Mausam, (1992), **43**, 2, 151-154

551.573 : 633.17

Fractional thermal units as the base scale for estimation of evapotranspiration for sorghum

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(*Received 26 February 1991*)

सार – तापीय एकक संकल्पना के प्रभीजी पर आधारित वाष्पोत्सर्जन फसल गुणांक वक्रों के लिए आधार माप के निर्धारण का प्रयास किया गया है। बेलारी में 1982 से 1988 तक के आंकड़ों का उपयोग करके शोरघम के लिए फसल गुणांक वक्र विकसित किया गया और बाद में इसका उपयोग 1988-89 तथा 1989-90 के वाष्पोत्सर्जन के आकलन के लिए किया गया। आकलित वाष्पोत्सर्जन मूल्यों के रैखिक समाश्रयण का वाष्पोत्सर्जन मूल्यों का दोनों वर्षों के लिए मापित निष्पादित किया गया और 1% स्तर पर सार्थक पाए गए।

ABSTRACT. An attempt has been made to determine a base scale for evapotranspiration (ET) crop coefficient curves based on a fraction of thermal units concept. A crop coefficient curve for sorghum was developed using data obtained from 1982 through 1988 at Bellary, and then used to estimate ET for 1988-89 and 1989-90. The linear regression of estimated ET rates against measured ET rates was performed for both the years and were found significant at 1% level.

Key words — Crop coefficient, Maturity, Fractional thermal unit, Evapotranspiration.

1. Introduction

A vital part of an irrigation management program is availability of reliable estimates of crop water use, *i.e.*, the loss due to evapotranspiration (ET) which depends on climatic parameters such as radiation received, temperature, wind speed and vapour pressure deficit, type of the soil and the growth stages of the crop. Evapotranspiration (ET) crop coefficient curves (ratio of actual crop ET to a reference crop ET plotted *vs*. a time or crop development base scale) are often used in estimating actual crop ET. The reference crop ET is usually approximated from weather data.

Various scales have been used in normalizing crop coefficients including days after emergence (Stegman *et al.* 1977), crop growth stage (Doorenbos and Kassam 1979), percentage time from harvest to harvest by cutting in alfalfa (*Medicago Sativa* L.) (Wright 1982), per cent of time from planting to full cover and then elapsed days after full cover (Wright and Jensen 1978) and cumulative reference ET (Hills *et al.* 1983). Wright (1985) stated that rather than percentage time of elapsed days as a basis for normalizing crop coefficients, a means of relating crop coefficients more directly to crop development would be better. Classifying crop development based on temperature was found to be useful by Mederski *et al.* (1973), since temperature is the major environmental factor that determines the rate of plant development (Johnson & Thornley 1985, McCloud 1984). A method used to evaluate the effect of temperature on development rate sums the daily mean temperature above a base temperature, currently referred to as thermal time measured in day-degrees (°Cd) (Monteith 1984) Mederski *et al.* (1973), found that accumulated heat unit methods based on temperature were about half as variable as the calendar day method for classifying hybrid maturity of corn.

One major drawback in basing a crop coefficient curve on accumulated thermal units is the difficulty in using the curve with cultivars that have different growth durations. Hattendorf *et al.* (1988) and Amos *et al.* (1989) used a fraction of growing season concept, based on thermal units, to normalize crop coefficients. The objective of this work was to develop such a curve

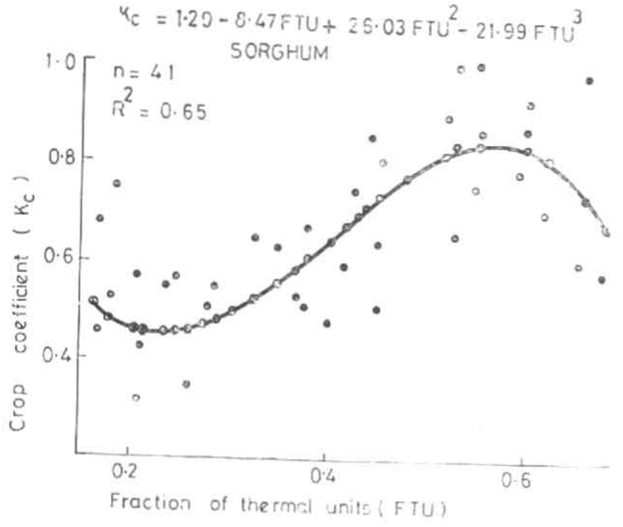

Fig. 1. Relationship between basal crop coefficient values *vs* fraction of thermal unit (1982-1988)

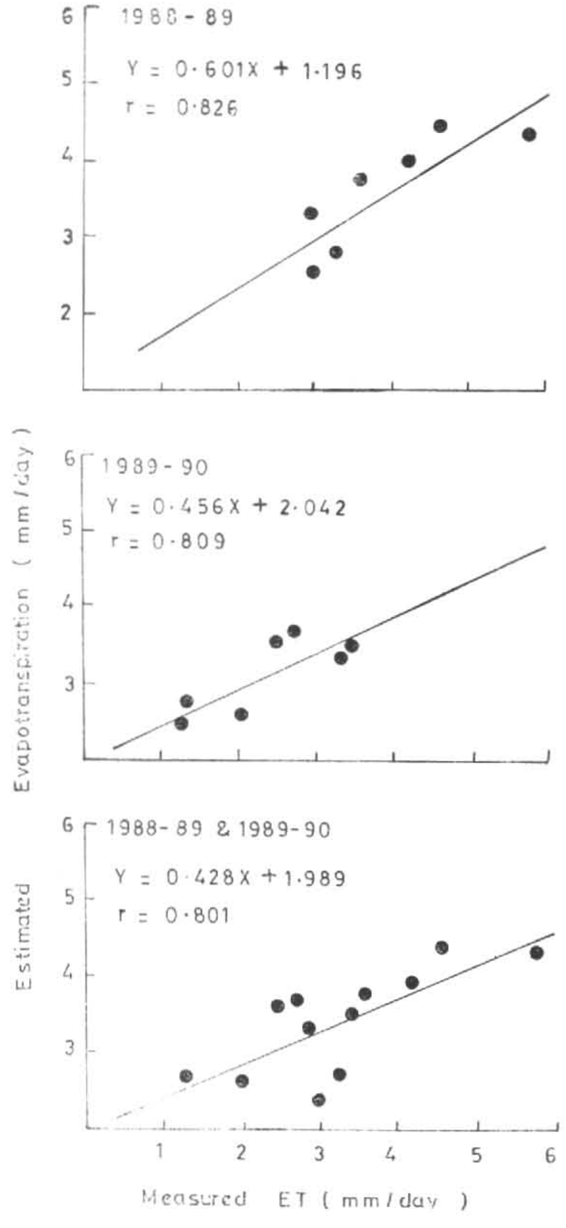

Fig. 2. Estimated evapotranspiration *vs* measured evapotranspiration by cultivar during 1988-89 & 1989-90 and regression analysis for pooled data

TABLE 1

Summary of total thermal units from crop emergence to physiological maturity and the fraction of total growing season thermal units accumulated from crop emergence to selected growth stages

Year	Cultivar	Emergence to		
		Flowering	Grain formation	Physiological maturity
		[Fraction of thermal units]		[Thermal units] (°Cd)
1982-83	SPV-86	0.68	0.88	1567
1983-84	SPV-86	0.67	0.87	1515
1983-84	CSH-5	0.62	0.84	1593
1984-85	SPV-86	0.67	0.86	1596
1984-85	CSH-5	0.65	0.90	1628
1985-86	M-35-1	0.62	0.81	1550
1986-87	SPV-86	0.67	0.87	1682
1987-88	SPV-86	0.65	0.84	1576

for sorghum and then to evaluate its ability to estimate ET of cultivars that differ in total thermal unit requirement.

2. Materials and method

Bellary (15° 09′ N, 76° 51′ E) is situated in the sub-tropics at an elevation of 445 metres a.m.s.l. Sorghum was chosen for the present study. The crop is grown during rabi season from September to February. Meteorological data for the crop growing period (September to February) were collected from 1982 through 1990. The daily weather data on temperature, relative humidity, wind speed, duration of bright sunshine and rainfall were collected from the data registers.

The AET values for sorghum crop was measured using gravimetric lysimeters. The weekly means of AET (referred hereafter as ET crop) were calculated from the daily mean values for each year. Modified Penman method (Doorenbos & Pruitt 1977) was used for the quantification of weekly mean PET, called reference evapotranspiration (ET_0) hereafter.

Crop coefficients (K_c) were computed using the measured evapotranspiration rates (ET crop) and the reference evapotranspiration rates (ET_0), from the following relation :

$$\text{ET crop} = K_c \ ET_0$$

The base temperature for sorghum is considered as 8°C for the study (Varshneya and Karande 1990). Accumulated thermal units for each of the phenological phases and from emergence to physiological maturity were computed by summing up daily thermal units. Fraction of thermal units (FTU) defined as the thermal units accumulated from emergence to the time in question, divided by the total thermal units accumulated from emergence to physiological maturity were computed.

3. Results and discussion

In order to assess the predictability of fractional thermal units (FTU) as the base scale in estimating evapotranspiration under rainfed conditions, the evapotranspiration crop coefficient *vs* fraction of thermal units relationship has been developed using a data set based on three different cultivars, *viz.*, SPV-86, CSH-5 and M-35-1.

Thermal unit totals from emergence to physiological maturity are summarized in Table 1. Also included is the fraction of total growing season thermal units accumulated from emergence to two selected growth stages, *viz.*, emergence to flowering and emergence to grain formation. It is seen that fraction of thermal units from emergence to flowering and from emergence to grain formation range between 0.62-0.68 and 0.81-0.90 respectively.

The crop coefficients calculated on weekly basis (1982 through 1988 data) *vs.* fraction of thermal units are plotted in Fig. 1. The K_c regression equation listed in Fig. 1 and the regression coefficients are signficant at $P < 0.01$ (F and t tests were performed respectively). Maximum K_c is 0.85 (Fig. 1) and occurs when corresponding FTU is 0.58, just before flowering stage (Table 1).

This finding is consistent with published data. From the data of Doorenbos and Pruitt (1977), the maximum crop coefficient value for sorghum was attained at active vegetative and flowering stages. Though the maximum values of K_c at these stages were slightly lower than that reported by Doorenbos and Pruitt yet the pattern of the K_c curve was similar. Slightly lower value of crop coefficient may be attributed due to low water supplying capacity of the soil under rainfed conditions. The secondary maxima at early stage of growth may probably be due to higher rate of soil evaporation under non-limiting water supplying capacity of the soil at this stage.

In order to assess usefulness of this technique the estimated ET was plotted *vs* measured ET for the 1988-89 and 1989-90 data (Fig. 2). The linear regression equations for the years separately and for pooled data are presented in Fig. 2. Correlation coefficients listed in Fig. 2 are significant at $P < 0.01$.

4. Conclusions

The use of fraction of thermal units to normalize basal crop coefficient values for sorghum was successful in this study. With the crop coefficient curve developed with 1982 through 1988 data, it was possible to successfully estimate ET during 1988-89 and 1989-90. Fraction of thermal units does appear to be a useful technique in normalizing sorghum development.

With the help of crop coefficient curve, it would be possible to estimate evapotranspiration for cultivars of different maturity lengths.

Acknowledgements

The authors are thankful to the Additional Director General of Meteorology (Agrimet) for giving encouragement and facilities for carrying out the work. They are also thankful to Dr. A. Chowdhury, DDGM (Agrimet) for giving valuable comments in preparing the manuscript.

The authors are thankful to Smt. S.L. Ashtekar for typing the manuscript.

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