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TANJUNG KARANG EVAPOTRANSPIRATION STUDY

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1987

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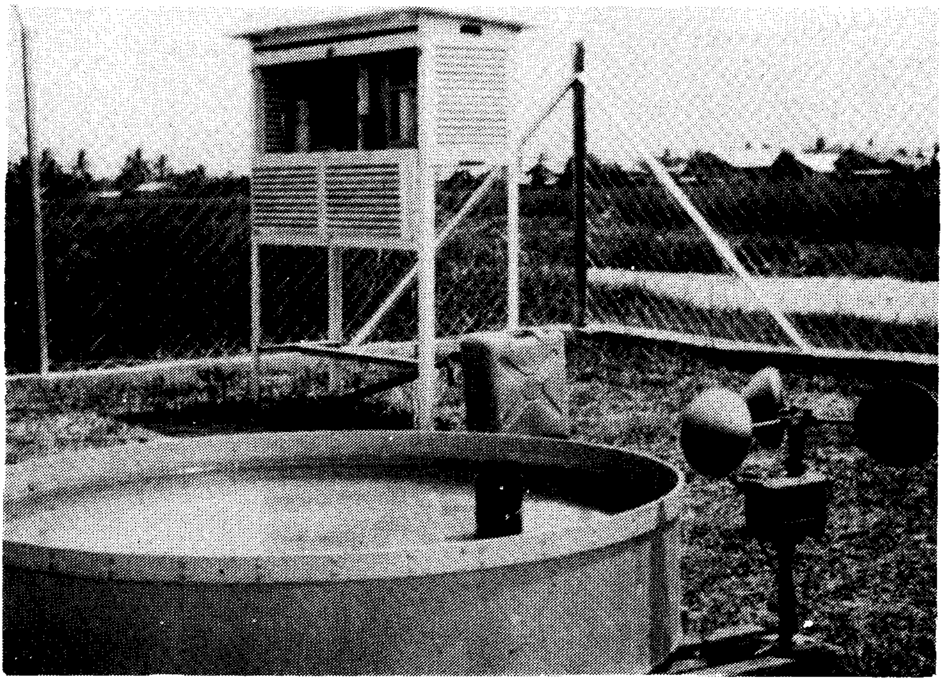

Plate 1 – Tanjung Karang Agro-hydrological Station (Stn. No. 3511201) showing a D.I.D. Standard Aluminium U.S. Class "A" evaporation pan, an anemometer and a Standard Stevenson Screen House.

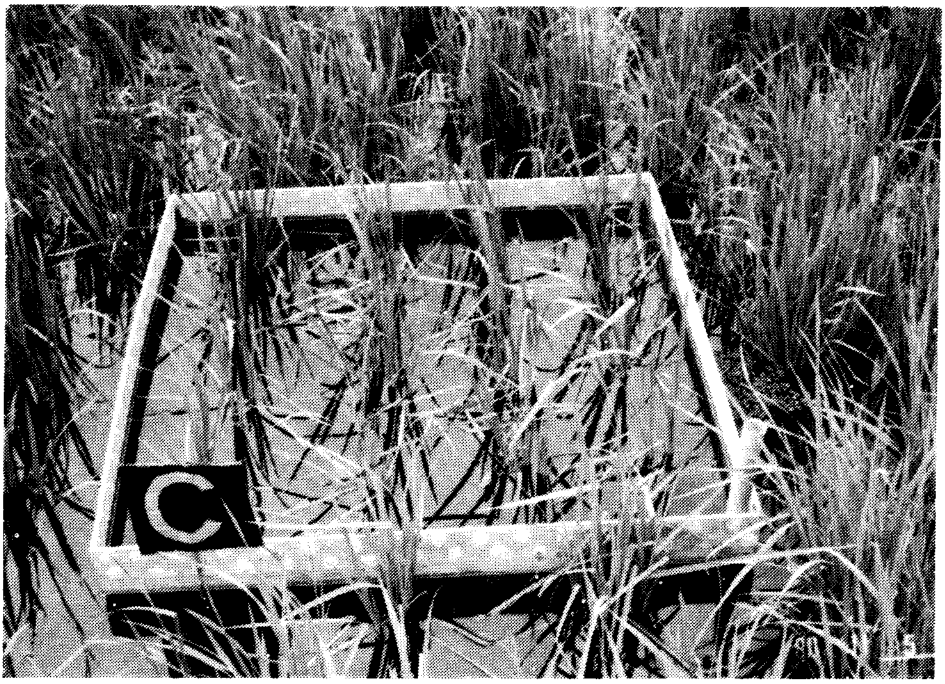

Plate 2 – One of the three lysimeters with paddy at early tillering stage.

Plate 3 – Lysimeter layout.

SUMMARY

The Tanjung Karang Evapotranspiration Study was initiated in 1979 with the main objective to estimate the evapotranspiration rate of paddy at different stages of growth. The study also attempts to establish the correlations between paddy evapotranspiration to aluminium pan evaporation and Penman potential evapotranspiration. Such correlations would be essential in the planning of major agricultural projects where agro-hydrological stations have been established in those areas.

This report covers the paddy seasons begining May 1979 to January 1985.

1. INTRODUCTION

The assessment of the agricultural potential of a project area is dependent on the availability of adequate agro-hydrological data. Such data are of fundamental importance to sound planning of agricultural project and are essential input for the assessment of crop water requirements, on which planning, design and operation of both rainfed and irrigated agriculture need to be based.

It is apparent that agro-hydrological data are not available in the past where major agricultural projects are planned. Consequent to the ever increasing rate of development in agriculture there is a need to collect agro-hydrological data for the optimisation of water and land resources.

The Drainage and Irrigation Department (D.I.D.) has proposed to establish agro-hydrological stations in the major agricultural project areas in Peninsular Malaysia and where deem necessary, lysimeters will be incorporated simultaneously. Measurement of parameters such as rainfall, evaporation, temperature, humidity, wind run and sunshine duration, which are necessary for the assessment of water requirement of crops, would be carried out in these stations.

The first water requirement assessment for paddy cultivation was conducted in Tanjung Karang, Selangor. Tanjung Karang has been selected because it lies within the 'North West Selangor Integrated Development Project' and is the 'Rice Bowl of Selangor'. Both the agro-hydrological station and lysimeter station were established for the study (see Plates 1, 2 and 3).

1.1 Objectives of the Study

The main aims of the study are anticipated at achieving the following objectives:–

(i) To estimate the evapotranspiration rate of paddy at different stages of growth.

(ii) To correlate the paddy evapotranspiration to aluminium pan evaporation and potential evapotranspiration rate by Penman Method.

2. PROJECT DESCRIPTION

2.1 Location

The area under study has a latitude of 3° 30′N and a longitude of 101° 12′E. The experimental paddy plot in this area is about 96km away from Kuala Lumpur and exactly 11km North of Tanjung Karang town. The agro-hydrological station is sited at the corner of the plot while 3 lysimeter tanks were installed in the proximity of the agro-hydrological station. The stations are approximately 245 meters from the coastal main road connecting Tanjung Karang and Sekinchan. They are directly accessible through a secondary road.

Figure 1 shows the location of Tanjung Karang Agro-hydrological Station and the experimental plot.

2.2 Topography

The stations lie within an extensive area of low lying flat coastal alluvium plain.

2.3 Project Duration

The study on assessment of water requirement for paddy cultivation is for the duration of 5 years. On the other hand, data collection at the agro-hydrological station shall continue over long period for future needs.

2.4 Climate

The area under study exhibits a typical west coastal climate of Peninsular Malaysia. The mean monthly climatic data collected from the climatic station is shown in Table 1. Mean annual rainfall for the period 1979 to 1984 was 1600mm with a standard deviation of 75mm. The distribution of rainfall is uniform with significant high rainfall during N-E monsoon seasons.

Mean monthly sunshine is 6 hours/day and generally sunshine is abundant in the drier months and less in the monsoonal periods. The annual mean temperature and relative humidity is 28°C and 75% respectively.

3. INSTRUMENTATION AND OBSERVATION

Two types of stations were established for this study. They are the agro-hydrological station and the lysimeter station. The measurement of pan evaporation, EP and other climatic parameters are carried out at the agro-hydrological station. Such parameters are required for the computation of 'Penman Evapotranspiration' ETo. Penman's formula is preferred than other formulae such as Blaney Criddle, Thorthwaite, Ture etc. since it takes into account a large number of climatic parameters. The direct measurement of evapotranspiration rates, ET of paddy crops is carried out at the lysimeter station. Thus enabling inter comparison between lysimeter ET, Pan Evapotranspiration EP and Penman Evapotranspiration ETo is made possible.

3.1. Agro-hydrological Station

The station is equipped with the following instrument:–

(i) A daily 203mm dia. daily raingauge.

(ii) A D.I.D. Standard Aluminium U.S. Class "A" evaporation pan.

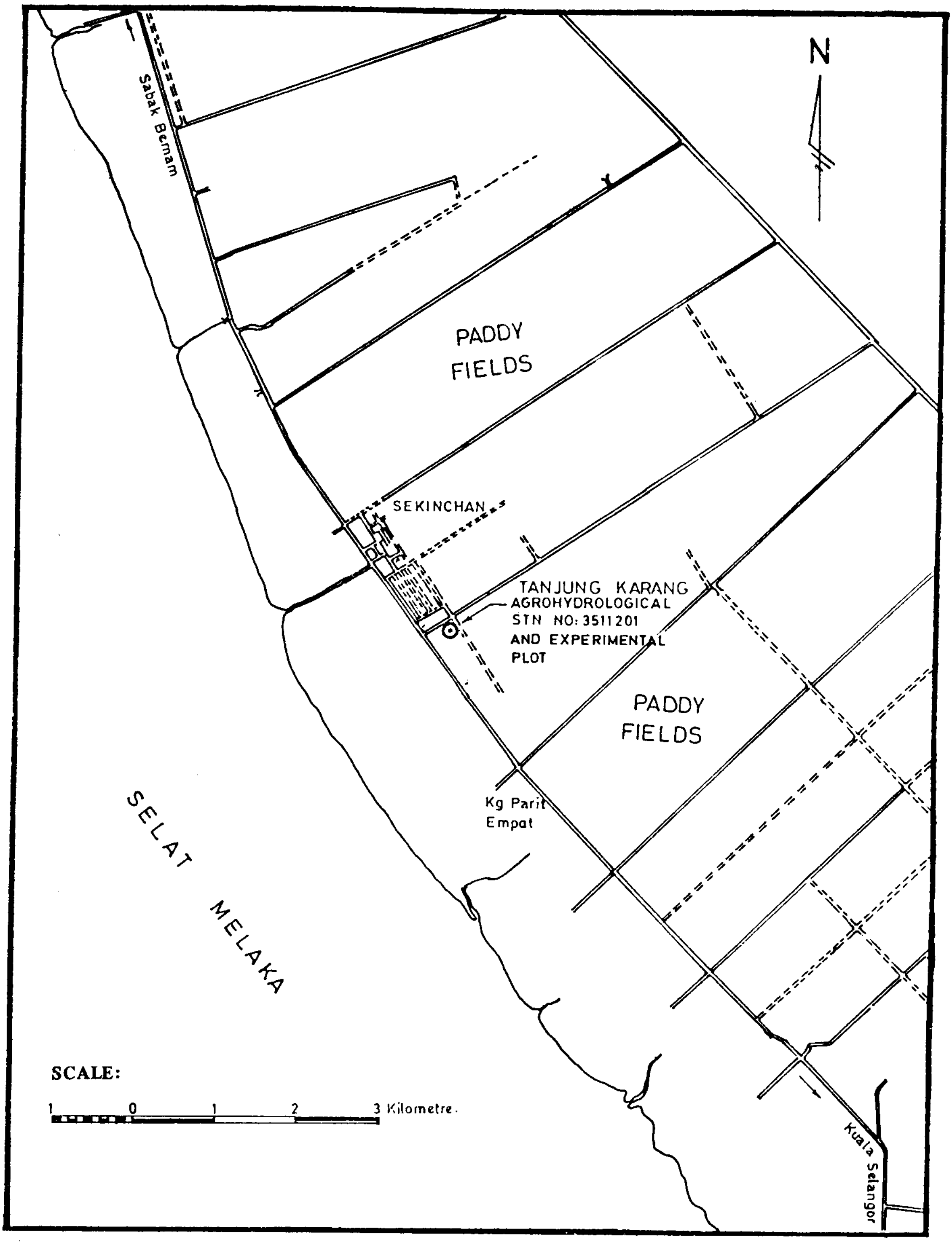

FIG. 1: AGRO-HYDROLOGICAL STATION AT TANJUNG KARANG LOCATION MAP

Table 1 Monthly Climatic Data (1979 – 1984)

ELEMENT		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
TEMPERATURE (°C)	MEAN	27.5	28.0	28.2	28.4	28.2	27.9	27.3	27.6	27.6	27.8	28.0	27.9
	HIGHEST	28.0	28.1	28.7	29.4	28.7	28.2	27.7	28.0	27.8	28.0	28.3	28.3
	LOWEST	27.0	27.8	27.9	28.0	28.0	27.5	27.0	27.3	27.3	27.7	27.7	27.5
SUNSHINE (hrs/day)	MEAN	5.8	6.8	7.3	6.4	7.0	6.9	6.7	6.0	5.3	5.8	5.4	5.3
	HIGHEST	6.8	8.3	8.2	6.9	9.4	8.1	7.0	7.5	6.2	6.3	6.2	7.6
	LOWEST	4.4	4.1	6.5	5.6	5.5	6.3	6.2	4.8	4.8	4.9	4.0	3.5
RELATING HUMIDITY (%)	MEAN	77.0	75.8	76.6	77.9	79.5	76.9	78.9	75.2	74.9	78.6	79.5	78.8
	HIGHEST	82.9	79.3	81.6	81.3	81.2	80.5	82.3	77.7	77.6	83.2	87.0	83.3
	LOWEST	75.1	73.8	73.7	74.8	75.8	75.2	73.5	71.8	71.2	75.9	72.8	75.9
WIND SPEED (km/day)	MEAN	49.8	82.7	91.3	93.5	70.0	59.4	68.4	83.4	86.9	89.7	78.2	46.2
	HIGHEST	110.2	150.0	165.3	147.4	126.3	105.0	120.6	162.4	153.7	141.8	134.2	95.5
	LOWEST	0.48	0.66	0.74	0.87	0.70	0.50	0.50	0.50	0.70	0.90	0.70	0.40
MAXIMUM TEMPERATURE	MEAN	33.1	33.3	33.1	33.3	33.2	32.5	32.2	33.5	32.6	32.7	33.6	33.5
	HIGHEST	35.0	35.0	36.0	36.0	34.5	35.0	34.0	39.0	34.5	34.5	35.5	35.5
	LOWEST	28.5	30.2	28.5	29.2	30.5	28.7	28.5	28.7	29.2	29.5	29.0	29.0
MINIMUM TEMPERATURE	MEAN	21.9	22.0	23.5	23.9	23.9	23.9	22.7	22.5	23.0	22.8	22.7	23.0
	HIGHEST	23.5	23.0	27.0	27.2	27.0	26.7	25.8	26.2	26.0	24.2	25.7	26.5
	LOWEST	21.0	21.0	22.0	22.5	22.5	22.0	21.0	21.0	21.5	22.0	20.0	21.5

(iii) A Standard Stevenson Screen containing:–

(a) maximum and minimum thermometers
(b) wet and dry bulb thermometers
(c) thermograph

(iv) Negretti & Zambra cup anemometer with counter (at 2 metres height).

(v) A daily sunshine recorder – Campbell Stokes type complete with levelling device.

The operation and observation procedures are described in Hydrological Procedure No. 24 entitled "Establishment of Agro-hydrological Stations". Figure 2 shows the location of the agro-hydrological station and lysimeter in the paddy field.

3.2 Lysimeter Station

3 lysimeters made of Aluminium tank of dimension 1m x 1m x 1m were installed in the experimental plot adjacent to the agro-hydrological station.

3.3 Observation Programmes

Observation programmes for various climatic parameter commenced on different dates in accordance with availability of the instruments.

The observation during the period of study for the paddy season, were initiated on 1st May, 1979. The status of the various observation programmes is shown below:

	Instruments	Commencement	Termination
1.	Anemometer	1.5.1979	Continuing
2.	Rainfall recorder and Rain gauge	1.5.1979	"
3.	Evaporation Pan	2.5.1979	"
4.	Lysimeters	2.5.1979	"
5.	Maximum and min. thermometer	4.6.1979	"
6.	Dry & Wet bulb thermometer	4.6.1979	"
7.	Thermograph	10.7.1979	"
8.	Sunshine recorder	19.9.1979	"

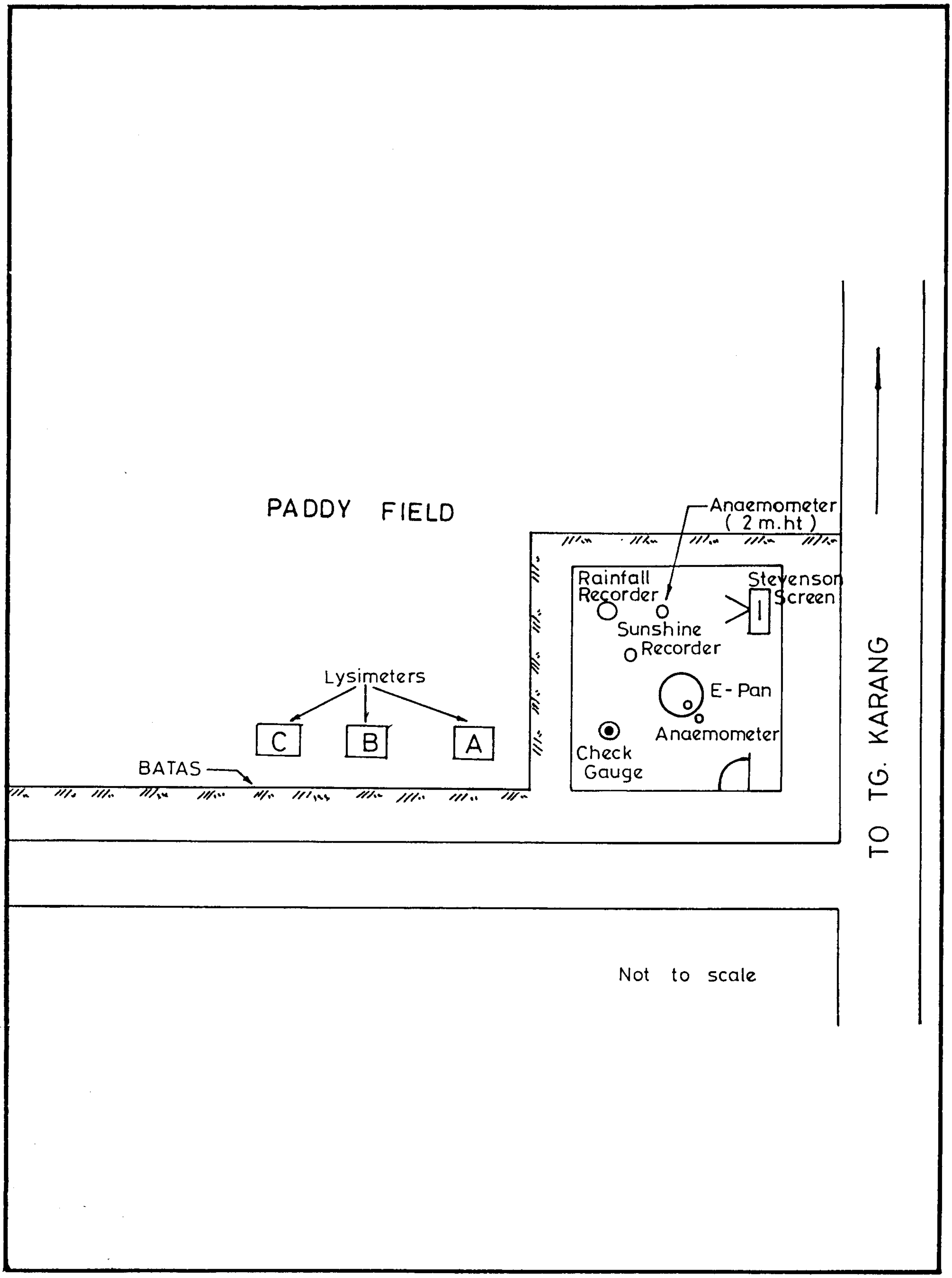

FIG.2: SKETCH SHOWING THE LOCATION OF AGRO-HYDROLOGICAL STATION AND LYSIMETER IN THE PADDY FIELD

DATA COLLECTION AND PROCESSING

The data collection at the agro-hydrological station continues form the installation dates of instruments. There were times where the data were missing from short periods mainly due to recorder malfunctioning, vandalism and extreme weather conditions.

Data collection at the lysimeter station is also a continual programme. As the lysimeter should be representative of surrounding paddy area, it was placed as close to the field as practicable and lysimeter evaporation was only measured when the field is wet.

4.1 Lysimeter Observations

A standard D.I.D. 50mm rainfall measuring cylinder was used to measure amount of water added to or removed from the lysimeter to bring back the water level in it to a fixed datum. The difference between two successive readings gives evapotranspiration rate (ET). ET were measured three times a day at 6.30 a.m., 12.30 p.m. and 6.30 p.m. respectively. The fact that the measuring cylinder was graduated in depth instead of volume, a calibration has to be carried out to convert the measuring cylinder depth into lysimeter depth. The calibration on the 3 lysimeters were carried out and the results are summarised in Table 2.

Table 2 Lysimeters' Conversion Factors

Lysimeter	Conversion factors
A	0.0322
B	0.0304
C	0.0305

It was apparent that when rainfall were excessive, measurements of ET might be unreliable because of likely difference between the rainfall catch at the raingauge and that which has fallen into the lysimeter and more importantly rainfall reception surface for lysimeter were complicated by paddy plants. Consequently, the ET reading would be discarded when the daily rainfall exceeds 10mm.

It should be noted that daily ET referred to total ET measured between 6.30 a.m. of successive days. Morning ET, afternoon ET and night ET are based on the measurement taken for the period between 7.00 a.m. to 1.00 p.m., 1.00 p.m. to 7.00 p.m. and 7.00 p.m. to 7.00 a.m. respectively.

4.2 Rainfall

Rainfall were measured 3 times a day simultaneously with lysimeter observations. Daily rainfall data were extracted from weekly charts and checked with manual raingauge readings.

4.3 Pan Evaporation

2mm graduated measuring can was used to measure the rate of evaporation. The method of measuring is similar to that of lysimeter.

Pan evaporation measurement were delicate particularly on rainy days. The following criteria were adopted for data screening (refer to Water Resources Pub. No. 5., D.I.D.):–

(i) Daily rainfall exceeded 38.1mm.

(ii) Observed evaporation $<$ 1.25mm whether rain occur or not.

(iii) The observed evaporation $>$ 7.65mm if rainfall occurred.

(iv) The observed evaporation $>$ 11.45mm if no rain.

4.4 Wind Measurement

A cup counter anemometer consists of three conical cups was used to measure the wind run. It was installed adjacent to the Evaporation pan 1.5 ft. above ground level. Daily wind run is found by taking counter readings at the same time each day and substracting the previous day's counter reading. As for this study, the wind run was computed based on the readings taken at 6.30 a.m.

4.5 Temperature

Temperature is measured in degree Celcius, commonly called centigrade. The mean daily temperature is the average of maximum and minimum temperatures recorded in the day.

The thermograph provides continuous records of temperature in a day and serves as a check on the thermometer readings. If higher accuracy of mean daily temperature is required thermograph could be used.

The temperature of water in the lysimeter and in the field was taken 3 times a day.

4.6 Relative Humidity

Relative humidity was recorded by thermograph housed in the standard Stevenson screen. The mean daily relative humidity of air was computed by averaging the maximum and minimum relative humidity extracted from the daily thermograph chart.

The accuracy of the thermograph was being checked by dry and wet bulb thermometer. Where discripancies existed, adjustments would be carried out immediately.

4.7 Sunshine Duration

Campbell Stokes Sunshine recorder was installed in the middle of study period to record daily sunshine duration.

5. RESULTS AND DISCUSSION

5.1 Crop Water Requirement for Paddy

The crop water requirements for paddy crops can be defined as the total depth of water needed to meet the water loss of a disease free crop, growing in large fields under non restricted soil conditions and achieving full production through the following processes:–

(i) Presaturation of the field before cultivation;
(ii) Evaporation from field before transplanting;
(iii) Evapotranspiration by paddy during the growth period to maturity;
(iv) Percolation or infiltration loss.

5.2 Evapotranspiration Requirement

The estimation of water needed for the establishment of nursery and growth of paddy was not performed as it is beyond the scope of the study. Evapotranspiration requirement of paddy growth normally taken as evapotranspiration loss for a period of until 4 weeks before harvesting is measured by means of lysimeter. Evapotranspiration loss, ET was not measured for the last 4 weeks of paddy growth because the field was drained prior to harvesting which means no water was needed for the period.

5.3 ET with Maturation Stage of Paddy Growth

Estimates on water needed to make up the ET with maturation stage of paddy growth are essential in irrigation planning. Such estimates enable the planner to allocate adequate water to the field without waste. The various stages of paddy growth as suggested by Dr. Seizo Matshushima on his report entitled "Some Experiments on Soil Water Plant Relationship in Rice" are defined as follows:–

(i) Rooting stage;
(ii) Early tillering stage;
(iii) Active tillering stage;
(iv) Late tillering stage;
(v) Maximum tillers stage;
(vi) Differentiation stage;
(vii) Heading stage;
(viii) Ripening stage.

ET with maturation stage of paddy growth for eleven paddy seasons under this study are tabulated in Table 3.

Table 3 Water Requirement of Paddy Crops At Various Stages of Growth Determined in Lysimeters

Stages of Paddy Growth	Water Requirement of Paddy Crops for the seasons (mm)										
	May 79 - Aug 79	Oct 79 - Jan 80	Mar 80 - Jun 80	Apr 81 - Jun 81	Oct 81 - Dec 81	Apr 82 - Jun 82	Oct 82 - Dec 82	Apr 83 - Jul 83	Dec 83 - Feb 84	Jun 84 - Aug 84	Nov 84 - Jan 85
Rooting	52.6	41.0	52.3	18.61	32.50	24.49	33.05	48.98	24.19	28.38	21.29
Early Tillering	57.4	28.2	30.2	35.56	16.81	27.22	26.74	45.66	18.32	22.09	25.92
Active Tillering	56.5	40.0	53.1	39.06	32.29	32.47	19.01	32.38	20.46	32.35	24.91
Late Tillering	49.4	31.8	38.1	40.51	38.63	28.06	32.03	28.53	26.45	32.90	26.96
Maximum No. of Tillers	60.2	28.4	33.8	33.74	45.86	23.10	27.98	41.74	29.65	24.37	25.14
Differentiation	189.8	148.9	152.2	93.63	100.66	89.01	58.26	150.36	80.80	78.57	56.24
Heading	46.6	51.0	44.1	41.77	36.35	30.99	22.11	45.89	13.43	24.19	15.62
Ripening	148.3	38.9	47.2	107.31	85.30	82.38	50.59	118.63	23.86	64.38	88.62
Total	660.8	408.2	451.0	410.19	388.40	337.72	269.77	512.17	237.16	307.23	284.70

The differences in ET for the various seasons were due to that different varieties of paddy crop being planted and abnormally wet or dry months. Table 4 shows the different paddy varieties planted during the study period.

Table 4 Paddy Varieties Planted

Year	Paddy Variety	
1979	Seri Sekinchang	MR 7
1980	Seri Sekinchang	MR 7
1981	Kadariya	MR 27
1982	Kadariya	MR 10
1983	Kadariya	MR 52
1984	Kadariya	MR 52

5.4 Penman Potential Evaporatranspiration, ETo

Penman potential evapotranspiration equations were used in this study for estimating potential evapotranspiration. The procedure for estimating Penman Potential Evapotranspiration is based on Hydrological Procedure No. 17 entitled "Estimating Potential Evapotranspiration Using the Penman Procedure". ETo for the first season May 1979 – August 1979 under this study was not computed because the daily sunshine hours being one of the important parameters in the Penman's equations were not recorded.

5.5 Correlation of D.I.D. U.S. Class A Aluminium Pan Evaporation with Lysimeter Paddy Evapotranspiration

Since long-term lysimeter observation programmes are very expensive the above correlation has been established so that evaporation data collected at a network of stations distributed well over Peninsular Malaysia could be used to compute lysimeter ET for long term assessment of water requirement for paddy.

Both pan evaporation EP and lysimeter ET have in common respond to climatic parameters but it is evident that lysimeter ET varies according to maturation period of paddy for specific variety of paddy and soil type. EP only varies with climatic changes and physical condition of the pan. It is thus necessary to determine the ratio of ET to EP. The relationship can be written as below:–

$$ET = K * EP$$

where K is a crop coefficient

Table 5 shows crop factor K for paddy crops at various stages of growth.

Table 5 Crop Coefficient $K = \frac{ET}{EP}$ for Paddy Crops at Various Stages of Growth

Stages of Paddy Growth	Crop Coefficient $K = \frac{ET}{EP}$ for Paddy Crops for the season										
	May 79 - Aug 79	Oct 79 - Jan 80	Mar 80 - Jun 80	Apr 81 - Jun 81	Oct 81 - Dec 81	Apr 82 - Jun 82	Oct 82 - Dec 82	Apr 83 - Jul 83	Dec 83 - Feb 84	Jun 84 - Aug 84	Nov 84 - Jan 85
Rooting	0.94	1.04	0.96	0.93	0.95	1.03	1.07	1.04	0.92	0.90	0.82
Early Tillering	0.93	1.12	1.00	1.03	1.09	0.97	0.97	1.06	0.94	0.93	0.87
Active Tillering	1.08	1.01	1.00	1.06	0.86	1.00	1.01	0.95	0.90	0.92	0.91
Late Tillering	1.16	0.89	0.95	1.17	1.11	0.98	1.02	0.98	0.87	0.92	0.97
Maximum No. of Tillers	1.41	0.95	1.05	1.10	1.06	1.01	1.06	1.09	0.91	0.92	1.03
Differentiation	1.50	1.08	1.13	1.17	1.26	1.03	1.02	1.24	0.88	0.96	0.90
Heading	1.34	1.13	1.21	1.22	1.33	1.13	1.08	1.22	0.92	0.94	0.99
Ripening	1.32	0.86	1.23	1.24	1.20	1.11	1.17	1.12	0.84	0.88	0.89
Average K	1.21	1.01	1.07	1.12	1.11	1.03	1.05	1.09	0.90	0.92	0.92
Overall Average K											1.04

5.5.1 Linear Regression by Least Square

Pan evaporation EP data and lysimeter evapotranspiration ET data collected during the eleven different seasons under this study were correlated using linear regression by least square and gave the following equation:–

$$ET = 0.762EP + 1.306$$

with a correlation coefficient of 0.612 and the student-t at level of significance of 0.05 which is 1.96 is less than the computed t of 18.183.

5.5.2 The Relation Between 5-Day Average K Factor, ($\frac{ET}{EP}$) and Stages of Paddy Growth

To minimise the daily fluctuations of K factors, the plotting of K values against the maturation period of paddy crops was based on 5-day Average K factors. The relation between 5-day Average K factors and stage of paddy growth for the different seasons are shown in Figures 3 to 13.

5.6 Correlation of Penman Potential Evapotranspiration and Lysimeter Paddy Evapotranspiration

The reference crop evapotranspiration ETo evaluated by Penman potential evapotranspiration method is a function of weather elements such as sunshine hours, mean temperature, wind velocity, relative humidity etc. and is independent of the type of plant and soil. In this study, however, an attempt has been made to relate Penman potential evapotranspiration and lysimeter paddy evapotranspiration which can be related as follows:–

$$ET = Kc * ETo$$

where Kc is a crop coefficient.

Table 6 shows crop coefficient Kc for paddy crops at various stages of growth.

5.6.1 Linear Regression by Least Square

Similarly, the Penman potential evapotranspiration data and lysimeter paddy evapotranspiration data for the eleven seasons were correlated using linear regression by least square and the following equation was obtained:–

$$ET = 0.551ETo + 2.339$$

with a correlation coefficient of 0.640 and student-t at level of significance of 0.05 which is 1.96 is less than computed t of 18.806.

FIG 3: RELATION BETWEEN 5 DAY AVERAGE K FACTOR ($\frac{ET}{EP}$) AND STAGES OF PADDY GROWTH FOR SEASON MAY '79 – AUGUST '79

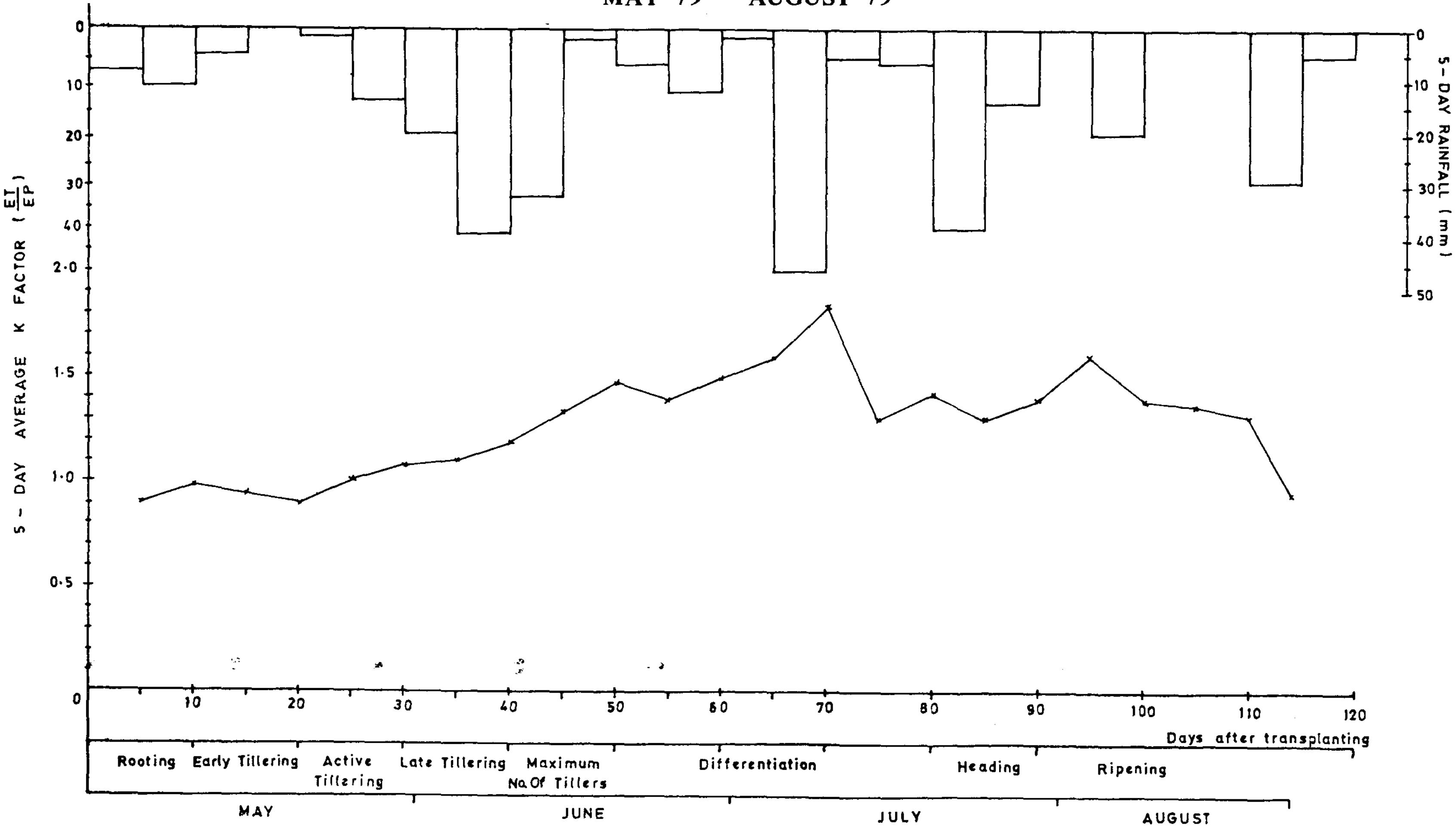

FIG. 4: RELATION BETWEEN 5 DAY AVERAGE K FACTOR ($\frac{ET}{EP}$) AND STAGES OF PADDY GROWTH FOR SEASON OCTOBER '79 – JANUARY '80

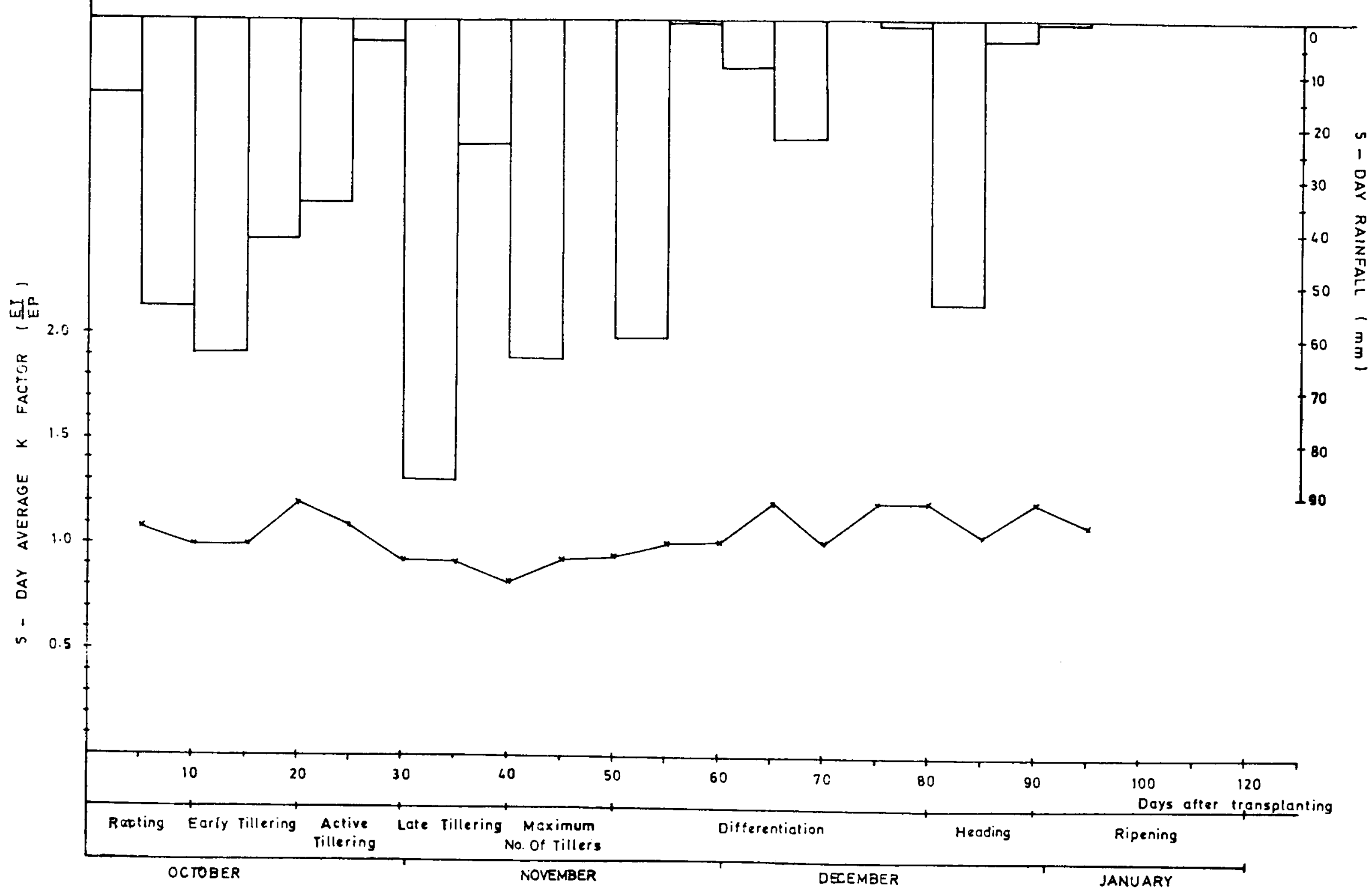

FIG. 5: RELATION BETWEEN 5 DAY AVERAGE K FACTOR ($\frac{ET}{EP}$) AND STAGES OF PADDY GROWTH FOR SEASON MARCH '80 – JUNE '80

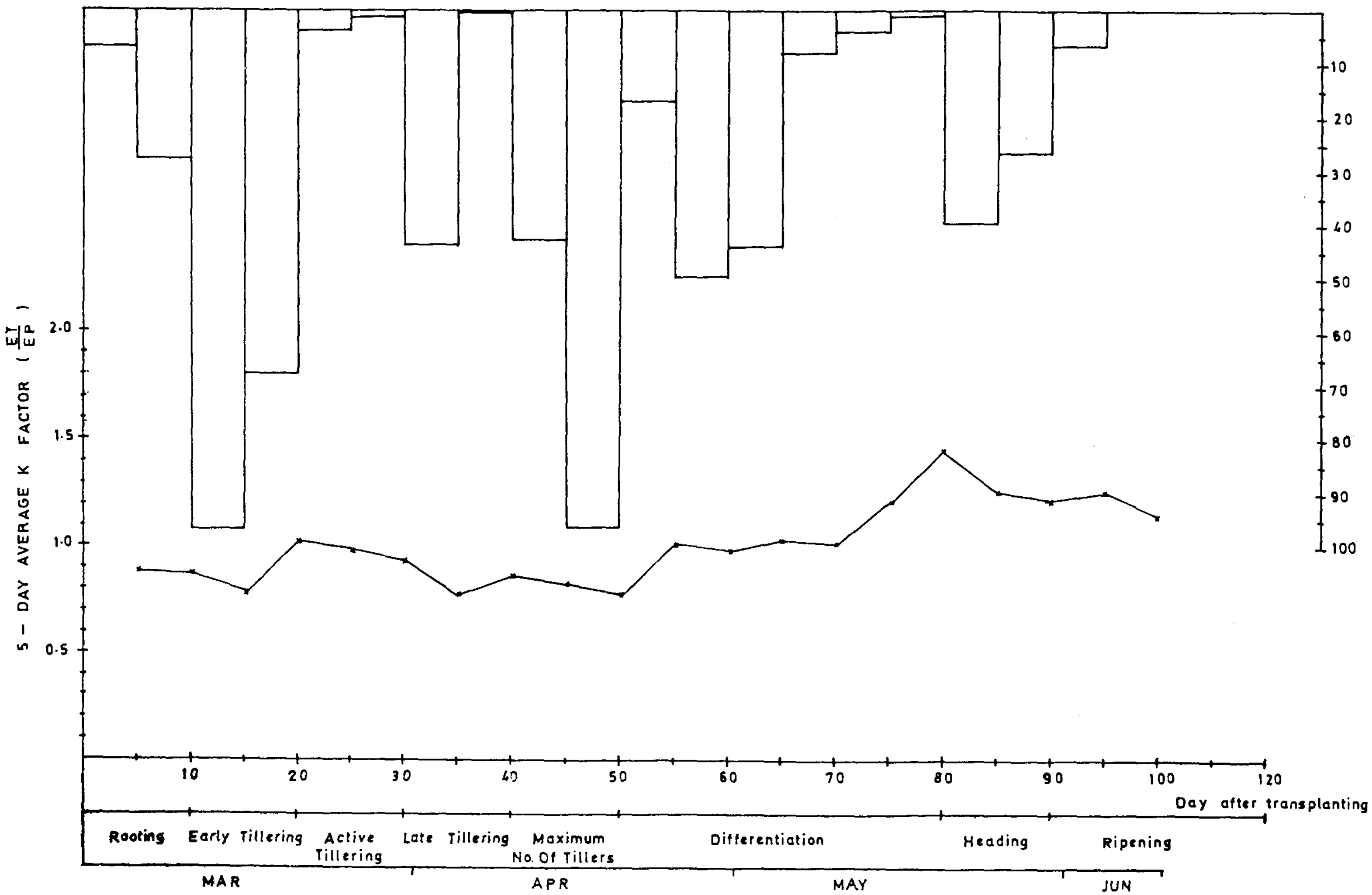

FIG. 6: RELATION BETWEEN 5 DAY AVERAGE K FACTOR ($\frac{ET}{EP}$) AND STAGES OF PADDY GROWTH FOR SEASON APRIL '81 – JUNE '81

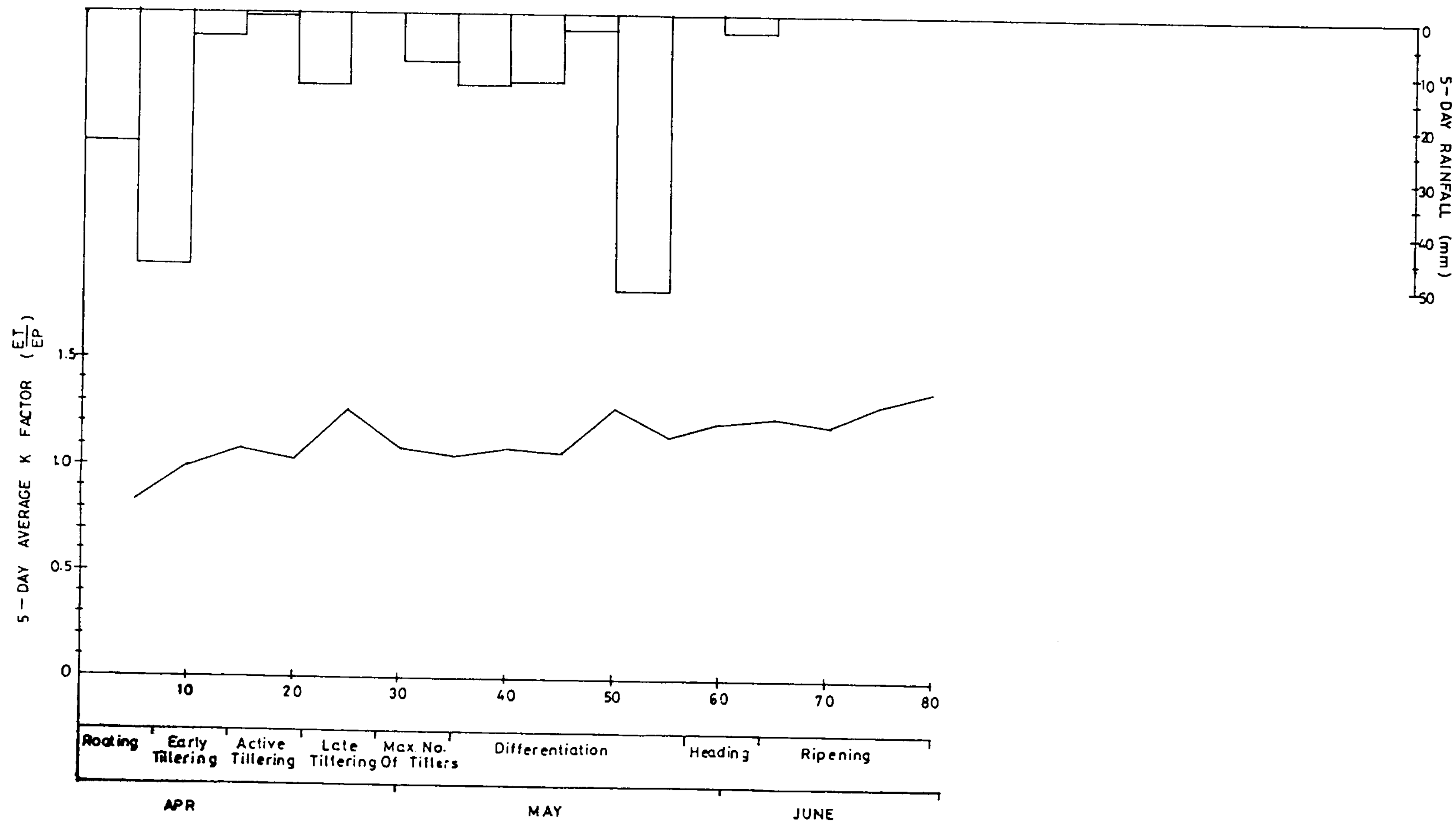

FIG. 7: RELATION BETWEEN 5 DAY AVERAGE K FACTOR ($\frac{ET}{EP}$) AND STAGES OF PADDY GROWTH FOR SEASON OCTOBER '81 – DECEMBER '81

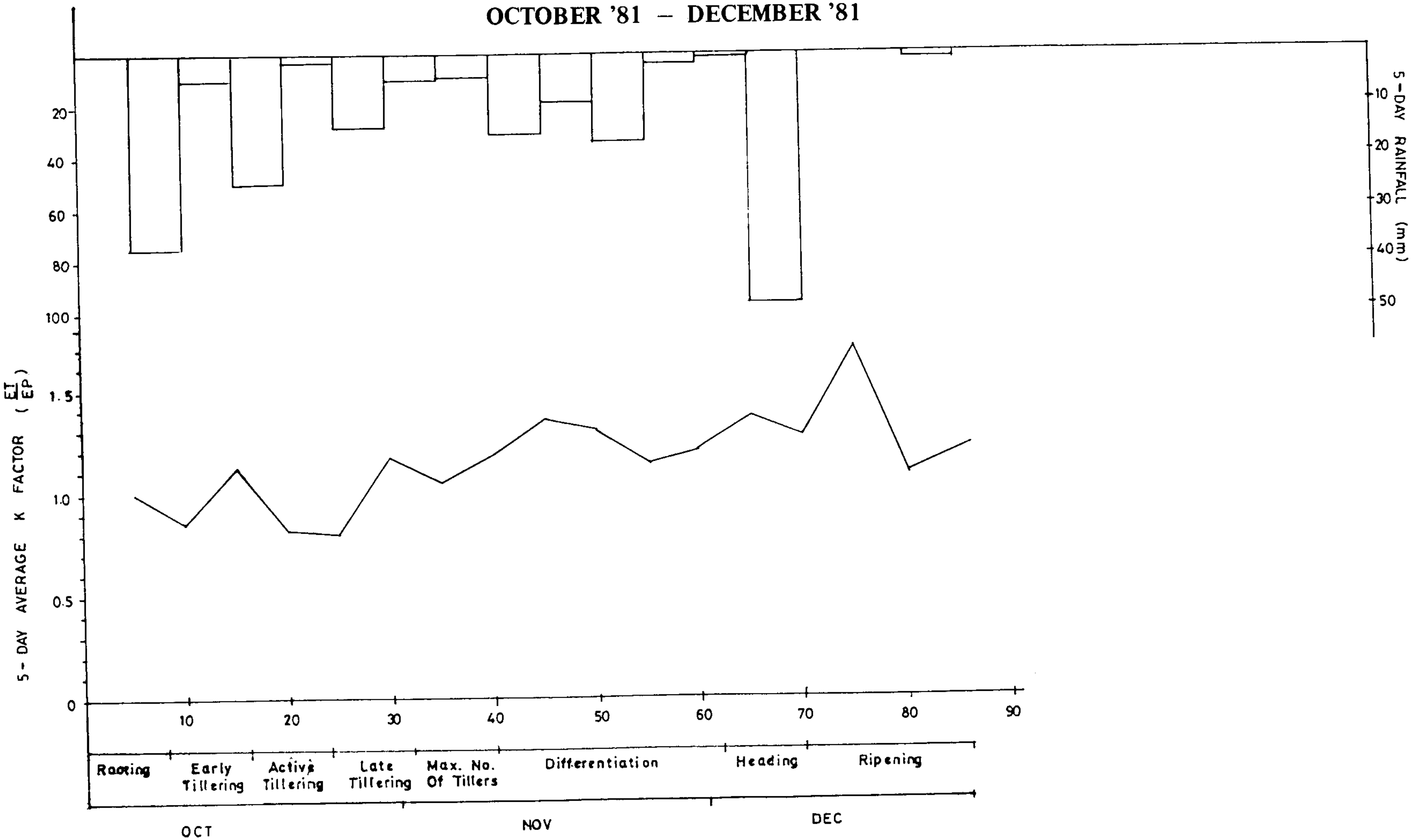

FIG. 8: RELATION BETWEEN 5 DAY AVERAGE K FACTOR ($\frac{ET}{EP}$) AND STAGES OF PADDY GROWTH FOR SEASON APRIL '82 – JUNE '82

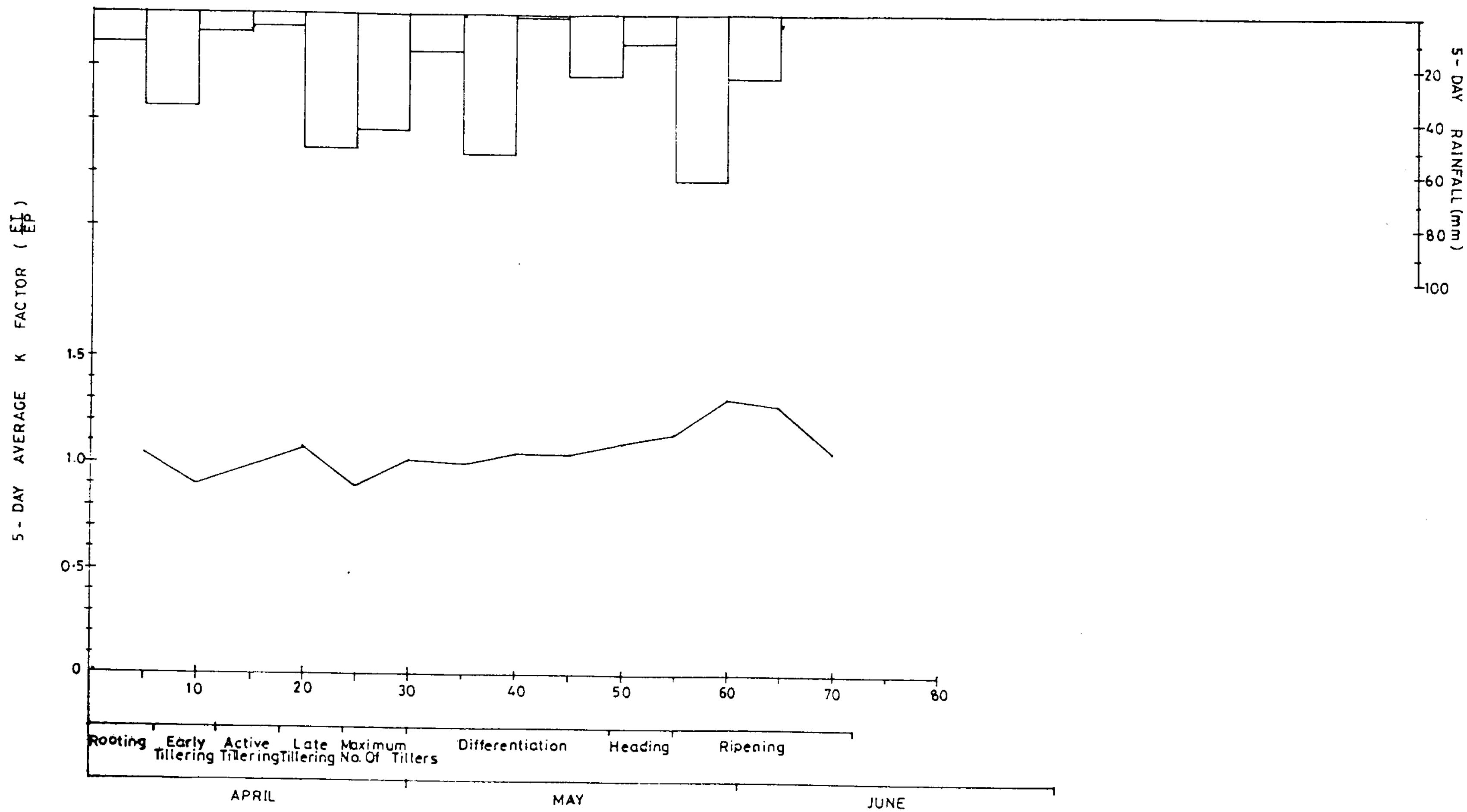

FIG. 9: RELATION BETWEEN 5 DAY AVERAGE K FACTOR ($\frac{ET}{EP}$) AND STAGES OF PADDY GROWTH FOR SEASON OCTOBER '82 – DECEMBER '82

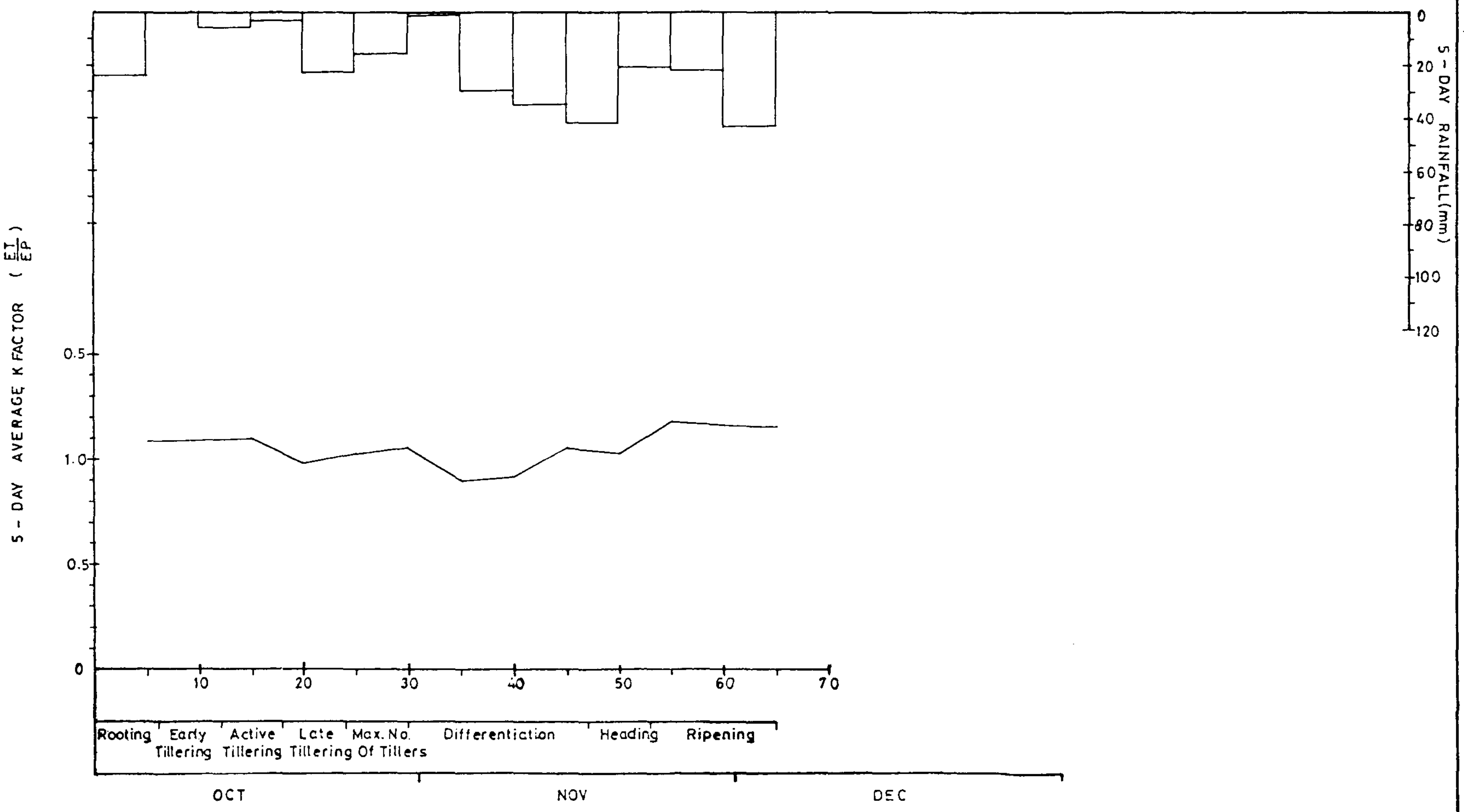

FIG. 10: RELATION BETWEEN 5 DAY AVERAGE K FACTOR ($\frac{ET}{EP}$) AND STAGES OF PADDY GROWTH FOR SEASON APRIL '83 – JULY '83

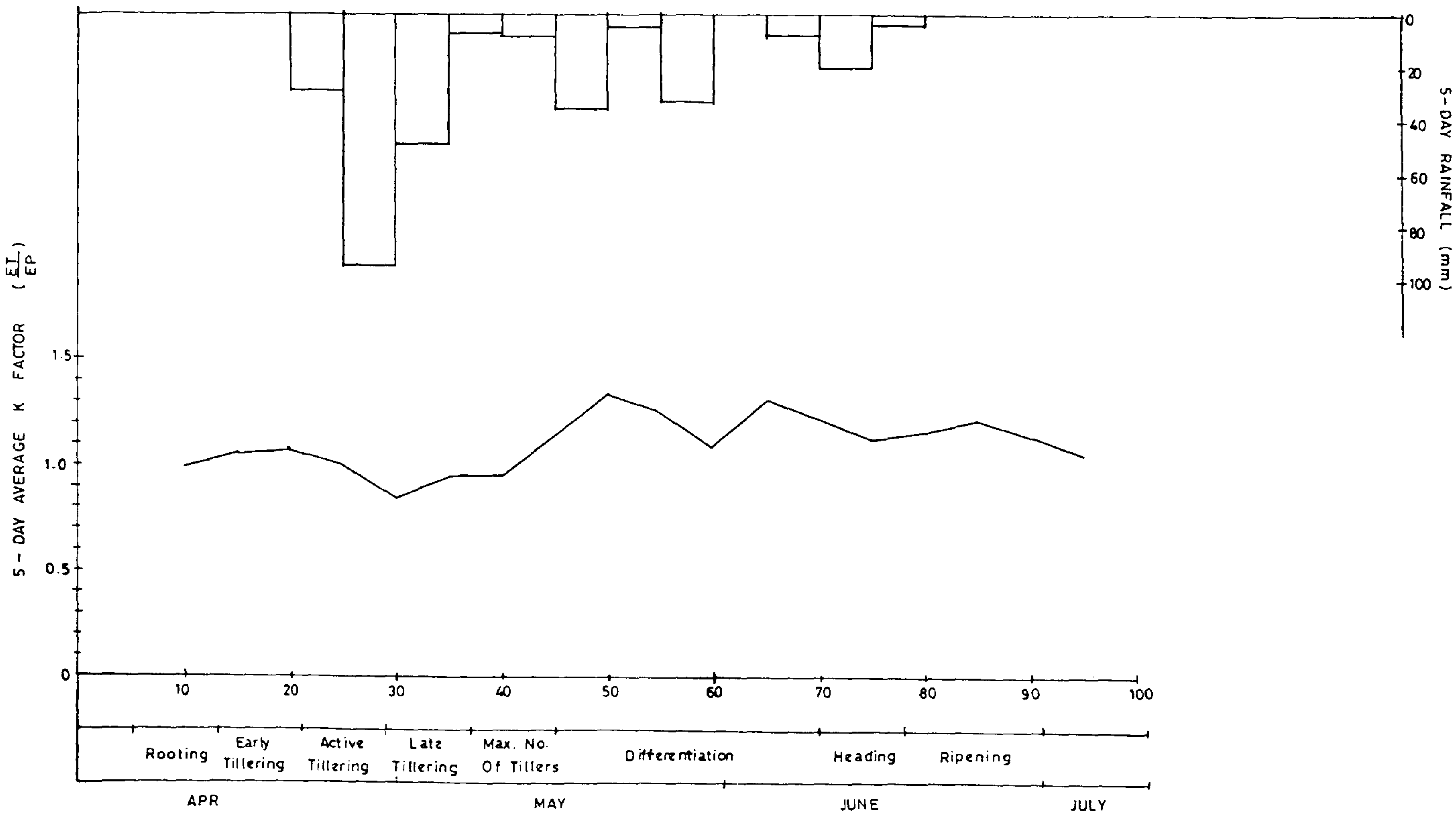

FIG. 11: RELATION BETWEEN 5 DAY AVERAGE K FACTOR ($\frac{ET}{EP}$) AND STAGES OF PADDY GROWTH FOR SEASON DECEMBER '83 – FEBRUARY '84

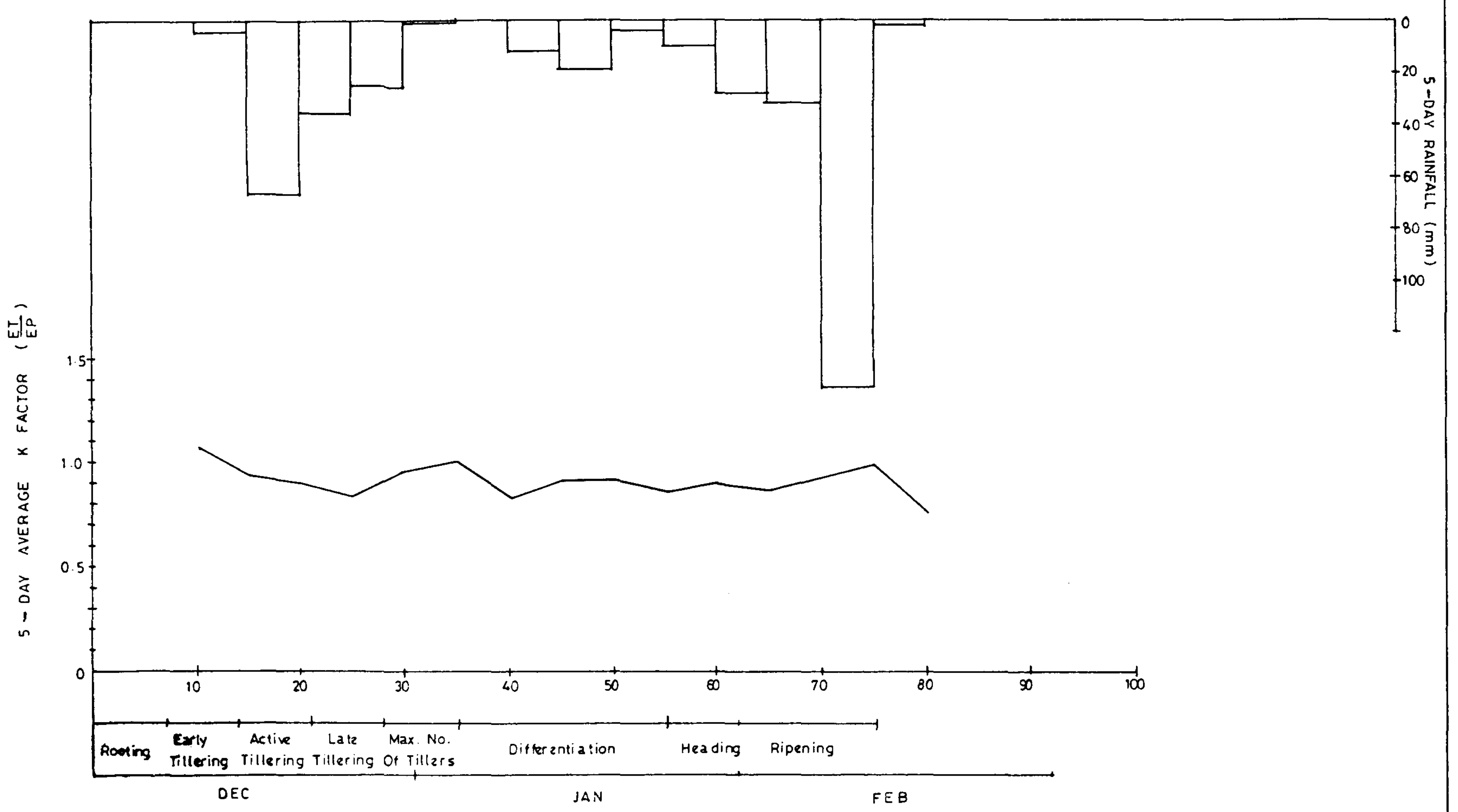

FIG. 12: RELATION BETWEEN 5 DAY AVERAGE K FACTOR ($\frac{ET}{EP}$) AND STAGES OF PADDY GROWTH FOR SEASON JUNE '84 – AUGUST '84

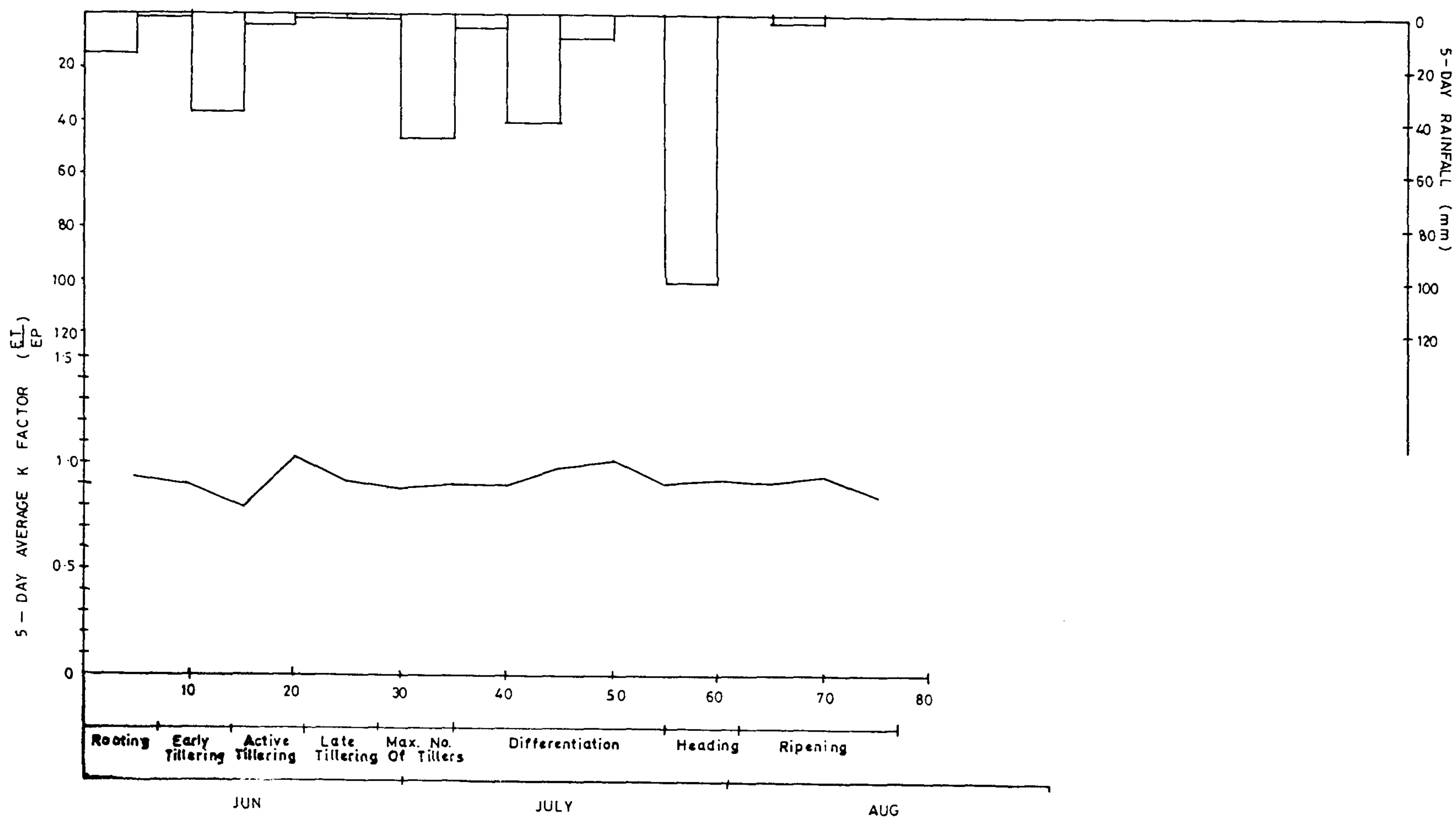

FIG. 13: RELATION BETWEEN 5 DAY AVERAGE K FACTOR ($\frac{ET}{EP}$) AND STAGES OF PADDY GROWTH FOR SEASON NOVEMBER '84 – JANUARY '85

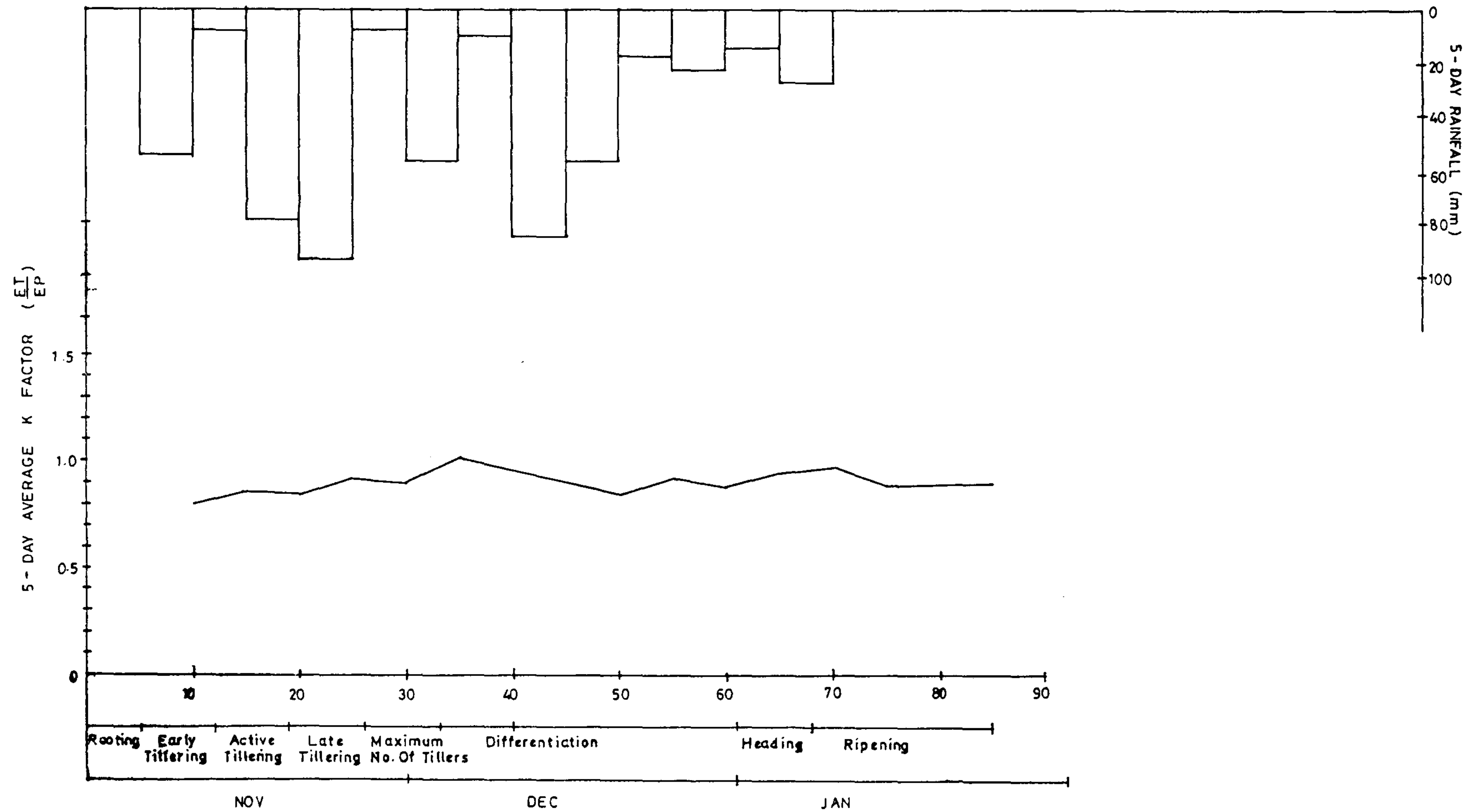

Table 6 Crop Coefficient $Kc = \frac{ET}{ETo}$ for Paddy Crops at Various Stages of Growth

Stages of Paddy Growth	Crop Coefficient $Kc = \frac{ET}{ETo}$ for Paddy Crops for the season										
	May 79 - Aug 79	Oct 79 - Jan 80	Mar 80 - Jun 80	Apr 81 - Jun 81	Oct 81 - Dec 81	Apr 82 - Jun 82	Oct 82 - Dec 82	Apr 83 - Jul 83	Dec 83 - Feb 84	Jun 84 - Aug 84	Nov 84 - Jan 85
Rooting	1.35	1.34	1.35	0.79	0.82	0.93	0.90	1.03	1.02	0.93	0.78
Early Tillering	1.17	1.20	1.19	0.93	0.77	0.83	0.79	1.12	0.84	0.79	0.80
Active Tillering	1.12	1.21	1.17	0.89	0.92	0.88	0.94	0.90	0.99	0.93	0.92
Late Tillering	1.18	1.19	1.19	1.08	0.90	0.90	0.92	0.93	0.95	0.96	0.88
Maximum No. of Tillers	1.11	1.09	1.10	0.86	1.15	0.87	0.97	1.10	0.97	0.94	0.94
Differentiation	1.08	1.32	1.20	1.02	1.10	0.98	0.95	1.17	1.05	1.04	0.93
Heading	1.42	1.36	1.39	1.08	1.27	0.98	0.95	1.08	0.93	1.02	1.06
Ripening	1.57	1.46	1.52	1.07	1.25	1.02	1.09	1.09	0.91	0.96	0.99
Average Kc	1.25	1.27	1.26	0.97	1.20	0.92	0.94	1.05	0.96	0.95	0.91
Overall Average Kc											1.06

6. EVALUATION OF RESULTS

6.1 Estimation of The Evapotranspiration Rate of Paddy At Different Stages of Growth

The rate of paddy evapotranspiration by means of lysimeter measurements at different stages of growth are shown in Table 3. It shows that generally at active tillering stage there is a significant increase in evapotranspiration requirement. Water is needed most at differentiation stage i.e. about 30% – 36% of the total requirement of paddy growth after transplanting.

6.2 Correlation of The Paddy Evapotranspiration to Aluminium Evaporation and Potential Evapotranspiration Rate by Penman Method

The above correlations were carried out and the results are summarised in Table 7 below: –

Table 7 Regression Equations of Paddy Evapotranspiration to Aluminium Pan Evaporation and Penman Potential Evapotranspiration

Regression Equation of Paddy Evapotranspiration to		Correlation Coefficient (r) of Paddy Evapotranspiration to	
Aluminium Pan Evaporation	Penman Potential Evapotranspiration	Aluminium Pan Evaporation	Penman Potential Evapotranspiration
ET = 0.762EP + 1.306	ET = 0.551ETo + 2.339	0.612	0.640

Such a low correlation coefficient is mainly because pan evaporation and Penman Potential Evapotranspiration respond to climatic changes and there were drastic changes in crop factors both K and Kc when rainfall were excessive. Secondly the above correlations are the overall correlations for all the seasons of the study period irrespective of the stages of paddy growth. In actual case, ET varies with maturation period thus causing large fluctuations.

7. CONCLUSION

The ET requirements for paddy vary with the rainfall patterns of the area where paddy is planted. In this study, on average 447mm of water was needed by paddy crop during seasons which fell on drier months and 318mm of water was needed during seasons which fell on wetter months.

At attempt to correlate lysimeter paddy evapotranspiration to pan evaporation and Penman potential evapotranspiration throughout the stages of paddy growth showed poor correlations. Neverthless, such correlations could be made for each of the maturation stages of paddy growth.

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