC					
	2E15	3E15	4E15	5E15	7E30	8E30	2E15	3E15	4E15	5E15	7E30	8E30
10.12	2.95	3.05	3.30	3.00	2.90	2.90	2.25	2.05	2.40	2.25	4.20	3.60
24.12	3.30	3.25	3.00	3.05	2.60	2.90	1.20	1.80	2.15	1.75	2.15	1.15
7.1.	3.10	3.20	3.10	3.45	..	4.55	2.05	2.10	1.90	1.80	2.50	1.90
21.1.	[illegible]	4.70	3.60	3.60	2.75	3.20	1.60	2.10	2.10	2.10	2.90	2.35
4.2.	3.95	4.00	3.90	3.35	3.00	3.10	2.00	2.15	1.90	1.80	1.65	2.30

Figure 4(3)

Variation of pH in water samples collected from different tile drains at fortnightly intervals.

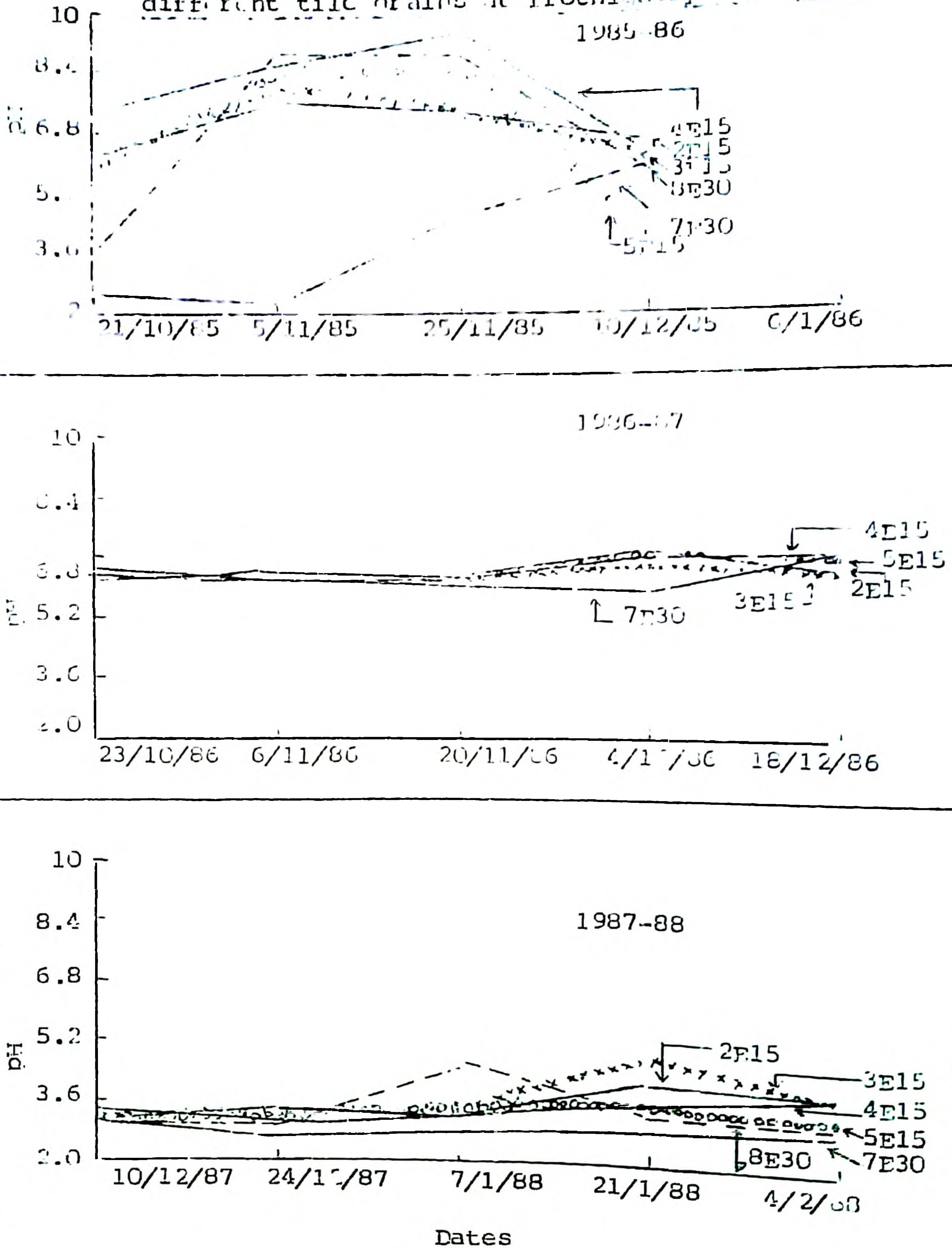
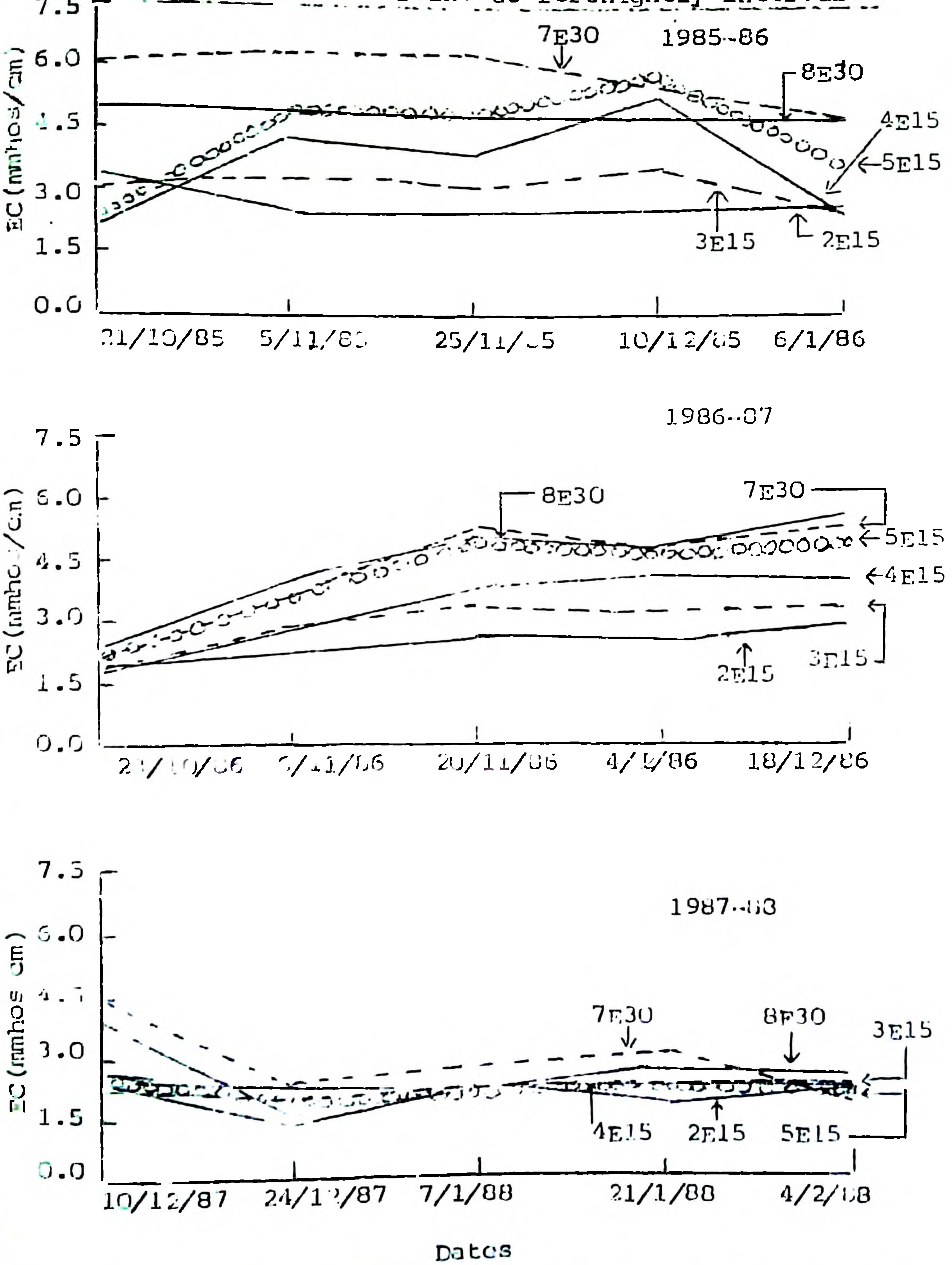


Figure - 4(4)

Variation of EC in water samples collected from different tile drains at fortnightly intervals.



3 years after the inception of the subsurface drainage system. The values which ranged from [illegible] to 6 mmhos/cm in 1985-86 were lowered to 2 to 4 mmhos/cm at the initial period of [illegible] and later to a still lower value of below 3mmhos/cm during the year 1987-88. It may be specifically noted that the water samples from the [illegible] line 7E30 which recorded EC value as high as 6 mmhos/cm reached a value below 3 mmhos/cm in a period of 3 years. This conclusively proves that by adopting sub-surface drainage system the total soluble salts can be kept under control and a favourable EC range for good crop growth and yield can be attained.

c) Quality comparison of irrigation water, surface and sub-surface drainage water:

Weekly monitoring of pH & EC of irrigation water, surface drained water and subsurface drainage water were also done during the cropping season. The data is given in the tables 4.5 & 4.6 and graphically represented in figure 4(5) and 4(6). The pH values of surface drained water were found to vary on par with that of the irrigation water ranging from 4.0 to 8.0 in 1985-86 and 5.0 to 7.0 in 1986-87. During these years the subsurface drained water recorded although a higher pH, the trend was more or less the same showing that it could contain the acidity as good as the surface drainage channels and was always in the tolerable limits for crop growth. But in the current year the pH of subsurface drained water was found to be much lower and remain in the range of 3 to 3.5 whereas the irrigation and surface drained water recorded higher value of 3.5 to 6.0. This difference may be due to the high acidic condition formed by the severe drought during the early period of 1987. This eventually proves that the acidity could also be controlled to a significant extent by adopting the sub-surface drainage system.

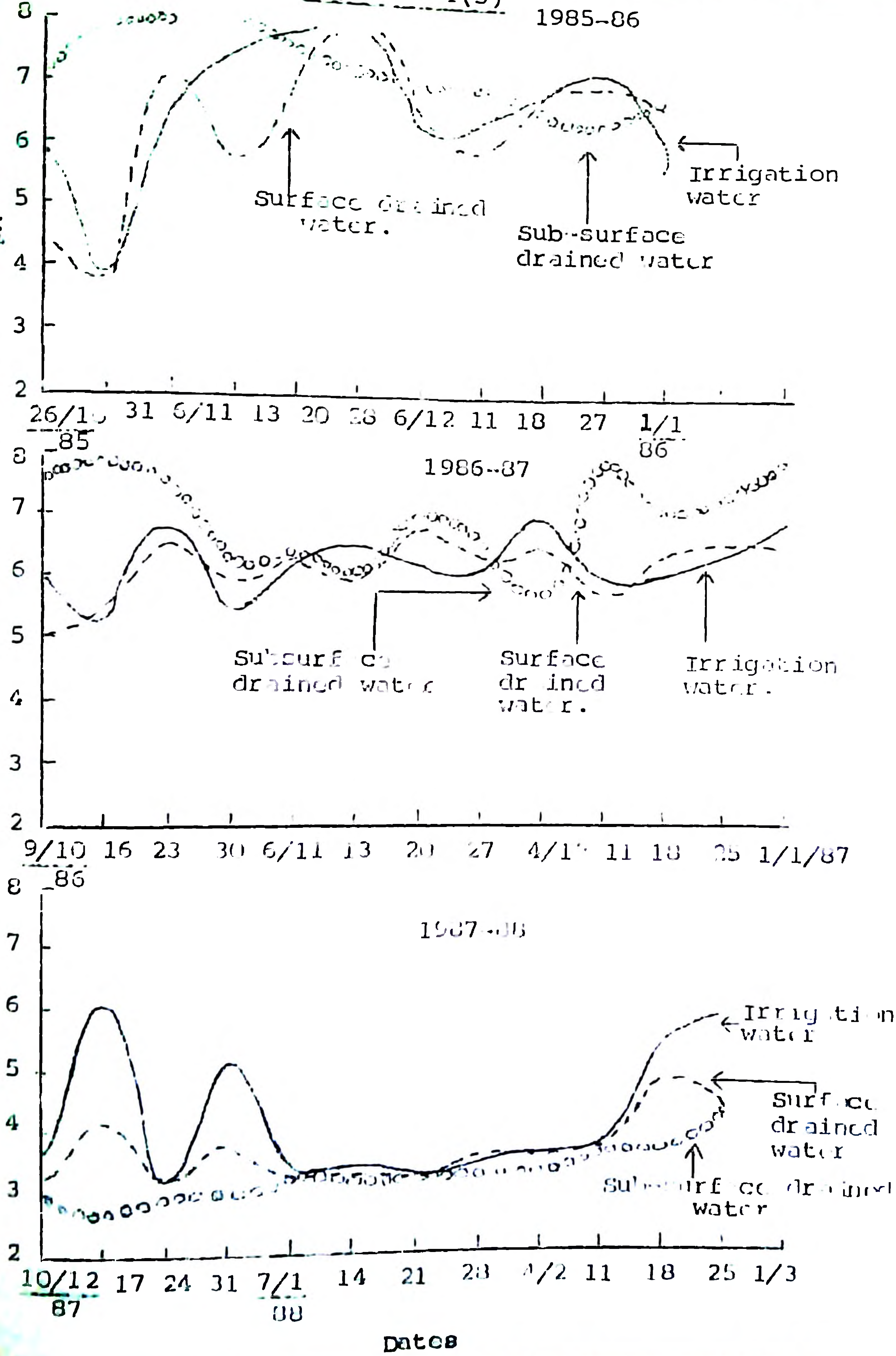
Table - 4.5 Weekly averages of pH

1985-86				1986-87				1987-88			
Date	Irriga-tion water.	Surface drained water.	Subsur face drained water	Date	Irriga-tion water	Surface drained water	Subsur-face drained water	Date	Irriga-tion water	Surface drained water	Subsur-face drained water.
26.10.85	5.79	4.36	7.10	9.10.86	5.95	5.10	7.60	10.12.87	3.65	3.25	2.95
31.10.85	3.86	3.83	7.90	16.10.86	5.30	5.50	7.78	17.12.87	6.10	4.20	2.73
6.11.85	6.63	7.10	8.00	23.10.86	6.75	6.50	7.50	24.12.87	3.15	3.30	2.99
13.11.85	7.61	5.77	8.10	30.10.86	5.50	5.90	6.20	31.12.87	5.10	3.80	2.97
20.11.85	7.90	7.13	7.60	6.11.86	6.25	6.30	6.40	7.1.1988	3.40	3.25	3.33
28.11.85	9.23	9.66	7.30	13.11.86	6.50	6.00	6.02	14.1.88	3.40	3.40	3.16
6.12.85	6.35	6.55	7.10	20.11.86	6.20	6.80	7.03	21.1.88	3.30	3.30	3.31
11.12.85	6.54	6.13	7.10	27.11.86	6.10	6.25	6.73	28.1.88	3.45	3.60	3.25
18.12.85	7.00	7.02	6.70	4.12.86	7.00	6.50	5.73	4.2.1988	3.60	3.65	3.28
27.12.85	7.38	7.06	5.50	11.12.86	6.00	5.70	8.15	11.2.88	3.65	3.65	3.58
1.1.1986	5.87	6.83	6.90	18.12.86	6.05	6.25	7.13	18.2.88	5.45	4.75	3.58
..	..	..	..	25.12.86	..	..	..	25.2.88	5.90	4.40	4.25
..	..	..	..	1.1.1987	6.90	6.45	8.00	..	..	..	..

Table - 4.6 Weekly averages of EC (mmhos/cm)

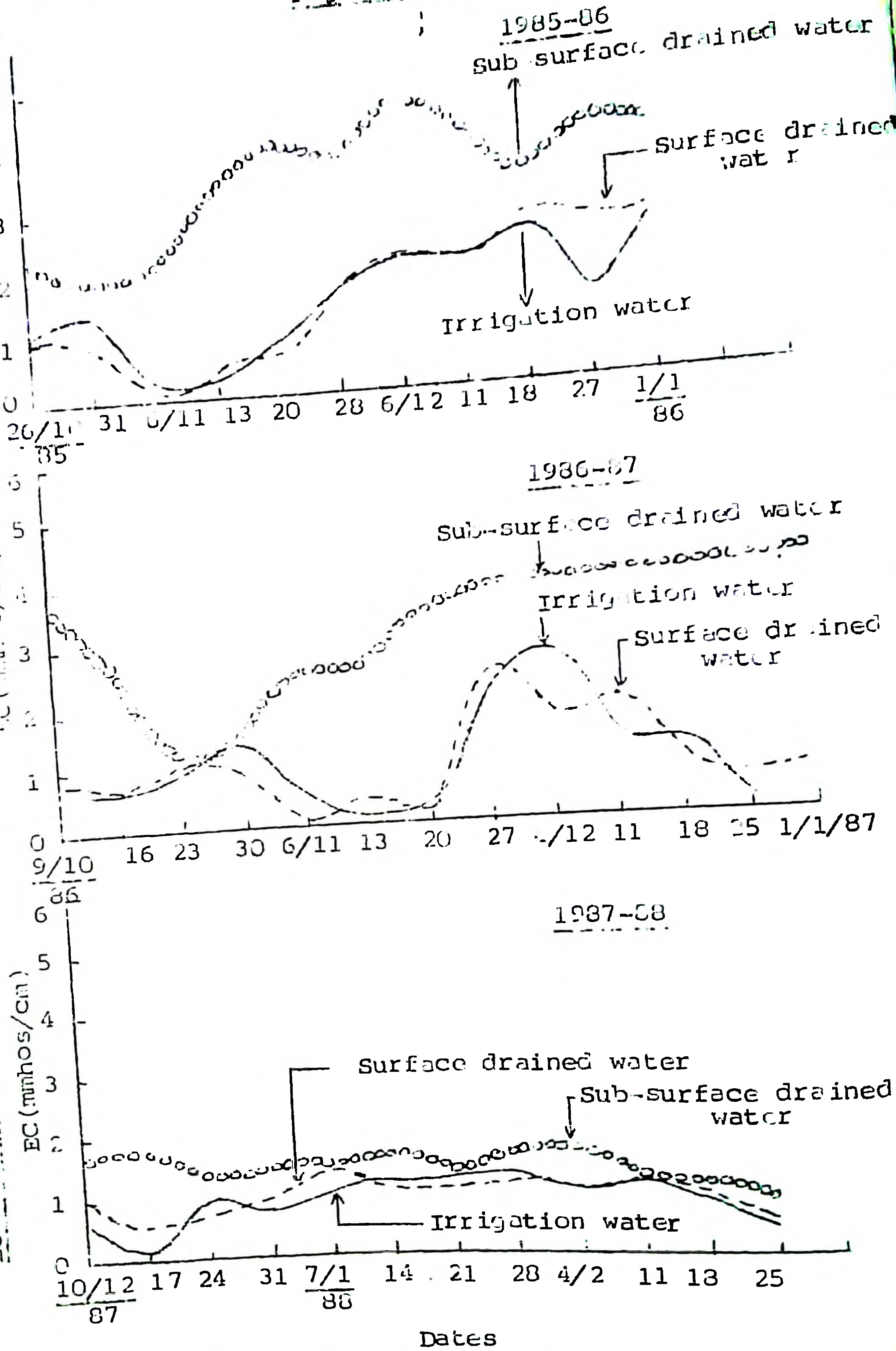
1985-86				1986-87				1987-88			
Date	Irrigation water.	Surface drained water	Subsurface drained water	Date	Irrigation water.	Surface drained water	Subsurface drained water	Date	Irrigation water.	Surface drained water	Subsurface drained water.
26.10.85	1.19	1.07	2.40	9.10.86	0.75	0.89	3.65	10.12.87	0.59	1.08	1.65
31.10.85	1.40	0.93	1.98	16.10.86	0.65	0.69	2.55	17.12.87	0.23	0.63	1.81
6.11.85	0.32	0.23	2.20	23.10.86	1.01	0.99	1.17	24.12.87	0.99	0.83	1.38
13.11.85	0.37	0.48	3.38	30.10.86	1.44	0.93	1.60	31.12.87	0.83	0.98	1.47
20.11.85	0.89	0.67	4.05	6.11.86	0.45	0.12	2.45	7.1.88	1.07	1.40	1.52
28.11.85	1.68	1.67	3.80	13.11.86	0.18	0.40	2.55	14.1.88	1.15	1.10	1.71
6.12.85	2.24	2.22	4.65	20.11.86	0.31	0.24	3.43	21.1.88	1.29	1.10	1.38
11.12.85	2.13	2.06	4.25	27.11.86	2.25	2.40	3.80	28.1.88	1.25	1.20	1.75
18.12.85	2.45	2.74	3.44	4.12.86	2.70	1.70	3.80	4.2.88	1.07	1.11	1.68
27.12.85	1.51	2.60	4.10	11.12.86	1.35	1.90	3.90	11.2.88	1.17	1.17	1.27
1.1.1986	2.45	2.61	3.95	18.12.86	1.20	..	3.85	18.2.88	0.93	0.96	1.16
..	..	..	..	25.12.86	..	..	..	25.2.88	0.50	0.60	1.05
..	..	..	..	1.1.1987	0.29	0.79	4.10	..	..	..	..

Figure - 4(5)



pH comparison among irrigation, surface drained and sub-surface drained water

Figure :- 4(C)



EC comparison among irrigation, surface drained and sub-surface drained water

A critical evaluation of the figure 4(6) indicate that the sub-surface drained water recorded the highest EC values in all the consecutive years from 1985-86 to 1987-88 whereas the difference between that of the surface drained water and irrigation water was negligible. This conclusively proves that by adopting sub-surface drainage system the total soluble salts can be brought down significantly. The other interesting feature derived from the figure is that in the course of 3 years time, the EC value of the water had been brought down significantly from 4.5 to 1.7 mmhos/cm.

It may be arrived at from the table 4.6 that the overall average difference in EC between the irrigation water and sub-surface drained water from the years 1985-86, 1986-87 and 1987-88 are 1.90, 2.25 and 0.56 mmhos/cm respectively. When quantitatively expressed, the sub-surface drains removed, 125 kg, 14[illegible] kg, and 36 kg of salt per ha per cm of drained water during the respective periods.

EXPERIMENT No.5.

1. Title:-

Evaluation of different filter materials to find its economic suitability including its design criteria for the sub-surface drainage system.

2. Objectives:

To study the effectiveness and economic suitability of different envelope materials used and its design criteria.

3. Practical utility:

One of the main factors which increases the cost per hectare of the sub-surface tile drainage system is the envelope material used. The study can throw light into the effectiveness of the envelope materials used and can suggest an economically viable envelope material.

4. Technical programme:-

The filter material will be statistically tested by the Radomized Block Design technique. Each block consists of 7 treatments and there will be three replications. The treatments are:

i) Sea sand all around the drain
ii) Sea sand around the joints only
iii) River sand all around the drain
iv) River sand around the joints only
v) Paddy straw around the joints only
vi) Coir fibre around the joints only
vii) No filter materials.

The filter materials were selected according to the local availability. Each treatment is a tile line of 40m length and is spaced at 15M. The drainage flow and the subsidence of water table will be studied from each treatment. The yield data also will be collected from each treatment.

5. Observations to be recorded:

1) Water table elevations
2) Drainage flow
3) Crop yield data

6. Date of start : January 1987

7. Date of completion : December 1990

8. Progress of work:-

The installation of the tile drains was carried out in 1986-87 after the harvest of the crop the layout of which is given in figure 5(1). All the observation wells have been installed in the experimental area during the period under report to monitor the water table fluctuations and discharge rates.

Observations related to this experiment could not be recorded during the period due to unfavourable conditions. The cost estimate of laying a sub-surface drainage system using different filter materials for a 30m spacing is given in table 5.1 and the cost/ha in table 5.2. The system has to be incorporated with the already existing main surface channels thereby fully utilizing the existing potential. The cost benefit ratio of the system will be worked out and presented later.

Figure 5(I) Layout of tile drains

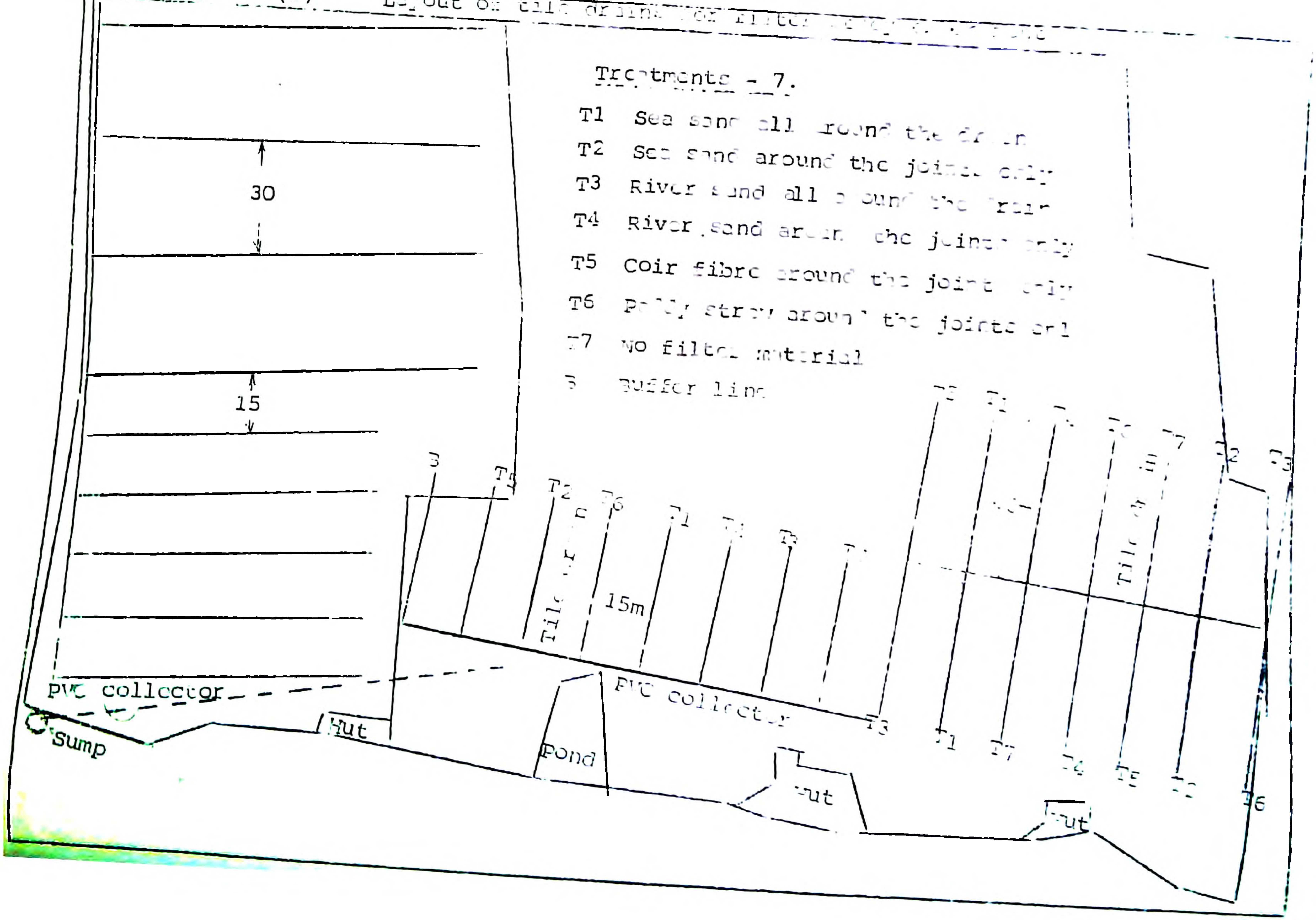


Table - 5.1

Cost estimate of laying of a sub-surface tile drainage system

Sl.No.	Filter material used	Cost of earthen pipe including transportation charges @ Rs7.00/pipe of 0.6m (Rs./m)	Excavation charges of the trench @ Rs.6.40/m^3 (Rs./m)	Laying of pipe and back filling including transportation charges to the field (Rs./m)	Quantity of filter material	Cost of filter material (Rs./m)	Charges for covering filter material (Rs./m)	Total cost (Rs./m)
1)	Sea sand all around the drain	11.60	5.10	1.25	$0.075 m^3/m$	.6	1	25.15
2)	Sea sand around the joints only	,,	,,	,,	0.015 ,,	1.[illegible]	1	20.35
3)	River sand all around the drain	,,	,,	,,	0.075 ,,	7.95	1	27.10
4)	River sand around the joints only	,,	,,	,,	0.015 ,,	1.[illegible]	1	20.75
5)	Coir fibre around the joints only	,,	,,	,,	0.5kg/m	1.5	1	[illegible].65
6)	Paddy straw around the joints only	,,	,,	,,	0.5kg/m	0.5	1	19.60
7)	No filter material	,,	,,	,,	-	-	-	18.15

Table - 5.2

Cost/ha for different tile drainage system for a 30m spacing*

Sl.No.	Filter material	Cost/m	Spacing	Cost/ha
1)	Sea sand all around the drain	Rs 25.15	30m	Rs 8383/-
2)	Sea sand around the joints only	Rs 20.35	,,	Rs 6783/-
3)	River sand all around the drain	Rs 27.10	,,	Rs 9033/-
4)	River sand around the joints only	Rs 20.75	,,	Rs 6917/-
5)	Coir fibre around the joints only	Rs 20.65	,,	Rs 6883/-
6)	Paddy straw around the joints only	Rs 19.60	,,	Rs 6533/-
7)	No filter material	Rs 18.15	,,	Rs 6050/-

* This estimate does not include the pumping system and the collector system.

EXPERIMENT No.6.

1. Title:

Studies on the changes of soil chemical properties with respect to time on sub-surface drainage.

2. Objectives:

1) To study the different ionic concentration in the soil at the critical stages of plant growth.

2) To monitor the changes in the soil chemical properties with reference to time.

3. Practical utility:

This study will give an indication of the tolerance of paddy crop to different salt concentrations. The quantity of such toxic salts removed also can be assessed.

4. Technical programme:

A few locations will be fixed, wherefrom soil samples need be drawn and chemical analysis work conducted at fixed intervals. To compare its effect soil samples will be drawn from the control plots also.

5. Observations to be recorded:

The following ionic concentrations and other changes in physico chemical properties of the soil samples, due to the adoption of sub-surface drainage system will be assessed.

pH, EC(mmhos/cm), Fe, SO4, Ca, Mg., Cl, Na, K, Al, NO3, HCO3, CO3, Av.N., P2O5 etc.

6. Date of start : November 1987.

7. Date of completion : Till the scheme ends.

8. Progress of work:

During the period under report a total number of 66 locations were marked in the whole area of 4 ha. where sub-surface drainage system has come in to vogue under two experimental heads as mentioned below for comparing with the control - where farmers adopt surface drainage system only.

1) Effectiveness of the subsurface drainage system in the performance of paddy crop in the kari lands (E).

2) Evaluation of different filter materials for the subsurface drainage system (F).

The modus-operandi and other details of soil sampling are shown in the following table.

Treatments(site)		No.of soil samples at a time	Remarks
E15	On the line	4	Soil samples were taken on 8 different dates viz. 21st November, 10th & 24th Dec. 1987, 7th & 21st January 4th & 18th February and 17th March of 1988.
	between the line	4	
E30	On the line	4	
	between the line	4	
F	On the line	21	
	between the line	19	
C	Control	10	
	Total :	66	

These locations were selected to find out the effect due to differential subsurface drainage among the 15m and 30m spacings (E15 & E30) which came into effect since 1985-86 and compared with the newly laid out experiment (F) 1987-88 and control.

These soil samples were subjected to laboratory analysis for studying periodic changes in the chemical properties viz. pH, EC, Fe, SO_4, Ca, Mg. and Cl concentrations on different dates as mentioned above. The data is then consolidated on monthly basis and presented in the tables 6(1) to 6(5). Accordingly they are represented graphically in the Figure Nos.6(1) to 6(5). The results are given below one by one.

1) Effectiveness of subsurface drainage system:

The figure No.6(1) and 6(2) clearly indicated the following.

a) pH:

In all the treatments during the cropping period pH tends to increase uniformly giving a stable value around 5.5 to 6. This value shows a drastic decline at harvest and after, consequent to the stoppage of drainage. Its minor drop in pH during the second observation correspond to the dewatering given to facilitate fertilizer application. Among the treatment values of pH "on the line" tends to be lower indicating the effect of the higher aerobicity created during the cropping season, thus suppressing the pH increase.

b) EC:

EC values clearly indicate more or less the same trend with respect to changes in time. However, the values for independent observation gives the highest figure for control, thus revealing the effectiveness of subsurface drainage in controlling the total soluable salts. The final increase in EC is supposedly due to the stoppage of drainage at harvest of the crop.

Table - 6.1

pH

Treatments	21.11.87	24.12.87	21.1.88	18.2.88	17.3.88
EOL(15)	4.63	4.20	[illegible].88	6.03	3.37
EBL(15)	4.50	[illegible].95	[illegible]	6.21	3.47
Control	4.50	3.75	5.34	5.79	3.11

EC (mmhos/cm)

Treatments	21.11.87	24.12.87	21.1.88	18.2.88	17.3.88
EOL(15)	0.56	0.39	0.64	0.32	1.52
EBL(15)	0.61	0.48	0.41	0.30	1.74
Control	1.02	1.27	1.05	0.65	2.66

Fe (ppm)

Treatments	21.11.87	24.12.87	21.1.88	18.2.88	17.3.88
EOL(15)	0.25	0	0	0	10.00
EBL(15)	0	0	0	0	0
Control	24.00	24	3	2	153.00

SO4 (ppm)

Treatments	21.11.87	24.12.87	21.1.88	18.2.88	17.3.88
EOL(15)	814	907	1005	1224	1482
EBL(15)	805	791	880	802	1544
Control	1240	1667	1141	1645	2076

Ca(ppm)

Treatments	21.11.87	24.12.87	21.1.88	18.2.88	17.3.88
EOL(15)	50	90	177	149	124
EBL(15)	36	75	105	118	128
Control	170	203	205	178	237

Mg (ppm)

Treatments	21.11.87	24.12.87	21.1.88	18.2.88	17.3.88
EOL(15)	[illegible]	1146	1123	1332	1822
EBL(15)	455	[illegible]	878	1321	1882
Control	[illegible]	1174	1461	1641	2066

Cl (ppm)

Treatments	21.11.87	24.12.87	21.1.88	18.2.88	17.3.88
EOL(15)	[illegible]	506	648	893	1076
EBL(15)	735	595	613	945	1234
Control	814	823	770	1120	1260

Figure - 6(1) Chemical changes on drainage(15m spacing)

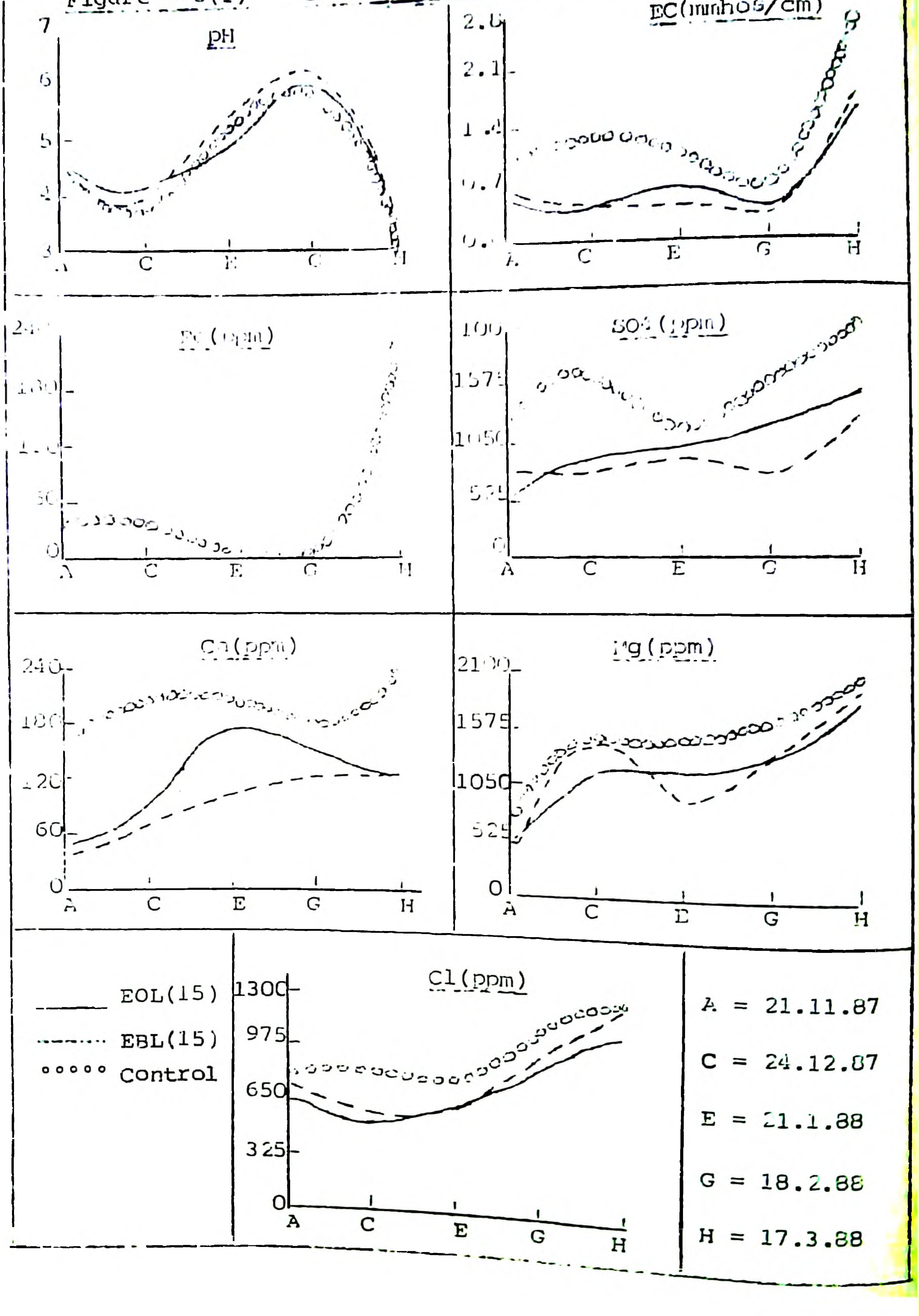


Table - 6.2

pH

Treatments	21.11.87	24.12.87	21.1.88	18.2.88	17.3.88
EOL(30)	4.62	3.69	4.15	5.18	3.45
EBL(30)	4.50	3.80	5.21	5.86	3.25
Control	4.50	3.75	5.34	5.79	3.11

EC (mmhos/cm)

Treatments	21.11.87	24.12.87	21.1.88	18.2.88	17.3.88
EOL(30)	0.75	0.46	0.66	0.42	1.04
EBL(30)	0.71	0.66	0.77	0.58	1.75
Control	1.02	1.27	1.05	0.65	1.66

Fe (ppm)

Treatments	21.11.87	24.12.87	21.1.88	18.2.88	17.3.88
EOL(30)	0	0	0	0	0
EBL(30)	0	0	0	0	0
Control	24	24	3	2	153

SO_4 (ppm)

Treatments	21.11.87	24.12.87	21.1.88	18.2.88	17.3.88
EOL(30)	[illegible]	787	953	1063	976
EBL(30)	813	953	792	1011	1279
Control	1240	1667	1141	1645	2076

Ca (ppm)

Treatments	21.11.87	24.12.87	21.1.88	18.2.88	17.3.88
EOL(30)	70	127	156	122	161
EBL(30)	48	92	110	114	180
Control	170	203	205	178	237

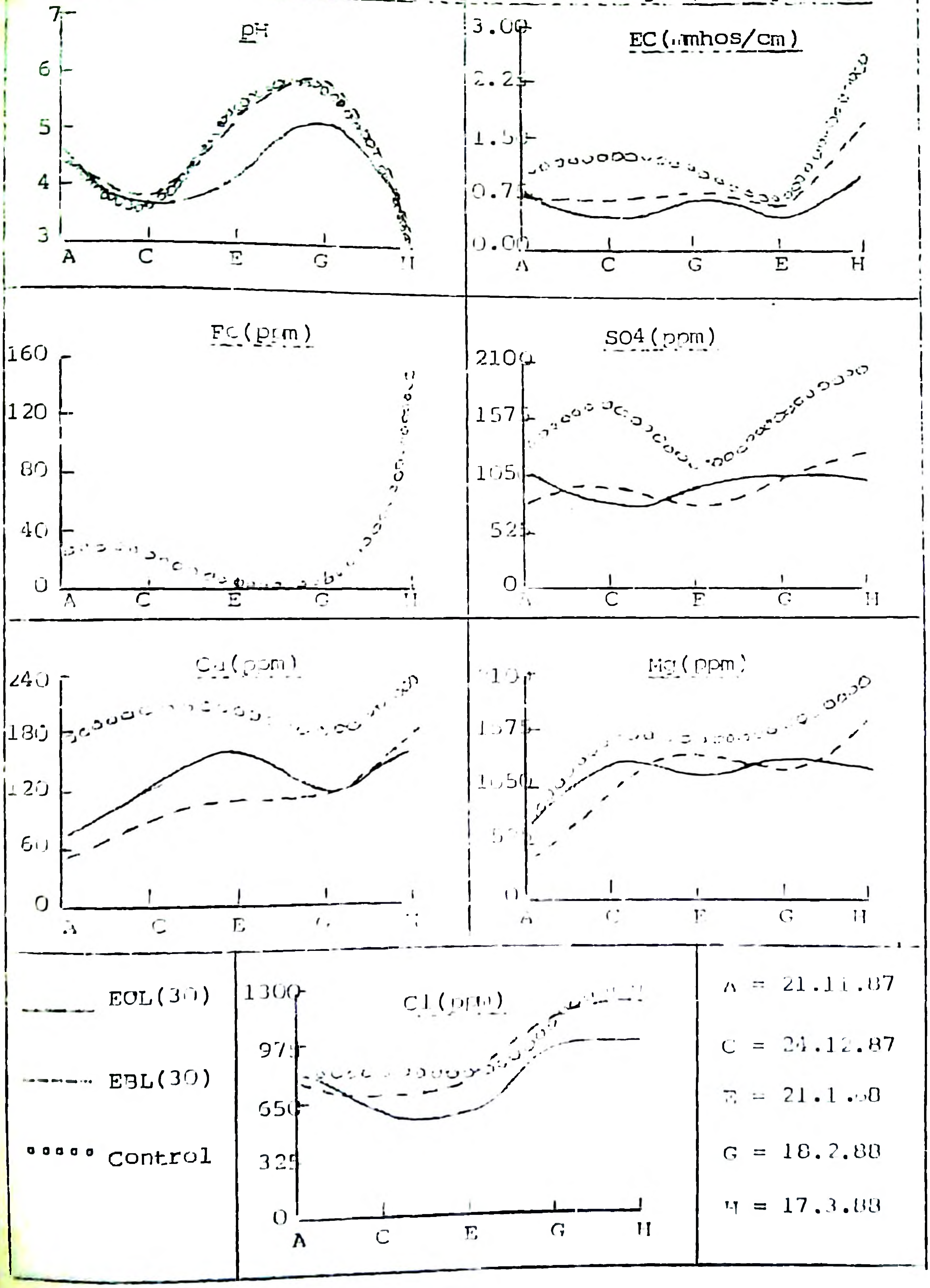
Mg (ppm)

Treatments	21.11.87	24.12.87	21.1.88	18.2.88	17.3.88
EOL(30)	668	1268	1118	1300	1199
EBL(30)	346	1068	1355	1189	1668
Control	696	1474	1461	1641	2066

Cl (ppm)

Treatments	21.11.87	24.12.87	21.1.88	18.2.88	17.3.88
EOL(30)	840	578	595	963	980
EBL(30)	770	683	788	1138	1190
Control	814	823	770	1120	1260

Figure 6(2) Chemical changes on drainage (30m spacing)



c) Fe :

Presence of water soluble Fe in detectable quantities is observed only in the control plots, where the stagnant water is sufficient enough to cause reduction, leading to high water soluble Fe content. In the other two treatments the levels of water soluble Fe was controlled by the incessant drainage with the consequent aerobicity created. This renders much of the Fe to water insoluble ferric forms.

d) SO_4, Ca, Mg & Cl :

The uniformly observed high values for control clearly brings out the role of sub surface drainage in reducing the concentration of SO_4, Ca, Mg and Cl under field situations. However, between the treatments "on the line" and "between the lines", the former gives higher values for SO_4, Ca, Mg & Cl. This can be due to the high retention capacity of the soil with respect to polyvalent ions upon drainage. This is again accelarated by the high CEC of the soil and the higher bonding energies for polyvalent cations. The colloidal system tends to adjust itself by throwing more of monovalent cations in the solution phase and giving provision for adsorption of the polyvalent cations.

2) Comparison among on the line, between the line and control in the filter studies experiment:

A study of the figures 6(3), 6(4) & 6(5) reveals the following:-

pH :

The control and treatments show not much of difference and the pattern of xx changes are more or less the same. However, during the last observation when drainage was stopped, the fall of pH values was drastic in all the treatments including control. This may be due to the preharvest closure of irrigation and allowing the soil to dry for facilitating the harvest of crop.

EC :

Electrical conductivity values show values below 2 mmhos/cm during the cropping period and after harvest. When the drainage was stopped the values, however, increased to more than 3 mmhos/cm. The same trend is observed for all the treatments. Further, the values for independant observation in the case of control appears to be slightly higher, though not significant. The drastic spurt in EC values during the last observation is supposedly due to the high accumulation of salts (ions) consequent the sudden stoppage of drainage.

Fe :

Soil Fe concentration as extracted by distilled water shows high to moderately high values during the cropping season in the treatments'on the line'

In all the treatments the decrease in Fe(water sol.) concentration during the 3rd observation may be due to the fluctuating hydrological flux created by repeated dewatering and letting in of water so as to facilitate fertilizer application. The aerobicity created by these operation, though not significant is considerable in controlling the dynamics of soluable Fe under the rice farming situation of the locality.

The analytical values for SO4, Ca^{++}, Mg^{++} and chloride show patterns similar to the one explained above.

This particular experiment has just been started during this year and hence any conclusive evidence regarding the changes in nutrient concentration, EC, pH etc. cannot be arrived at with the present data.

Table - 6.3

pH

Treatments	21.11.87	24.12.87	21.1.88	18.2.88	17.3.88
FOL	4.67	3.88	5.18	5.69	2.91
FBL	4.57	3.9[illegible]	4.97	5.58	3.10
Control	4.50	3.75	5.34	5.79	3.11

EC (mmhos/cm)

Treatments	21.11.87	24.12.87	21.1.88	18.2.88	17.3.88
FOL	0.91	0.80	0.77	0.53	3.32
FBL	0.84	0.84	0.96	0.71	2.60
Control	1.02	1.27	1.05	0.65	2.66

Fe (ppm)

Treatments	21.11.87	24.12.87	21.1.88	18.2.88	17.3.88
FOL	170	139	73	127	233
FBL	24	79	50	45	200
Control	24	24	3	2	153

SO4 (ppm)

Treatments	21.11.87	24.12.87	21.1.88	18.2.88	17.3.88
FOL	2437	2200	2389	2433	2450
FBL	1491	2229	1994	1776	2188
Control	1240	1667	1141	1645	2075

Ca (ppm)

Treatments	21.11.87	24.12.87	21.1.88	18.2.88	17.3.88
FOL	163	198	240	200	177
FBL	110	213	256	168	150
Control	170	203	205	178	239

Mg (ppm)

Treatments	21.11.87	24.12.87	21.1.88	18.2.88	17.3.86
FOL	1213	1946	2312	2037	2107
FBL	841	1580	2[illegible]64	1699	2384
Control	696	1474	1461	1641	2056

Cl (ppm)

Treatments	21.11.87	24.12.87	21.1.88	18.2.88	17.3.88
FOL	557	720	687	1140	1313
FBL	862	770	759	1120	1396
Control	814	623	770	1120	1260

Figure - 6(3) Chemical changes in filter study experiment

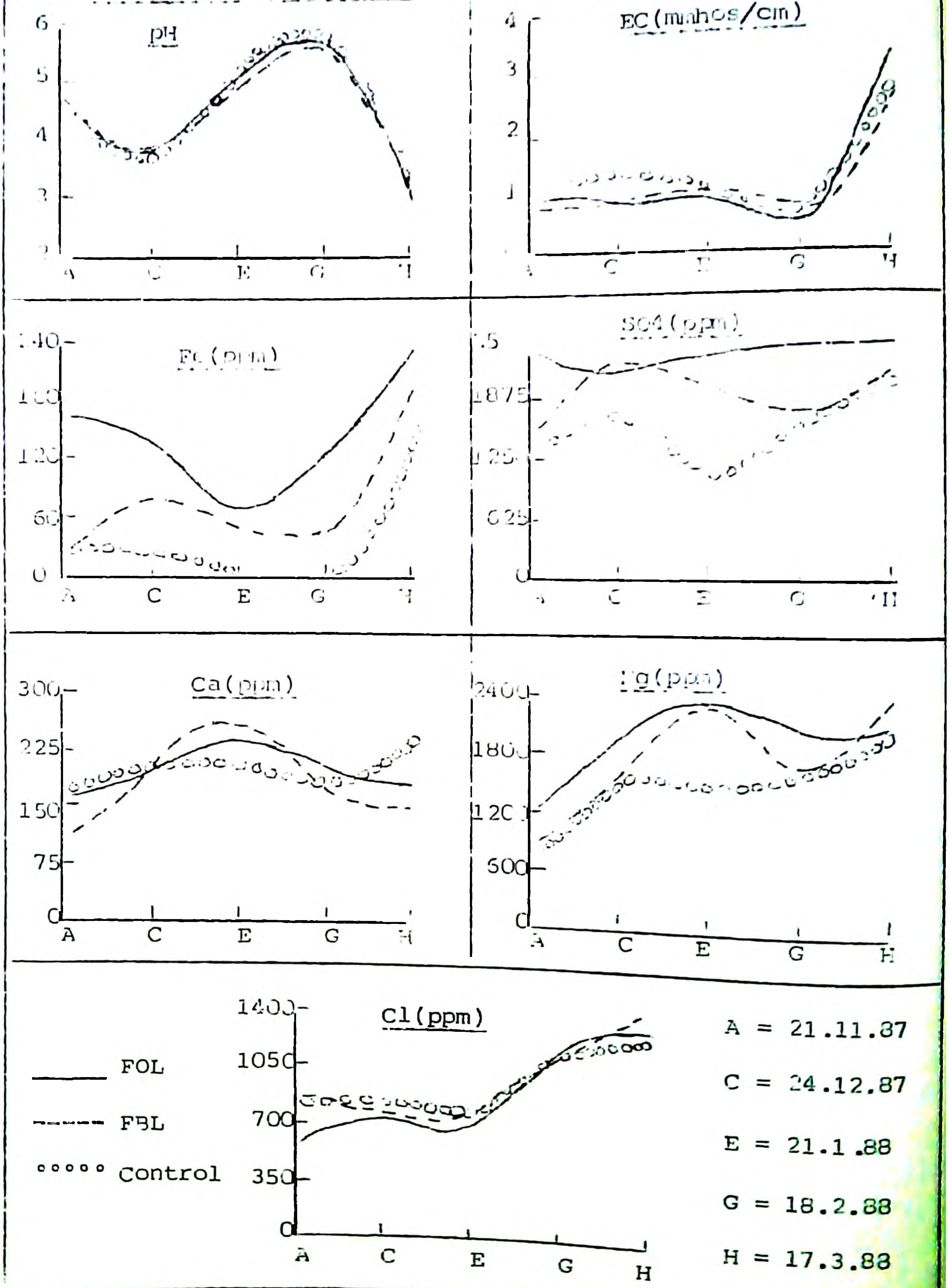


Table - 5.4

pH

Treatments	21.11.87	24.12.87	21.1.88	18.2.88	17.3.88
EOL(15)	4.63	4.20	4.88	6.03	3.37
EOL(30)	4.62	3.69	4.15	5.18	3.45
FOL	4.67	3.88	5.18	5.69	2.91
Control	4.50	3.75	5.34	5.79	3.11

EC (mmhos/cm)

Treatments	21.11.87	24.12.87	21.1.88	18.2.88	17.3.88
EOL(15)	0.56	0.39	0.64	0.32	1.52
EOL(30)	0.75	0.46	0.66	0.42	1.04
FOL	0.91	0.60	0.77	0.53	3.32
Control	1.02	1.27	1.05	0.65	2.66

Fe (ppm)

Treatments	21.11.87	24.12.87	21.1.88	18.2.88	17.3.88
EOL(15)	.25	0	0	0	10.0
EOL(30)	0	0	0	0	0
FOL	170	139	73	127	233
Control	24	24	3	2	153

SO_4 (ppm)

Treatments	21.11.87	24.12.87	21.1.88	18.2.88	17.3.88
EOL(15)	814	907	1005	1224	1482
EOL(30)	1109	787	953	1063	976
FOL	2437	2200	2389	2433	2450
Control	1240	1667	1141	1645	2075

Ca (ppm)

Treatments	21.11.87	24.12.87	21.1.87	18.2.88	17.3.88
EOL(15)	50	90	177	149	124
EOL(30)	70	127	156	122	161
FOL	163	198	240	200	177
Control	170	203	205	178	237

Mg (ppm)

Treatments	21.11.87	24.12.87	21.1.87	18.2.88	17.3.88
EOL(15)	480	1146	1123	1332	1822
EOL(30)	668	1268	1118	1300	1199
FOL	1213	1946	2312	2037	2107
Control	696	1474	1461	1641	2066

Cl (ppm)

Treatments	21.11.87	24.12.87	21.1.87	18.2.88	17.3.88
EOL(15)	700	508	648	893	1076
EOL(30)	840	578	595	963	980
FOL	557	720	687	1140	1313
Control	314	823	770	1120	1260

Figure - 6(4) Chemical changes on the line

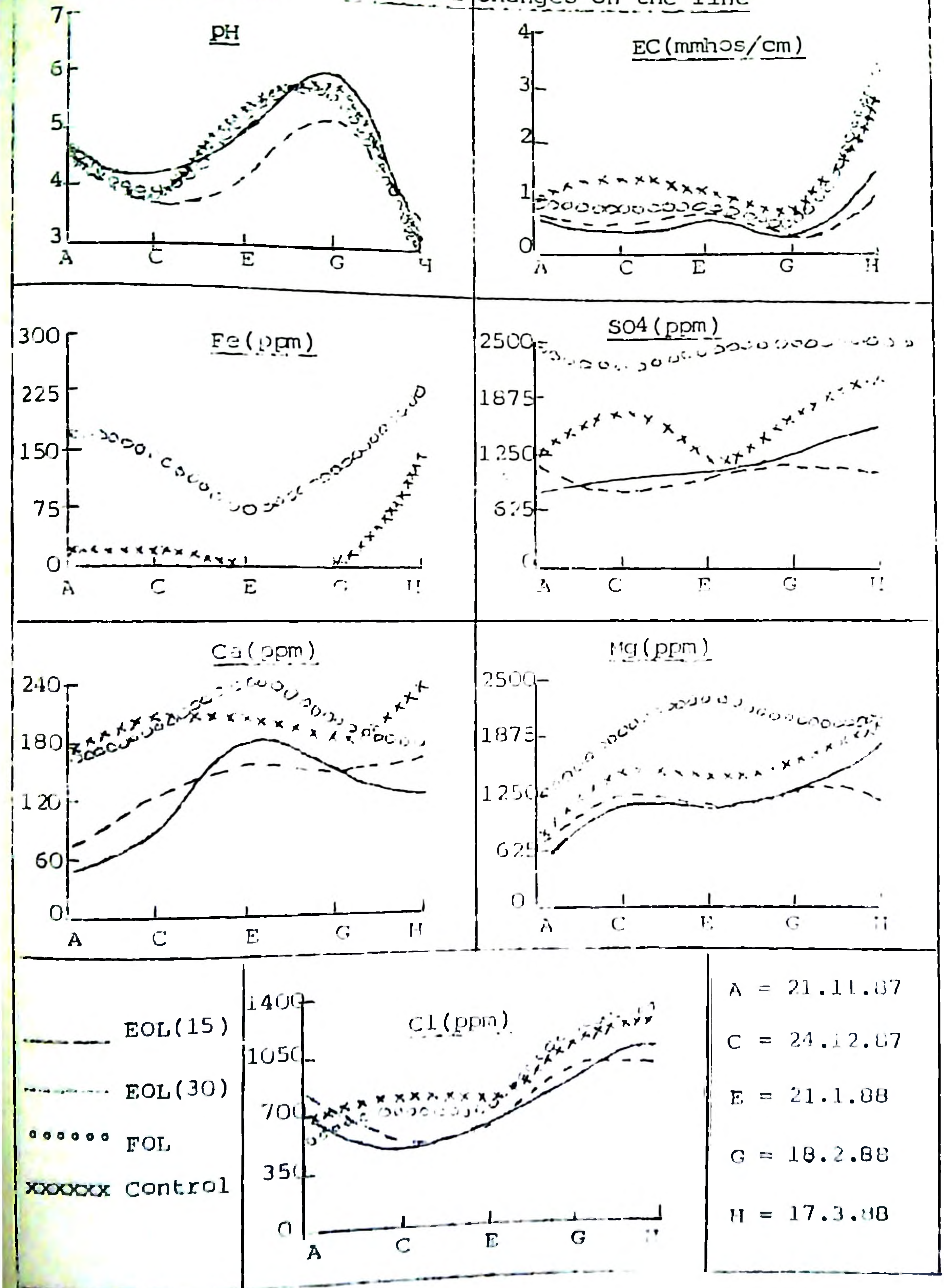


Table - 6.5

pH

Treatments	21.11.87	24.12.87	21.1.88	18.2.88	17.3.88
EBL(15)	4.50	3.95	5.41	6.21	3.47
EBL(30)	4.00	3.80	5.21	5.86	3.25
FBL	4.57	3.92	4.97	5.58	3.10
Control	4.50	3.75	5.34	5.79	3.11

EC (mmhos/cm)

Treatments	21.11.87	24.12.87	21.1.88	18.2.88	17.3.88
EBL(15)	0.61	0.48	0.41	0.30	1.74
EBL(30)	0.71	0.66	0.77	0.56	1.75
FBL	0.84	0.84	0.96	0.71	2.60
Control	1.02	1.27	1.05	0.65	2.66

Fe (ppm)

Treatments	21.11.87	24.12.87	21.1.88	18.2.88	17.3.88
EBL(15)	0	0	0	0	0
EBL(30)	0	0	0	0	0
FBL	24	79	50	46	200
Control	24	24	3	2	153

SO_4 (ppm)

Treatments	21.11.87	24.12.87	21.1.88	18.2.88	17.3.88
EBL(15)	805	791	830	802	1544
EBL(30)	813	953	792	1011	1279
FBL	1491	2229	1994	1776	2188
Control	1240	1667	1141	1645	2075

Ca(ppm)

Treatments	21.11.87	24.12.87	21.1.88	18.2.88	17.3.88
EBL(15)	36	75	105	118	128
EBL(30)	48	92	110	114	180
FBL	110	213	256	168	150
Control	170	203	205	178	237

Mg(ppm)

Treatments	21.11.87	24.12.87	21.1.88	18.2.88	17.3.88
EBL(15)	435	1434	87[illegible]	1321	1882
EBL(30)	[illegible]	1068	1353	1189	1668
FBL	941	1560	2164	1699	2384
Control	[illegible]	[illegible]	1461	1641	2066

Cl(ppm)

Treatments	21.11.87	24.12.87	21.1.88	18.2.88	17.3.88
EBL(15)	[illegible]	595	513	945	1234
EBL(30)	770	683	788	1138	1190
FBL	862	770	759	1120	1396
Control	814	823	770	1120	1260

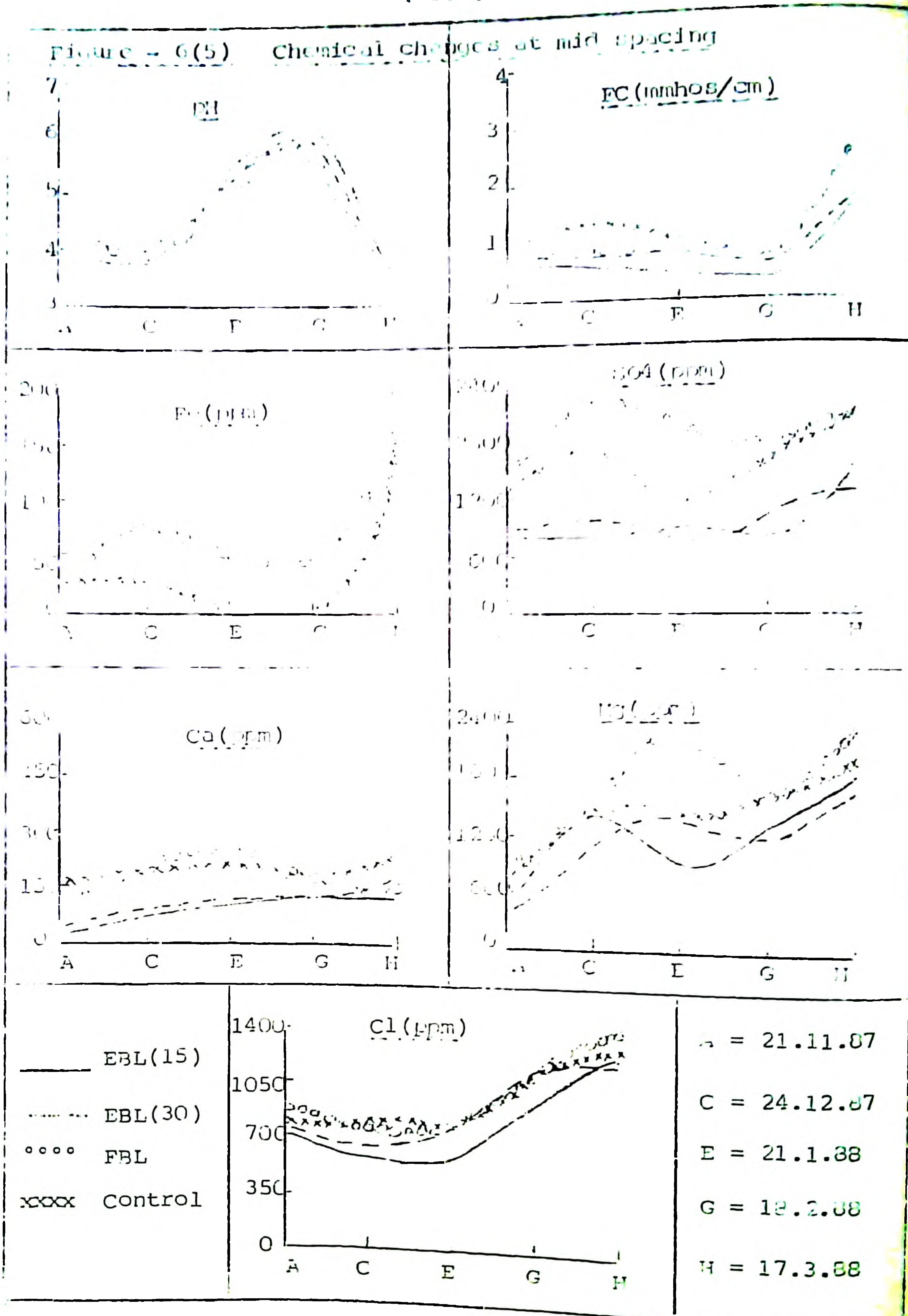


Figure - 6(5) Chemical changes at mid spacing
PH
EC (mmhos/cm)
Ca (ppm)
Cl (ppm)
EBL(15)
EBL(30)
FBL
Control
A = 21.11.87
C = 24.12.87
E = 21.1.88
G = 18.2.88
H = 17.3.88

SECTION - E.

S U M M A R Y.

The weekly monitoring of quality of irrigation and surface drained water was continued this year also. The acidity and salinity of the different waterbodies were evaluated. The pH range was from 3.40 to 6.30 for both, whereas the EC values ranged from 0.5 to 6.8 mmhos/cm, the trend being the same for both irrigation and surface drained water. This indicated that the adoption of surface drainage alone cannot improve the soil health by reducing the acidity or salinity. The data pooled over for the last 5 years show that the optimum condition for growing paddy in Kari soils is from August to November when the pH and EC of irrigation water remain in the favourable limits.

With regard to the experiment on finding the water table fluctuations in the project area, the data generated since 1982 had shown that there is no definite pattern of ground water movement in the soil and that the water movement is greatly influenced by the outside water level, intermittent flooding and draining.

The analysis on the hydraulic properties of the tile drainage system has confirmed the earlier results that there is a continuous recharge towards the drains from the outside waterbody and the intensity of this recharge reduces with distance. The average hydraulic conductivity of the area is 0.2 m/day as against 0.19 m/day, the value arrived in the previous year.

Under the experiment "Effectiveness of tile drainage system in the performance of paddy crop in Kari land" this year, there was significant difference in the performance of crop growth as well as yield.

The overall increase in grain yield by the adoption of tile drainage was 2.10 tons/ha. The significant increase was mainly found in the treatments 0 - 2.5m on either side of the line, which recorded as high as 5.68 tons/ha. The yield comparison for the last three years viz. 1985-86, 1985-87 and 1987-88 reveals that the highest yields were obtained from the treatments 0 - 2.5m and 2.5 - 5m on either side of the line and were on par. The quality of water from each tile drain was also evaluated and compared with that of irrigation and surface drainage water. The pH values for tile drainage water this year were found to be very low, [illegible] the previous years. This may be due to the [illegible] the harvest [illegible] previous [illegible] irrigation [illegible] concerned, they behave alike [illegible] with time. The EC values [illegible] always higher in the tile drainage water than in the other waterbodies. As usual [illegible] previous years, although the [illegible] has come down to [illegible].0 mmhos/cm from as high as [illegible].6 mmhos/cm showing that significant leaching of salts have taken place. It has been estimated that during the years 1985-86, 1986-87 and 1987-88 a quantity of 175kg, 14[illegible]kg and 36kg of salts/ha/cm of drained water respectively have been washed off from the experimental area.

The installation of tile drains for finding out the suitability of different filter materials have been carried out during the summer of 1986-87. Although the drainage system was brought into effect this season the merits/demerits could not be ascertained due to unfavourable conditions in the farmer's fields. A visual evaluation indicated the advantage of tile drains by the overall better crop growth on the lines, than that at midspacing. However, the effect due to different filter materials were not so conspicuous. The cost for laying out the tile drains with different filter materials has been worked out. The minimum expenditure of Rs.5533/ha was involved for the paddy straw around the joints whereas the maximum of Rs.9033/ha was required for the river sand all around the drains. The coir fibre as filter material was found to be the easiest in terms of installation and the cost is Rs.6873/ha.

During this year a new experiment entitled "Studies on the changes of soil chemical properties with respect to time on subsurface drainage" was introduced. A fixed number of 66 sites were earmarked for drawing soil samples fortnightly. The chemical analysis of the samples showed that there is not much of difference in pH and EC for the treatments viz. on the line, between the line and control. The change in the pattern of its magnitude was also same at the critical stages of crop growth. In the other observations viz. Na, SO_4, Ca, Mg, and Cl concentration the control recorded higher values at all stages, bringing out the role of subsurface drainage system in reducing the ionic concentrations under actual farming conditions. Among the other two treatments "on the line" recorded greater values which may be due to the high retention capacity of the soils with reference to polyvalent ions upon drainage. This is again accelerated by [illegible] of the soil and higher bonding energies for polyvalent cations. The colloidal system tends to adjust itself by throwing more of monovalent cations in the solution phase and giving provision for adsorption of the polyvalent cations. In all the observations, the values were found to increase suddenly after the harvest of the crop when drainage pumping was stopped. This is mainly due to the aerobicity created after the harvest of crop by drying of the soil surface.

SECTION - F

Technical programme for 1988-89

1) Monitoring of periodical changes in the quality of surface and sub-surface water in the project area.

2) Assessment of hydraulic properties of the tile drainage system.

3) Effectiveness of tile drainage system in the performance of paddy crop in the Kari land.

4) Evaluation of different filter materials to find its economic suitability including its design criteria for the sub-surface drainage system.

5) Studies on the changes of soil chemical properties with respect to time on sub-surface drainage.

SECTION - G.

A P P E N D I X - I.

Discharge at 10 hours interval in mm/day for different tile drains

Sl. No.	Time	[illegible]E15* mm/day	3E1[illegible]* mm/day	4E15* mm/day	5E15* mm/day	7E30Ω mm/day	8E30Ω mm/day
1.	0	13.00	13.40	12.90	12.10	2.25	2.50
2.	10	7.50	7.60	4.20	4.00	0.85	1.00
3.	20	6.30	5.70	3.10	2.90	0.55	0.70
4.	30	5.50	4.90	2.60	2.20	0.38	0.55
5.	40	5.05	4.50	2.30	1.80	0.30	0.48
6.	50	4.85	4.15	2.00	1.65	0.23	0.39
7.	60	4.70	3.90	1.90	1.50	0.20	0.35
8.	70	4.60	3.70	1.80	1.40	0.18	0.33
9.	80	4.55	3.60	1.70	1.70	0.15	0.30
10.	90	4.50	3.50	1.65	1.25	0.13	0.28
11.	100	4.40	3.40	1.60	1.15	0.10	0.26
12.	110	4.4[illegible]	3.30	1.50	1.10	0.10	0.25
13.	120	4.35	3.20	1.50	1.10	0.10	0.23
14.	130	4.30	3.10	1.40	1.05	0.10	0.[illegible]3
15.	140	4.30	3.10	1.40	1.00	0.10	0.[illegible]3
16.	150	4.30	3.00	1.35	1.00	0.10	0.21
17.	160	4.30	3.00	1.30	1.00	0.10	0.20
18.	170	4.30	3.00	1.25	1.00	0.10	0.20

* 15m spacing

Ω 30m spacing

Average head at 10 hour interval in m for different tile drains

Time	2E15*	3E15*	4E15*	5E15*	7E30@	8E30@
0	0.55	0.50	0.46	0.44	0.35	0.30
10	0.49	0.47	0.45	0.42	0.32	0.28
20	0.46	0.44	0.42	0.40	0.30	0.26
30	0.42	0.41	0.40	0.38	0.28	0.25
40	0.40	0.38	0.38	0.36	0.26	0.23
50	0.37	0.35	0.35	0.33	0.25	0.21
60	0.35	0.32	0.33	0.32	0.23	0.19
70	0.34	0.30	0.31	0.30	0.21	0.18
80	0.32	0.28	0.29	0.28	0.19	0.16
90	0.31	0.27	0.28	0.26	0.18	0.15
100	0.31	0.26	0.26	0.25	0.16	0.14
110	0.29	0.24	0.25	0.23	0.15	0.13
120	0.29	0.23	0.24	0.22	0.13	0.12
130	0.28	0.23	0.22	0.21	0.12	0.11
140	0.28	0.22	0.21	0.19	0.11	0.10
150	0.27	0.21	0.21	0.18	0.10	0.09
160	0.27	0.21	0.20	0.17	0.09	0.08
170	0.27	0.21	0.19	0.16	0.08	0.08

* 15m spacing

@ 30m spacing

Hydraulic head at 10 hour interval in meters for different observation wells

Time	Head (m)				
	OBW-111	OBW-112	OBW-113	OBW-114	OBW-115
0	0.580	0.550	0.570	0.530	0.445
10	0.310	0.515	0.450	0.355	0.370
20	0.245	0.480	0.400	0.305	0.310
30	0.210	0.455	0.375	0.275	0.265
40	0.185	0.430	0.355	0.260	0.225
50	0.175	0.410	0.345	0.250	0.195
60	0.160	0.395	0.335	0.245	0.175
70	0.150	0.380	0.325	0.240	0.155
80	0.145	0.365	0.315	0.235	0.140
90	0.140	0.355	0.310	0.230	0.125
100	0.135	0.345	0.300	0.225	0.120
110	0.130	0.335	0.300	0.220	0.110
120	0.125	0.330	0.295	0.215	0.105
130	0.125	0.325	0.295	0.215	0.100
140	0.125	0.320	0.290	0.210	0.095
150	0.125	0.320	0.290	0.205	0.095
160	0.120	..	0.290	0.205	0.090
170	0.120	..	0.290	0.205	0.085

The subscripts of observation wells denote the following:

1. First digit indicates the observation well line number
2. Second digit indicate the drain line number.
3. Third digit indicate the position of the observation well number from the drain line towards the north.

Time	Head (m)				
	OBW-121	OBW-122	OBW-123	OBW-124	OBW-125
0	0.510	0.455	0.505	0.450	0.450
10	0.265	[illegible]	[illegible]	0.390	0.325
20	0.170	0.355	0.475	0.340	0.250
30	0.125	0.315	0.420	0.300	0.200
40	0.095	0.285	0.390	0.270	0.160
50	0.085	0.260	0.350	0.245	0.135
60	0.080	0.240	0.315	[illegible]	0.120
70	0.075	0.220	0.265	0.205	0.100
80	0.070	0.210	0.270	0.195	0.095
90	0.070	0.200	0.260	0.180	0.090
100	0.065	0.195	0.250	0.175	0.085
110	0.060	0.190	0.240	0.165	0.080
120	0.060	0.185	0.235	0.165	0.075
130	0.060	0.185	0.235	0.16[illegible]	0.070
140	0.055	0.180	0.230	0.155	0.070
150	0.055	0.175	0.225	0.155	0.065
160	0.050	0.175	0.225	0.155	0.065
170	0.045	0.170	0.225	0.155	0.060

Time (hrs.)	Head (m)				
	OBW-131	OBW-132	OBW-133	OBW-134	OBW-135
0	0.510	0.505	0.415	0.480	0.320
10	0.150	0.280	0.350	0.280	0.295
20	0.075	0.230	0.300	0.230	0.250
30	0.045	0.200	0.270	0.200	0.215
40	0.045	0.185	0.255	0.190	0.185
50	0.040	0.175	0.240	0.180	0.165
60	0.035	0.175	0.230	0.175	0.150
70	0.035	0.170	0.220	0.165	0.140
80	0.035	0.165	0.210	0.160	0.135
90	0.030	0.160	0.205	0.160	0.130
100	0.030	0.160	0.200	0.155	0.125
110	0.030	0.155	0.195	0.150	0.120
120	0.025	0.150	0.190	0.150	0.110
130	0.025	0.150	0.190	0.150	0.105
140	0.025	0.150	0.185	0.150	0.105
150	0.025	0.145	0.185	0.150	0.100
160	0.025	0.145	0.180	0.150	0.100
170	0.025	0.145	0.180	0.150	0.100

Time (hrs)	(Head (m))				
	OBW-141	OBW-142	OBW-143	OBW-144	OBW-145
0	0.325	0.315	0.460	0.500	0.470
10	0.155	0.310	0.355	0.230	0.250
20	0.090	0.295	0.315	0.175	0.170
30	0.065	0.285	0.290	0.180	0.130
40	0.055	0.270	0.270	0.135	0.110
50	0.055	0.255	0.260	0.130	0.095
60	0.055	0.240	0.245	0.125	0.090
70	0.050	0.225	0.240	0.125	0.080
80	0.050	0.215	0.230	0.120	0.075
90	0.050	0.210	0.225	0.120	0.075
100	0.050	0.200	0.220	0.120	0.070
110	0.045	0.195	0.215	0.120	0.070
120	0.045	0.190	0.205	0.115	0.065
130	0.045	0.185	0.200	0.115	0.065
140	0.045	0.180	0.200	0.110	0.060
150	0.045	0.175	0.200	0.110	0.060
160	0.040	0.170	0.200	0.105	0.055
170	0.040	0.170	0.195	0.105	0.055

Time (hrs.)	Head (m)				
	OBW-151	OBW-152	OBW-153	OBW-155	OBW-156
0	..	0.410	0.340	0.380	0.395
10	..	0.330	0.310	0.285	0.350
20	..	0.265	0.285	0.235	0.310
30	..	0.225	0.260	0.200	0.275
40	..	0.195	0.240	0.175	0.245
50	..	0.170	0.220	0.160	0.220
60	..	0.155	0.210	0.150	0.205
70	..	0.145	0.195	0.140	0.190
80	..	0.135	0.190	0.130	0.180
90	..	0.125	0.180	0.125	0.175
100	..	0.120	0.175	0.120	0.165
110	..	0.115	0.175	0.115	0.160
120	..	0.110	0.165	0.110	0.160
130	..	0.105	0.160	0.105	0.160
140	..	0.105	0.155	0.100	0.155
150	..	0.105	0.155	0.100	0.155
160	..	0.105	0.150	0.100	0.155
170	..	0.100	0.150	0.100	0.155

Time (hrs.)	Head (m)				
	OBW-161	OBW-162	OBW-163	OBW-164	OBW-165
0	0.360	0.385	0.380	0.300	0.265
10	0.290	0.350	0.350	0.280	0.210
20	0.245	0.315	0.315	0.265	0.175
30	0.215	0.285	0.290	0.250	0.150
40	0.190	0.260	0.265	0.230	0.135
50	0.170	0.235	0.240	0.215	0.125
60	0.155	0.220	0.220	0.200	0.120
70	0.150	0.200	0.200	0.185	0.115
80	0.140	0.190	0.180	0.170	0.110
90	0.135	0.180	0.165	0.160	0.105
100	0.130	0.175	0.150	0.145	0.100
110	0.125	0.170	0.140	0.135	0.100
120	0.125	0.165	0.125	0.125	0.095
130	0.120	0.165	0.115	0.110	0.090
140	0.120	0.165	0.105	0.100	0.090
150	0.115	0.165	0.095	0.090	0.085
160	0.115	0.165	0.085	0.080	0.080
170	0.110	0.165	0.080	0.075	0.075

Time (hrs.)	Head (m)				
	OBW-171	OBW-172	OBW-173	OBW-174	OBW-175
0	0.260	0.270	0.275	0.275	0.275
10	0.215	0.245	0.235	0.230	0.225
20	0.175	0.225	0.215	0.195	0.185
30	0.150	0.210	0.295	0.165	0.160
40	0.140	0.195	0.180	0.140	0.135
50	0.130	0.185	0.165	0.125	0.110
60	0.125	0.175	0.150	0.105	0.095
70	0.120	0.165	0.140	0.095	0.085
80	0.115	0.155	0.125	0.085	0.070
90	0.110	0.150	0.115	0.075	0.060
100	0.110	0.140	0.105	0.065	0.050
110	0.105	0.135	0.095	0.055	0.045
120	0.105	0.130	0.085	0.050	0.040
130	0.100	0.125	0.075	0.040	0.035
140	0.100	0.120	0.065	0.035	0.030
150	0.095	0.115	0.055	0.030	0.025
160	0.090	0.110	0.045	0.020	0.020
170	0.090	0.105	0.040	0.015	0.015

Time (hrs.)	Head (m)				
	OBW-181	OBW-182	OBW-183	OBW-184	OBW-185
0	0.360	0.270	0.310	0.360	0.320
10	0.240	0.230	0.285	0.310	0.290
20	0.180	0.195	0.265	0.295	0.265
30	0.140	0.165	0.245	0.275	0.240
40	0.105	0.145	0.225	0.260	0.225
50	0.085	0.125	0.205	0.250	0.205
60	0.070	0.110	0.190	0.235	0.190
70	0.060	0.095	0.175	0.220	0.175
80	0.055	0.085	0.160	0.210	0.160
90	0.050	0.075	0.150	0.200	0.150
100	0.045	0.065	0.135	0.190	0.135
110	0.040	0.055	0.125	0.180	0.125
120	0.035	0.050	0.110	0.170	0.115
130	0.030	0.045	0.100	0.165	0.110
140	0.025	0.040	0.095	0.155	0.100
150	0.025	0.035	0.085	0.150	0.095
160	0.200	0.030	0.080	0.150	0.090
170	0.020	0.025	0.075	0.145	0.085

Time (hrs.)	Head (m)				
	OBW-211	OBW-212	OBW-213	OBW-214	OBW-215
0	0.565	0.565	0.575	0.565	0.550
10	0.265	0.465	0.450	0.415	0.330
20	0.175	0.410	0.405	0.350	0.245
30	0.145	0.375	0.380	0.320	0.205
40	0.140	0.360	0.360	0.305	0.180
50	0.135.	0.345	0.355	0.295	0.165
60	0.130	0.340	0.350	0.290	0.155
70	0.130	0.330	0.345	0.285	0.150
80	0.130	0.320	0.340	0.280	0.145
90	0.125	0.320	0.335	0.275	0.140
100	0.125	0.315	0.330	0.275	0.135
110	0.125	0.310	0.325	0.270	0.130
120	0.125	0.310	0.325	0.270	0.130
130	0.125	0.310	0.325	0.365	0.130
140	0.120	0.305	0.320	0.210	0.130
150	0.120	0.305	0.320	0.210	0.130
160	0.120	0.300	0.320	0.210	0.125
170	0.115	0.300	0.320	0.210	0.125

Time (hrs.)	Head (m)				
	OBW-221	OBW-222	OBW-223	OBW-224	OBW-225
0	0.600	0.550	0.520	0.500	0.525
10	0.050	0.250	0.390	0.355	0.200
20	0.045	0.220	0.330	0.295	0.155
30	0.045	0.205	0.310	0.260	0.140
40	0.045	0.195	0.295	0.240	0.130
50	0.045	0.195	0.285	0.230	0.125
60	0.045	0.190	0.275	0.220	0.120
70	0.045	0.185	0.270	0.215	0.120
80	0.045	0.185	0.265	0.210	0.115
90	0.045	0.185	0.260	0.205	0.115
100	0.040	0.180	0.255	0.200	0.110
110	0.040	0.180	0.250	0.200	0.210
120	0.040	0.175	0.250	0.195	0.110
130	0.040	0.175	0.250	0.195	0.105
140	0.040	0.175	0.250	0.190	0.105
150	0.035	0.175	0.250	0.190	0.105
160	0.035	0.170	0.250	0.190	0.100
170	0.030	0.170	0.250	0.185	0.100

Time (hrs.)	Head (m)				
	OBW-231	OBW-232	OBW-233	OBW-234	OBW-235
0	0.600	0.430	0.420	0.460	0.545
10	0.030	0.380	0.385	0.340	0.195
20	0.025	0.340	0.335	0.285	0.140
30	0.025	0.295	0.295	0.250	0.115
40	0.025	0.265	0.280	0.225	0.105
50	0.025	0.235	0.250	0.205	0.100
60	0.025	0.210	0.240	0.195	0.100
70	0.025	0.190	0.230	0.180	0.095
80	0.020	0.175	0.220	0.175	0.090
90	0.020	0.160	0.215	0.170	0.085
100	0.020	0.150	0.210	0.165	0.085
110	0.020	0.145	0.200	0.160	0.080
120	0.020	0.135	0.200	0.155	0.075
130	0.020	0.130	0.195	0.150	0.075
140	0.015	0.125	0.195	0.150	0.075
150	0.015	0.125	0.195	0.150	0.075
160	0.015	0.120	0.195	0.150	0.070
170	0.015	0.120	0.195	0.150	0.070

Time (hrs.)	Head (m)				
	OBW-241	OBW-242	OBW-243	OBW-244	OBW-245
0	0.450	0.385	0.520	0.415	0.470
10	0.330	0.360	0.505	0.380	0.310
20	0.230	0.335	0.495	0.335	0.225
30	0.280	0.310	0.480	0.300	0.175
40	0.145	0.285	0.460	0.265	0.140
50	0.125	0.265	0.445	0.240	0.115
60	0.110	0.245	0.430	0.220	0.100
70	0.100	0.230	0.415	0.200	0.090
80	0.090	0.210	0.400	0.185	0.085
90	0.085	0.200	0.385	0.175	0.085
100	0.080	0.190	0.375	0.160	0.080
110	0.075	0.175	0.365	0.155	0.075
120	0.070	0.165	0.350	0.145	0.075
130	0.065	0.160	0.340	0.140	0.070
140	0.065	0.150	0.325	0.135	0.070
150	0.060	0.140	0.315	0.130	0.065
160	0.060	0.135	0.305	0.125	0.065
170	0.055	0.130	0.295	0.125	0.065

Time (hrs)	Head (m)					
	OBW-251	OBW-252	OBW-253	OBW-254	OBW-255	OBW-256
0	0.550	0.425	0.410	0.400	0.445	0.455
10	0.035	0.385	0.380	0.395	0.285	0.440
20	0.030	0.340	0.360	0.375	0.215	0.415
30	0.030	0.305	0.345	0.350	0.180	0.395
40	0.030	0.275	0.325	0.320	0.160	0.375
50	0.030	0.245	0.300	0.295	0.145	0.350
60	0.030	0.220	0.285	0.270	0.135	0.330
70	0.030	0.200	0.265	0.250	0.130	0.305
80	0.025	0.180	0.250	0.235	0.120	0.285
90	0.025	0.165	0.230	0.225	0.115	0.265
100	0.025	0.150	0.215	0.210	0.110	0.245
110	0.025	0.140	0.200	0.195	0.105	0.230
120	0.025	0.130	0.185	0.185	0.105	0.215
130	0.025	0.120	0.180	0.175	0.100	0.205
140	0.025	0.115	0.155	0.170	0.100	0.195
150	0.025	0.110	0.145	0.165	0.095	0.185
160	0.025	0.105	0.130	0.160	0.095	0.180
170	0.025	0.100	0.120	0.155	0.090	0.175

Time (hrs.)	Head (m)				
	OBW-261	OBW-262	OBW-263	OBW-264	OBW-265
0	0.405	0.385	0.400	0.375	0.365
10	0.345	0.350	0.370	0.350	0.245
20	0.290	0.320	0.350	0.325	0.175
30	0.250	0.295	0.335	0.300	0.135
40	0.220	0.275	0.315	0.280	0.115
50	0.195	0.250	0.305	0.260	0.100
60	0.175	0.235	0.275	0.240	0.095
70	0.160	0.220	0.260	0.220	0.085
80	0.150	0.200	0.240	0.200	0.075
90	0.140	0.190	0.220	0.180	0.070
100	0.130	0.185	0.210	0.165	0.065
110	0.125	0.175	0.195	0.150	0.060
120	0.115	0.165	0.175	0.135	0.055
130	0.110	0.160	0.160	0.125	0.055
140	0.105	0.155	0.145	0.110	0.050
150	0.100	0.150	0.135	0.100	0.045
160	0.100	0.145	0.125	0.090	0.040
170	0.100	0.140	0.120	0.085	0.035

Time (hrs.)	Head (m)				
	OBW-271	OBW-272	OBW-273	OBW-274	OBW-275
0	0.325	0.360	0.260	0.295	0.230
10	0.280	0.335	0.235	0.255	0.225
20	0.240	0.315	0.215	0.225	0.200
30	0.205	0.295	0.195	0.200	0.175
40	0.180	0.275	0.180	0.180	0.155
50	0.160	0.255	0.160	0.160	0.135
60	0.150	0.240	0.140	0.145	0.120
70	0.140	0.225	0.125	0.130	0.105
80	0.130	0.210	0.110	0.120	0.095
90	0.120	0.190	0.090	0.110	0.085
100	0.110	0.175	0.080	0.100	0.080
110	0.105	0.160	0.065	0.090	0.075
120	0.100	0.145	0.055	0.085	0.065
130	0.095	0.130	0.045	0.075	0.060
140	0.090	0.115	0.035	0.070	0.050
150	0.090	0.100	0.025	0.060	0.050
160	0.085	0.090	0.015	0.055	0.045
170	0.080	0.080	0.005	0.050	0.040

Time (hrs.)	Head (m)				
	OBW-281	OBW-282	OBW-283	OBW-284	OBW-285
0	0.295	0.300	0.308	0.835	0.360
10	0.255	0.270	0.293	0.320	0.345
20	0.225	0.240	0.275	0.305	0.285
30	0.195	0.215	0.258	0.295	0.260
40	0.165	0.185	0.240	0.280	0.240
50	0.145	0.165	0.225	0.270	0.225
60	0.125	0.150	0.210	0.260	0.220
70	0.110	0.135	0.195	0.250	0.210
80	0.100	0.120	0.183	0.240	0.205
90	0.090	0.110	0.173	0.230	0.200
100	0.080	0.100	0.160	0.220	0.195
110	0.075	0.095	0.150	0.215	0.190
120	0.065	0.085	0.140	0.210	0.190
130	0.060	0.080	0.133	0.205	0.185
140	0.055	0.075	0.128	0.200	0.180
150	0.050	0.065	0.120	0.195	0.180
160	0.045	0.060	0.115	0.190	0.175
170	0.045	0.055	0.113	0.185	0.175

Time (hrs.)	Head (m)				
	OBW-311	OBW-312	OBW-313	OBW-314	OBW-315
0	0.490	0.540	0.510	0.490	0.435
10	0.425	0.510	0.510	0.400	0.365
20	0.365	0.480	0.475	0.325	0.300
30	0.320	0.460	0.445	0.285	0.245
40	0.285	0.440	0.420	0.260	0.210
50	0.250	0.415	0.400	0.245	0.180
60	0.225	0.395	0.380	0.235	0.155
70	0.200	0.375	0.365	0.225	0.135
80	0.180	0.360	0.350	0.215	0.115
90	0.170	0.345	0.340	0.210	0.110
100	0.155	0.330	0.330	0.200	0.090
110	0.145	0.320	0.320	0.200	0.080
120	0.135	0.310	0.310	0.195	0.070
130	0.130	0.300	0.300	0.190	0.065
140	0.125	0.290	0.295	0.190	0.060
150	0.120	0.285	0.290	0.190	0.055
160	0.120	0.280	0.285	0.185	0.050
170	0.115	0.275	0.285	0.185	0.045

Time (hrs.)	Head (m)				
	OBW-321	OBW-322	OBW-323	OBW-324	OBW-325
0	0.435	0.465	0.635	0.490	0.590
10	0.345	0.425	0.655	0.520	0.535
20	0.275	0.390	0.650	0.500	0.480
30	0.230	0.360	0.615	0.465	0.430
40	0.190	0.335	0.560	0.425	0.380
50	0.150	0.310	0.510	0.385	0.335
60	0.120	0.290	0.465	0.345	0.295
70	0.095	0.270	0.420	0.300	0.265
80	0.080	0.250	0.390	0.270	0.235
90	0.065	0.235	0.355	0.240	0.210
100	0.050	0.225	0.335	0.210	0.190
110	0.040	0.210	0.315	0.185	0.170
120	0.030	0.200	0.300	0.160	0.155
130	0.025	0.190	0.285	0.140	0.140
140	0.015	0.185	0.270	0.120	0.130
150	0.010	0.180	0.260	0.105	0.120
160	0.010	0.175	0.250	0.090	0.110
170	0.005	0.170	0.240	0.080	0.105

Time (hrs.)	Head (m)				
	OBW-331	OBW-332	OBW-333	OBW-334	OBW-335
0	0.645	0.525	0.490	0.435	0.460
10	0.400	0.505	0.535	0.475	0.470
20	0.250	0.450	0.535	0.480	0.390
30	0.185	0.385	0.520	0.445	0.305
40	0.095	0.330	0.485	0.390	0.235
50	0.070	0.280	0.450	0.340	0.185
60	0.055	0.240	0.415	0.290	0.140
70	0.035	0.205	0.375	0.250	0.115
80	0.025	0.175	0.340	0.210	0.095
90	0.020	0.150	0.310	0.185	0.080
100	0.015	0.130	0.280	0.160	0.065
110	0.010	0.115	0.250	0.140	0.055
120	0.005	0.100	0.230	0.125	0.045
130		0.080	0.200	0.115	0.040
140		0.065	0.180	0.105	0.035
150		0.055	0.165	0.095	0.030
160		0.050	0.150	0.090	0.025
170		0.045	0.140	0.080	0.020

Time (hrs.)	Head (m)				
	OBW-341	OBW-342	OBW-343	OBW-344	OBW-345
0	0.495	0.530	0.470	0.550	0.420
10	0.365	0.470	0.565	0.355	0.385
20	0.240	0.415	0.550	0.255	0.335
30	0.155	0.370	0.530	0.190	0.295
40	0.110	0.325	0.500	0.145	0.255
50	0.080	0.290	0.460	0.125	0.220
60	0.055	0.255	0.420	0.160	0.180
70	0.040	0.225	0.385	0.100	0.150
80	0.035	0.200	0.350	0.095	0.130
90	0.025	0.175	0.320	0.0[illegible]5	0.110
100	0.025	0.155	0.290	0.080	0.095
110	0.020	0.135	0.265	0.075	0.080
120	0.020	0.120	0.240	0.065	0.070
130	0.015	0.110	0.220	0.060	0.060
140	0.010	0.095	0.200	0.055	0.055
150	0.010	0.090	0.180	0.050	0.045
160	0.010	0.080	0.160	0.045	0.040
170		0.075	0.145	0.045	0.035

Time (hrs.)	Head (m)					
	OBW-351	OBW-352	OBW-353	OBW-354	OBW-355	OBW356
0	0.325	0.485	0.425	0.515	0.475	0.410
10	0.175	0.430	0.410	0.325	0.335	0.365
20	0.110	0.395	0.395	0.280	0.255	0.330
30	0.080	0.360	0.370	0.240	0.205	0.300
40	0.065	0.325	0.350	0.215	0.180	0.280
50	0.060	0.295	0.320	0.200	0.165	0.255
60	0.050	0,260	0.300	0.180	0.150	0.240
70	0.050	0.230	0.275	0.170	0.135	0.220
80	0.045	0.205	0.250	0.160	0.125	0.200
90	0.040	0.180	0. 30	0.145	0.110	0.180
100	0.035	0.155	0.2[illegible]5	0.135	0.100	0.165
110	0.030	0.135	0.185	0.125	0.090	0.150
120	0.030	0.115	0.160	0.115	0.080	0.135
130	0.030	0.100	0.140	0.105	0.070	0.125
140	0.025	0.085	0.120	0.095	0.060	0.110
150	0.020	0.070	0.095	0.090	0.055	0.100
160	0.015	0.055	0.075	0.080	0.050	0.090
170	0.015	0.045	0.050	0.075	0.045	0.080

Time (hrs.)	Head (m)				
	OBW-361	OBW-362	OBW-363	OBW-364	OBW-365
0	0.580	0.455	0.425	0.415	0.445
10	0.545	0.425	0.415	0.390	0.210
20	0.520	0.400	0.400	0.365	0.155
30	0.490	0.375	0.390	0.340	0.125
40	0.460	0.350	0.375	0.315	0.105
50	0.440	0.325	0.360	0.290	0.090
60	0.415	0.305	0.340	0.265	0.085
70	0.395	0.280	0.220	0.245	0.080
80	0.375	0.260	0.305	0.225	0.075
90	0.355	0.240	0.285	0.205	0.070
100	0.335	0.215	0.265	0.185	0.065
110	0.320	0.195	0.245	0.170	0.060
120	0.300	0.175	0.230	0.155	0.060
130	0.285	0.160	0.210	0.140	0.055
140	0.270	0.140	0.195	0.130	0.050
150	0.255	0.125	0.175	0.115	0.045
160	0.245	0.110	0.160	0.105	0.040
170	0.335	0.095	0.145	0.095	0.035

Time (hrs.)	Head (m)				
	OBW-371	OBW-372	OBW-373	OBW-374	OBW-375
0	0.475	0.330	0.345	0.365	0.440
10	0.075	0.290	0.330	0.260	0.080
20	0.065	0.250	0.310	0.195	0.070
30	0.060	0.225	0.290	0.165	0.065
40	0.060	0.195	0.270	0.145	0.065
50	0.060	0.175	0.245	0.140	0.065
60	0.055	0.150	0.225	0.130	0.065
70	0.055	0.130	0.205	0.120	0.065
80	0.050	0.115	0.190	0.115	0.060
90	0.045	0.100	0.175	0.110	0.060
100	0.045	0.090	0.160	0.105	0.060
110	0.040	0.080	0.140	0.105	0.055
120	0.040	0.070	0.130	0.100	0.055
130	0.035	0.060	0.120	0.095	0.050
140	0.035	0.055	0.105	0.095	0.050
150	0.030	0.045	0.095	0.090	0.045
160	0.030	0.040	0.085	0.090	0.045
170	0.025	0.035	0.075	0.085	0.040

Time (hrs.)	Head (m)				
	OBW-381	OBW-382	OBW-383	OBW-384	OBW-385
0	0.535	0.355	0.305	..	0.330
10	0.170	0.275	0.300	..	0.290
20	0.155	0.210	0.285	..	0.285
30	0.155	0.175	0.270	..	0.235
40	0.155	0.150	0.255	..	0.210
50	0.155	0.130	0.245	..	0.190
60	0.155	0.120	0.230	..	0.175
70	0.155	0.110	0.215	..	0.160
80	0.155	0.105	0.205	..	0.150
90	0.155	0.100	0.195	..	0.145
100	0.155	0.095	0.185	..	0.140
110	0.155	0.090	0.175	..	0.135
120	0.155	0.090	0.170	..	0.130
130	0.155	0.085	0.165	..	0.125
140	0.155	0.085	0.160	..	0.120
150	0.155	0.085	0.155	..	0.120
160	0.155	0.085	0.150	..	0.115
170	0.155	0.085	0.150	..	0.115

APPENDIX - II.

Theoretical approach to non-steady state condition

The differential equation for non-steady state flow, as derived on the basis of the Dupuit - Forchheimer assumption is

$$KD \frac{\partial^2 h}{\partial x^2} = \mu \frac{\partial h}{\partial t} - R \quad \text{or} \qquad (a)$$

when the recharge rate R equals zero

$$KD \frac{\partial^2 h}{\partial x^2} = \mu \frac{\partial h}{\partial t} \quad \text{where} \qquad (b)$$

KD = transmissivity of the aquifer (m^2/day)

R = recharge rate per unit surface area (m/day)

h = hydraulic head as a function of x and t (m)

x = horizontal distance from the centre of drain

t = time (days)

μ = drainable pore space (dimension less)

The solution to equation (b) is found by Glover which is given below:

$$h(x,t) = \frac{4ho}{\pi} \sum_{n = 1, -3, 5}^{\infty} \frac{1}{n} e^{-2\alpha t} \sin \frac{n \pi x}{L} \qquad (c)$$

Where $\alpha = \frac{\pi^2 KD}{\mu L^2}$ (reaction factor, days^{-1}) where

L is the spacing.

For the water table height at midway between the drains at any time t, $x = \frac{L}{2}$ and hence $ht = \frac{4}{\pi} ho \sum_{n = 1, -3, 5} \frac{1}{n} e^{-n^2 \alpha t}$ (d)

Apparently the value of each term of equation (d) decreases with increasing n. If $t > 0.2$ the second and next term will be comparatively small and may be neglected. Thus equation (d) reduces to

$$ht = \frac{4}{\pi} ho \; e^{-\alpha t} \qquad (e)$$

Hence at time $t = t1$ and $t = t2$

$$ht1 = \frac{4}{\pi} ho\, e^{-\alpha t1}$$

$$ht2 = \frac{4}{\pi} ho\, e^{-\alpha t2}$$

Therefore, $$\frac{ht1}{ht2} = \frac{e^{-\alpha t1}}{e^{-\alpha t2}} \qquad \text{(f)}$$

From Darcy's law, we can also prove that

$$\frac{qt1}{qt2} = \frac{e^{-\alpha t1}}{e^{-\alpha t2}} \qquad \text{(g)}$$

Hence a plot of qt or ht on a log scale and time (t) on a linear scale will result in a straight line and the slope of the line will give the factor α where

$$\alpha = \frac{\pi^2 Kd}{\eta L^2} \qquad \text{(h)}$$

To calculate the hydraulic conductivity K, plot qt vs ht. The relationship yields a straight line when most of the water passes to the drains through the soil below the drain level.

Therefore, $$Kd = \frac{q}{h} \frac{L^2}{2\pi} \qquad \text{(i)}$$

Once the Kd value is known, the η, the effective porosity can be found out from equation (h).

The equivalent depth d can be found out from the expression $$d = \frac{D}{\frac{8D}{\pi L} \ln \frac{D}{U} + 1} \qquad \text{(j)}$$ where

$U = \pi r$, r being the radius of the drain.

If $D > L/2$ Then D is taken as $L/2$.

The hydraulic conductivity K is then found out by dividing the Kd value by d.

The parameters arrived at from the data collected for the last season is given below.

Drain line No.	q/h 1/day	Kd m^2/day	d m	K m/day
2E15	13.33×10^{-3}	0.477	1.27	0.375
3E15	13.33×10^{-3}	0.477	1.27	0.375
4E15	5×10^{-3}	0.179	1.27	0.141
5E15	4×10^{-3}	0.143	1.27	0.113
7E30	0.83×10^{-3}	0.119	2.2	0.054
8E30	2×10^{-3}	0.286	2.2	0.13
Average	..	0.28	1.58	0.20

A P P E N D I X - III.

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

Tr.	R1	R2	R3	R4	R5	R6	R7	R8	Mean
T1	120	110	150	160	170	70	180	140	137.50
T2	140	120	90	170	130	180	150	1[illegible]0	143.75
T3	170	160	110	100	80	120	150	120	126.25
T4 (Control)	110	90	100	1[illegible]0	90	80	140	13[illegible]	107.50
Total	540	480	450	550	520	450	320	510	

Grand Total = 4120

Variance table

	Df	SS	MS	F ratio	F table	Remarks
Block	7	5650	807.14	0.81	2.487	N.S
Treat	3	6075	2025.00	2.04	3.072	N.S
Error	21	20825	991.67			
Total	31	32550				

Height at maturity (15m spacing) (cm)

Treat.	R1	R2	R3	R4	R5	R6	R7	R8	Mean
T1	9[illegible].30	104.30	93.91	96.9[illegible]	90.44	101.10	89.40	103.70	97.16
T2	86.80	84.67	87.20	9[illegible]	90.[illegible]	87.00	101.20	84.20	89.75
T3	91.50	93.45	90.[illegible]	100.30	88.20	99.1[illegible]	99.90	92.20	95.26
T4 (control)	86.4[illegible]	81.60	83.60	83.60	77.00	7[illegible].50	87.10	9[illegible].20	83.40
Total	359.2[illegible]	3[illegible]	360.11	373.3[illegible]	345.04	381.00	377.50	377.30	

Grand Total = 2918.57

Variance 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	641.75	30.56			
Total	31	1807.71				

Length of panicle (cm)

Treat.	R1	R2	R3	R4	R5	R6	R7	R8	Mean
T_1	19.77	20.5[illegible]	21.50	21.13	21.70	21.05	18.30	20.15	20.56
T_2	21.45	18.80	18.50	17.73	[illegible].05	19.50	[illegible].25	19.45	19.72
T_3	[illegible]	19.13	19.72	19.56	19.60	19.60	21.30	21.40	20.42
T_4 (Control)	17.9[illegible]	20.00	18.70	18.13	18.60	16.60	18.10	16.52	18.32
Total	81.[illegible]	78.47	76.50	76.55	79.95	76.75	81.15	77.52	

Grand Total = 681.86

Variance 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 (15m spacing)

Treat.	R1	R2	R3	R4	R5	R6	R7	R8	Mean
T1	85.20	100.80	107.60	111.70	124.10	120.10	94.30	102.0	105.73
T2	112.30	73.80	75.30	70.00	105.20	89.90	123.00	97.7	93.44
T3	106.00	78.00	86.00	99.40	89.50	54.20	110.50	115.5	96.14
T4 (Control)	66.10	86.00	66.30	65.40	86.30	57.40	71.10	60.4	69.88
Total	339.60	338.60	335.50	346.50	405.10	356.60	396.90	375.6	

Grand Total = 2921.40

Variablce 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				

CD = 15.58

Grain yield MT/ha - 15m spacing

Treat.	R1	R2	R3	R4	R5	R6	R7	R8	Mean
T_1	5.17	5.21	5.97	5.32	5.[illegible]7	5.70	5.35	5.80	5.46
T_2	4.63	3.59	4.23	4.95	[illegible].08	5.13	5.24	4.88	4.59
T_3	5.02	5.10	4.68	5.09	4.37	4.71	[illegible].08	[illegible].10	4.63
T_4 (Control)	3.07	2.86	2.04	2.96	2.35	2.22	3.17	2.34	2.96
Total	17.89	16.82	16.92	18.32	15.[illegible]	17.76	16.67	15.72	

Grand Total = 140.95

Variance 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	76.70[illegible]	3.072	Significant
Error	21	3.15	0.15			
Total	31	39.48				

CD = 0.40

100 grain weight - 15m spacing (g)

Treat.	R1	R2	R3	R4	R5	R6	R7	R8	Mean
T1	2.52[illegible]	2.533	2.495	[illegible].574	[illegible].551	2.53[illegible]	2.679	2.662	2.570
T2	2.700	2.637	2.491	2.700	2.639	2.889	2.634	2.593	2.670
T3	2.643	[illegible].416	2.69[illegible]	2.59[illegible]	2.617	2.551	2.505	2.586	2.600
T4 (Control)	2.352	2.136	2.405	2.361	2.269	2.166	2.433	2.436	2.342
Total	1[illegible].533	9.302	10.087	10.[illegible]	10.076	10.138	10.301	10.277	

Grand total = 81.459

Variance table

	DF	SS	MS	F ratio	F table	Remarks
Block	7	0.08	0.01	0.88	2.[illegible]	N.S
Treat	3	0.46	0.16	13.31	3.697	Significant
Error	21	0.25	0.01			
Total	31	0.81				

CD = 0.11

Chaff % - 15m spacing

Treat.	R1	R2	R3	R4	R5	R6	R7	R8	Mean
T1	14	15	17	25	17	12	14	10	15.50
T2	24	19	22	26	21	17	11	22	20.25
T3	29	18	17	25	[illegible]	[illegible]	20	13	20.50
T4 (Control)	13	23	24	48	33	66	15	[illegible]	20.25
Total	30	75	80	124	93	115	60	75	

Variance table

	DF	SS	MS	F ratio	F table	Remarks
Block	7	690.5	9[illegible].6	[illegible]	[illegible].497	
Treat	3	380.5	1[illegible]	3.[illegible]7	3.[illegible]	Significant
Error	21	720.5	34.33			
Total	31	1791.5				

CD = 6.09

Straw yield t/ha - 15cm spacing

Treat	R1	R2	R3	R4	R5	R6	R7	R8	Mean
T1	5.70	4.60	7.60	5.70	3.80	7.30	6.60	6.60	5.99
T2	5.00	3.30	3.60	5.80	4.70	4.80	8.20	3.50	4.86
T3	5.10	7.50	5.10	4.40	5.90	4.00	5.60	4.50	5.28
T4 (Control)	3.20	3.60	3.50	4.20	2.10	1.60	5.40	4.00	3.48
Total	19.0[illegible]	19.3[illegible]	19.[illegible]	20.10	1[illegible].50	17.70	25.80	18.60	

Grand total = 156.80

Variance 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 - 30m spacing

Treat.	R1	R2	R3	R4	Mean
T1	130	150	140	140	152.50
T2	130	160	120	130	135.00
T3	160	150	140	190	160.00
T4	150	100	160	220	165.00
T5	150	110	130	140	132.50
T6	130	90	80	200	125.00
T7 (Control)	150	40	100	60	87.50
Total	1080	800	870	1080	

Grand Total = 3830

Variance table

	DF	SS	MS	F ratio	Ftable	Remarks
Block	3	2925.00	2975.00	[illegible].85	3.[illegible]0	N.S
Treat	6	16685.71	2780.95	2.60	[illegible].661	N.S
Error	18	18[illegible]00.00	1044.44			
Total	27	4441[illegible].71				

Height at maturity - 30m spacing (cm)

Treat.	R1	R2	R3	R4	Mean
T1	100.10	96.20	[illegible].45	92.20	92.24
T2	94.70	101.00	7[illegible].1[illegible]	90.82	91.16
T3	88.40	96.90	81.10	92.30	90.18
T4	75.4[illegible]	97.[illegible]	91.10	91.30	88.90
T5	93.10	91.50	9[illegible].10	92.10	90.45
T6	84.20	98.55	94.00	89.30	91.51
T7 (Control)	75.60	73.10	70.60	80.90	76.55
Total	61[illegible].00	662.05	587.45	61[illegible].92	

Grand total = 2483.92

Variance 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	8[illegible]4.5[illegible]	44.70			
Total	27	19[illegible].40				

CD = 9.93

Length of panicle - 30cm spacing (cm)

Treat.	R1	R2	R3	R4	Mean
T1	20.80	20.85	20.[illegible]5	19.95	20.46
T2	20.[illegible]0	21.25	19.[illegible]	20.45	20.42
T3	20.33	20.36	20.78	21.05	20.78
T4	18.31	20.35	20.15	19.75	19.64
T5	19.58	19.95	20.10	19.[illegible]5	19.72
T6	19.79	20.55	21.58	20.35	[illegible].59
T7 (Control)	18.15	18.30	18.11	18.45	18.25
Total	137.36	20.23	140.66	1[illegible]9.85	

Grand Total = 559.48

Variance 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 - 30m spacing

Treat	R1	R2	R3	R4	Mean
T1	106.20	99.40	93.50	101.10	100.05
T2	103.50	112.80	92.10	90.80	101.05
T3	90.90	102.70	105.00	112.20	105.20
T4	36.70	99.90	103.50	105.20	95.07
T5	91.50	[illegible]	101.20	82.10	90.65
T6	[illegible]	102.20	139.00	100.50	108.40
T7	[illegible]	[illegible]	62.40	91.10	76.98
Total	[illegible]	675.10	721.70	693.00	

Grand total = 27[illegible].60

Variance table

	DF	SS	MS	F ratio	F table	Remarks
Block	3	789.64	261.28	2.47	3.160	N.S
Treat	6	2570.27	445.4	2.465	2.661	N.S
Error	18	3224.06	179.12			
Total	27	6584.18				

Grain yield - 30m spacing (MT/ha)

Treat.	R1	R2	R3	R4	Mean
T1	5.53	5.69	5.39	6.11	5.68
T2	5.16	5.41	3.50	4.81	4.72
T3	3.88	4.62	4.16	4.22	4.22
T4	4.27	4.32	4.34	4.14	4.27
T5	4.31	4.18	4.01	3.22	3.93
T6	4.23	4.81	4.80	4.96	4.71
T7 (Control)	2.43	2.50	2.62	2.90	2.61
Total	29.81	31.53	28.82	30.38	

Grand total = 120.54

Variance table

	DF	SS	MS	F ratio	F table	Remarks
Block	3	0.549	0.183	0.974	3.16	N.S
Treat	6	20.947	3.491	18.592	2.661	Significant
Error	18	3.380	0.186			
Total	27	24.875				

CD = 0.64

100 grain weight - 30m spacing (g)

Treat.	R1	R2	R3	R4	Mean
T1	2.516	2.616	2.7[illegible]7	2.508	2.587
T2	2.583	2.547	2.516	2.613	2.565
T3	2.623	2.579	2.558	2.482	2.563
T4	2.298	2.450	2.370	2.473	2.398
T5	2.562	2.738	2.683	2.613	2.649
T6	2.648	2.478	2.644	2.491	2.565
T7 (Control)	2.392	2.521	2.446	2.496	2.464
Total	17.620	17.929	17.934	17.678	

Grand Total = 71.163

Variance 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 % - 30m spacing

Treat.	R1	R2	R3	R4	Total	Mean
T1	25	13	14	15	67	16.75
T2	20	30	29	24	103	25.75
T3	30	31	27	20	108	27.00
T4	38	16	22	26	102	25.50
T5	11	20	23	23	77	19.25
T6	21	25	19	22	87	21.75
T7	29	24	29	13	95	23.75
Total	174	159	163	143		

Variance table

	DF	SS	MS	F ratio	F table	Remarks
Block	3	70.68	23.56	0.601	3.160	N.S
Treat	6	339.36	56.56	1.[illegible]	2.661	N.S
Error	18	706.07	39.23			
Total	27	1116.11				

Straw yield - 30m spacing(MT/ha)

Treat.	R1	R2	R3	R4	Mean
T1	5.30	6.00	4.80	4.60	5.18
T2	5.80	7.30	4.10	3.60	5.20
T3	5.20	3.90	3.90	3.60	4.15
T4	3.10	3.00	4.10	5.90	4.03
T5	5.90	6.90	4.70	4.60	5.53
T6	5.10	6.80	5.00	3.90	5.20
T7 (Control)	4.30	2.80	3.30	2.90	3.33
Total	34.70	36.70	29.90	29.10	

Grand total = 130.40

Variance 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				