CROP COEFFICIENTS FOR IMMATURE RUBBER

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Crop coefficients were worked out for immature rubber using lysimetrically measured crop evapotranspiration and reference evapotranspiration estimated using weather based empirical methods (pan evaporation, modified Penman, Hargreaves and radiation methods). The mean evapotranspiration measured was 2.60, 4.24 and 4.98 mm per day during the first, second and third year respectively. The Kc values increased from the first year to third year of planting for all the four methods studied. A regression analysis indicated that modified Penman method and Hargreaves method are suitable for estimating evapotranspiration of rubber during the summer season.

Key words: Crop coefficient, Evapotranspiration, *Hevea brasiliensis*, Lysimeter.

INTRODUCTION

In India, *Hevea brasiliensis*, the most important commercial source of natural rubber (NR) is traditionally grown in Kerala, parts of Tamil Nadu and Karnataka under rainfed conditions. It is also cultivated in non-traditional areas like the north eastern states, Maharashtra, Orissa and West Bengal. Since the former experiences soil moisture stress for a period of four to five months starting from December to April, and the climatic conditions of the latter are less congenial for the growth of rubber trees, the effect of irrigation on the growth and yield of rubber has to be examined (Vijayakumar *et al.*, 1988)

Estimation of water requirement of a crop is essential for planning and operating irrigation systems. It is also useful to understand the water use by a given crop. Water requirement of a crop is directly related to its evapotranspiration and varies with the weather conditions and stage of growth.

A widely accepted approach for estimating evapotranspiration of a crop (ETc) is to apply an experimentally derived crop coefficient to a reference crop evapotranspiration (ETo) calculated from weather based empirical methods (Doorenbos and Pruitt, 1977). Crop coefficient (Kc) is the ratio of actual evapotranspiration (ETc) of the crop under non-stressed conditions to reference crop evapotranspiration (ETo). It represents crop specific water use.

Evapotranspiration and crop coefficient of two year old rubber plants have been reported earlier (Jessy *et al.*, 1992). The present study was taken up to develop crop coefficients for the first three years of plant growth using ETc measured lysimetrically and ETo estimated using weather based empirical methods.

MATERIALS AND METHODS

Measurement of ETc

The ETc was measured using a non-weighing lysimeter (diameter 3.5 m and depth 1.5 m). The lysimeter was installed

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in the farm of the Rubber Research Institute of India, Kottayam, Kerala (9^0 32' N, 76^0 36' E and 73 m above msl). The lysimeter was filled with soil leaving 2 cm from the rim three months before planting. A rubber plant raised in a polybag (clone RRII 105) was planted at the centre of the lysimeter in August 1991. The surrounding area of one acre was also planted with rubber plants of same clone and age.

The soil inside the lysimeter was maintained at field capacity by providing regular irrigation. Tensiometers were installed in the lysimeter to monitor the soil moisture at 30 and 60 cm depths. Periodic gravimetric determination of soil moisture was also done. The run off into the lysimeter was prevented by the raised rim of the lysimeter and the run off out of the lysimeter was collected in tanks. The water percolating down the lysimeter was collected in drainage tanks through outlets provided at the bottom of the lysimeter

Irrigation, rainfall, percolation and runoff were recorded daily during the summer season, December to February of 1991-92 and December to April of 1992-93 and 1993-94 and ETc worked out for weekly intervals.

The water balance equation of the lysimeter can be expressed as:

$P+I+RO = ET+D+\Delta W$ where P is the precipitation, I is the irrigation, RO is the run off in to or out of the lysimeter, ET is the evapotranspiration, D is the percolation or drainage and ΔW is the change in water content of the isolated soil mass over the time period (Aboukhaled *et al.*, 1982).

Since the soil was always maintained at field capacity, the factor ΔW can be eliminated from the water balance equation and the equation can be rewritten as:

$$P + I - RO = ET + D,$$

ie., $$ET = P + I - (RO + D)$$

Estimation of ETo

The ETo was estimated using the climatological and pan evaporation methods. The weather data during the period of experimentation were collected from the agrometeorological observatory located near the experimental area (Table 1).

The climatological methods used in the present study were modified Penman method, radiation method (Doorenbos and Pruitt,1977) and Hargreaves method (Hargreaves and Samani, 1982). For the computation of ETo by the pan evaporation method, data collected from a US class A pan evaporimeter were used (Doorenbos and Pruitt, 1977).

Crop evapotranspiration (ETc) over a period of time can be estimated by

ETc = ETo x Kc, where ETo is the reference evapotranspiration and Kc is the crop coefficient.

Comparison of the methods used for estimating ETc

ETc measured was regressed on crop coefficients computed using the four empirical methods to find out the most efficient method. The method with the highest R^2 was selected as the best.

RESULTS AND DISCUSSION

The ETc showed variation depending on weather conditions (Fig.1-3). The mean ETc during 1991-92 , 1992-93 and 1993-94 were 2.60, 4.24 and 4.98 mm per day respectively. Haridas (1980) observed that

Table 1 **Mean monthly weather data recorded during summer season**

Month	Temperature (°C)		R.H. (%)	Wind speed (km/h)	Sun shine hours	Total rainfall (mm)	Total evaporation (mm)
	Maximum	Minimum					
1991-92							
December	32.2	21.2	73.0	2.1	8.6	22.9	128
January	32.8	19.5	63.0	2.5	8.8	0.0	146
February	33.5	22.1	70.0	2.9	9.5	3.1	148
March	35.7	23.1	69.5	3.1	9.8	0.0	185
April	33.8	24.7	70.0	3.4	9.1	120.3	186
1992-93							
December	32.9	21.3	70.5	1.5	8.5	1.2	128
January	32.7	20.2	67.0	2.3	8.5	0.0	135
February	33.5	21.9	67.0	2.7	9.9	27	142
March	34.9	24.1	69.0	2.7	9.3	12.3	153
April	34.6	24.4	72.0	2.5	9.4	159.6	155
1993-94							
December	31.8	22.8	78.0	1.3	6.3	77.2	100
January	31.9	21.6	71.0	1.8	8.3	35.6	121
February	32.7	23.6	75.0	2.1	8.0	99.2	116
March	33.0	23.5	74.0	2.2	8.9	60.1	152
April	32.6	23.9	80.0	2.0	7.5	258.8	127

evapotranspiration of young rubber (clone RRIM 600) grown in a glass house in Malaysia varied from 2.1 to 6.9 mm per day. Under field conditions, the mean evapotranspiration was found to be 4.4 mm per day when averaged over 21 months. In Ivory Coast, Monteny *et al.* (1985) found that evapotranspiration of rubber varied from 4 to 6 mm per day when estimated using Bowen ratio - energy balance method. Jessy

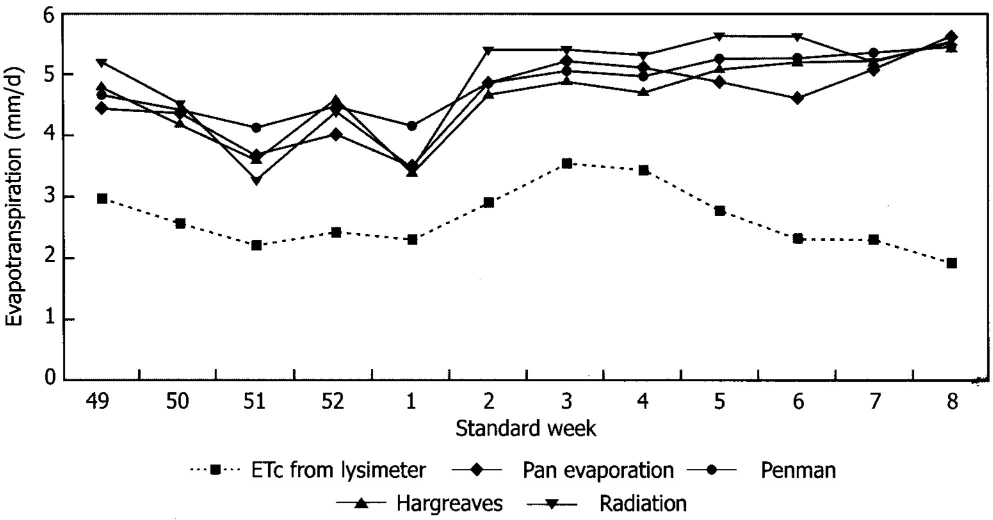

Fig. 1. ETc measured using lysimeter and ETo calculated by different methods: 1991-92

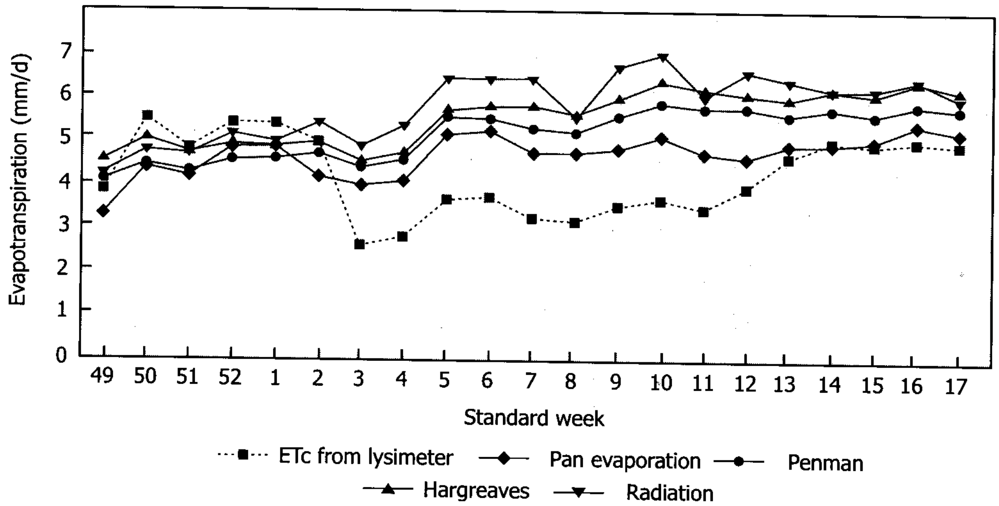

Fig. 2. ETc measured using lysimeter and ETo calculated by different methods: 1992-93

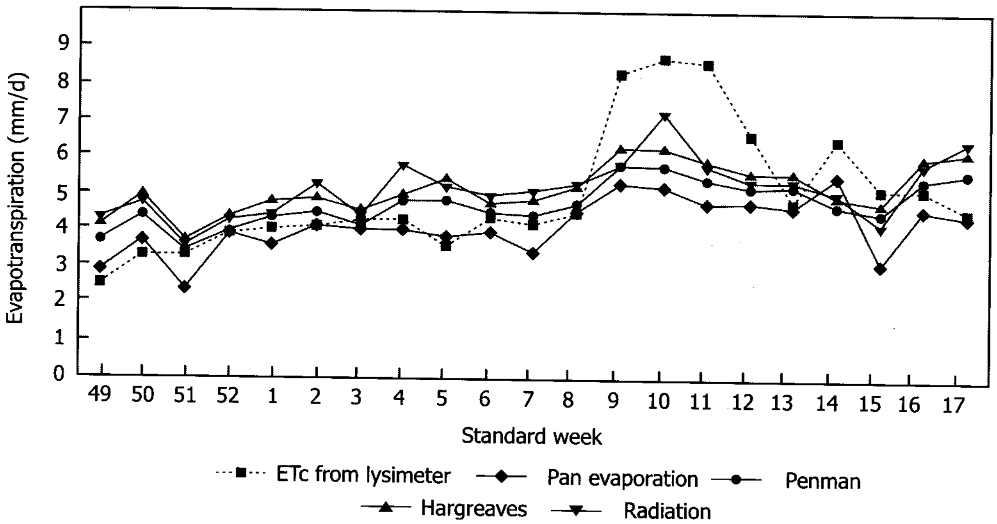

Fig. 3. ETc measured using lysimeter and ETo calculated by different methods: 1993-94

et al. (1992) reported the evapotranspiration of two year old rubber plants as 4.97 mm per day when the soil was maintained at field capacity. In the present experiment evapotranspiration of rubber increased from the first year to the third year. Roberts and Rosier (1993) have also reported similar trend in the transpiration rate of eucalyptus plants in South India. The transpiration rate of one year old eucalyptus plants was 3.5 and that of two year old plants was 5.5 mm per day during post monsoon period.

When soil moisture is adequate, evaporative demand of the atmosphere is the most important factor determining ETc. Variation in any one of the weather parameters (temperature, relative humidity, sunshine hours, wind speed and rainfall) directly influences evapotranspiration. Doorenbos and Kassam (1979) also recognised climate as the major factor determining crop water requirement. In the present experiment, the variation in the ETc computed at weekly intervals was more pronounced during the third year, indicating that the effect of weather parameters on ETc increases as the plant grows.

Crop coefficient

The mean crop coefficient (Kc) computed during 1991-92 (when plants were 5 to 7 months old) were 0.58, 0.55, 0.57 and 0.52 for the pan evaporation, modified Penman, Hargreaves and radiation methods respectively (Table 2). During 1992-93 , the mean values calculated were 0.90, 0.83, 0.77 and 0.70 for the respective methods. Jessy *et al.* (1992) reported the Kc values of two year old rubber plants during the summer season as 0.95, 0.92 and 0.87 for the pan evaporation, modified Penman and Hargreaves methods respectively. During 1993-94, the Kc values computed during the summer season were 1.18, 1.02, 0.93 and 0.95 respectively. The Kc values computed followed the same trend in all the years. The transpiration coefficient of mature rubber was reported to be 1.06 during the post monsoon period (Devakumar *et al.*, 1988). Vijayakumar *et al.* (1988) and Jessy *et al.* (1994) observed improvement in the growth of immature rubber when irrigation was given assuming a Kc of 1.0 to 1.25. The Kc of mature rubber was observed to vary between 1.0 and 1.25 when the fraction of available water in the root zone was 120 to 200 mm (Monteny *et al.*, 1985). In North Konkan region, when irrigation was given assuming a Kc of 1.00, water stress was observed, but when it was revised to 1.25, plants did not show any symptoms of water stress and based on the physiological observations, it was concluded that rubber has a high water requirement (Vijayakumar *et al.*, 1998).

Table 2. **Mean crop coefficients (Kc) estimated by different methods**

Month	Pan evaporation	Penman	Hargreaves	Radiation
1991-92				
December	0.62	0.57	0.59	0.51
January	0.65	0.63	0.69	0.63
February	0.47	0.44	0.44	0.42
Mean	0.58	0.55	0.57	0.52
1992-93				
December	1.17	1.12	1.01	1.04
January	0.90	0.86	0.81	0.76
February	0.69	0.63	0.60	0.55
March	0.79	0.67	0.63	0.59
April	0.96	0.86	0.80	0.80
Mean	0.90	0.83	0.77	0.75
1993-94				
December	1.03	0.85	0.76	0.78
January	1.07	0.94	0.87	0.87
February	1.05	0.90	0.82	0.82
March	1.48	1.34	1.23	1.25
April	1.25	1.07	0.98	1.03
Mean	1.18	1.02	0.93	0.95

Crop coefficient values above 1.0 were reported for many tree crops. In Malaysia, Hong (1979) reported a Kc value of 1.25 for immature oil palm. In Australia Kc values up to 1.3 were reported for eucalyptus when the canopy closed (Meyers *et al.*, 1999).

The data indicate that, as the plant grows, the Kc increases for all the methods studied. Kc values were the highest for the pan evaporation method, followed by the modified Penman method. From the second week of December 1992 to the second week of January 1993, ETc measured was comparatively high due to the higher evaporative demand of the atmosphere (low RH and more sunshine hours). During this period, all the four methods under predicted the water requirement and Kc values were higher than unity. From the third week of January onwards, the evaporative demand of the atmosphere decreased with a corresponding decrease in both ETc and ETo and the values of Kc were less than 1.

In 1993-94, the ETc and ETo values increased gradually from December onwards and maximum values were noticed in March. The Kc values computed during March were higher than unity in all the four methods.

Even though the information available on Kc for different stages of growth of perennial crops is very limited, several authors have reported a linear increase in the values from planting to active growing phase of different annual crops. A linear increase from 0.33 to 1.45 in the ratio of evapotranspiration to class A pan evaporation up to the active growing phase and a gradual decrease thereafter was reported for wheat by Singh and Wolkewitz (1998). Elliot *et al.* (1988) noticed an increase in Kc values for peanut evapotranspiration from planting to the active growing phase and a declining trend afterwards.

Regression equations were developed for the four methods using Kc and ETc during 1992-93 and 1993-94. The R^2 values worked out were 0.71, 0.76, 0.76 and 0.73 during 1992-93 and 0.64, 0.89, 0.88 and 0.77 during 1993-94 for the pan evaporation, modified Penman, Hargreaves and radiation methods respectively. No significant difference was found between R^2 of modified Penman method and Hargreaves method in both the years. Hence based on the available weather data any of these two methods can be used for estimating ETo.

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