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Research Article

Determination of Evapotranspiration and Crop Coefficient of *Tossa* Jute (*Corchorus olitorius*)

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ABSTRACT

Knowledge of evapotranspiration (ET) and crop coefficient is useful for irrigation water management to crops. Determination of crop water requirement requires measurement of crop ET (ET_c), which is a critical component of water balance at any scale. In this study, readily available pan evaporation data were used to estimate the ET_0 for hot and humid region of West Bengal considering the factor of pan coefficient (K_p) depending on fetch, wind speed, and relative humidity. The estimation of ET_c for *tossa* jute crop was carried out by using soil moisture depletion method. The ratio of ET_c to ET_0, called the crop coefficient (K_c), was calculated on weekly basis for irrigation scheduling of jute in a hot and humid region of West Bengal.

Key words: Evapotranspiration, Crop coefficient, Crop water requirement, Jute

Introduction

Jute, the second most important natural fibre crop after cotton in India, is one of the important cash crops in West Bengal. About 80% of India's jute growing areas exist in hot and humid regions of West Bengal, which is cultivated prevalently as a rainfed crop. Jute is sown during 2nd fortnight of March and 1st fortnight of April after the norwester rain. However, rainfall during this period has been considerably reduced during last decade (2001-2010) (Barman *et al*., 2012). Thus, 1-2 life saving irrigations becomes necessary for establishment of the crop in its early growing period. Crop coefficient (K_c), the ratio of crop evapotranspiration (ET_c) to reference evapotranspiration (ET_o), is used to extrapolate the computed ET_c for irrigation planning at regional scale.

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In crop water management studies, readily available pan evaporation data are often used to estimate ET_0 (Snyder *et al*., 2005) considering the factor of pan coefficient (K_p) depending on fetch, wind speed, and relative humidity (Doorenbos and Pruitt, 1977, Allen and Pruitt, 1991). The ET_c can be estimated by soil moisture depletion method (Michael, 2006; Odofin *et al*., 2011).

Successful cultivation of jute and its retting require precise estimation of irrigation water during early growth period and the drainage requirement at the later crop growth stage in conjunction with construction of water harvesting-cum-jute retting structure to hold the excess water for jute retting. The present study was undertaken to estimate the ET_c and the K_c of *tossa* jute for irrigation scheduling.

Materials and Methods

Experimental set up

The experiment was conducted at Research Farm of Central Research Institute for Jute &

Allied Fibres (CRIJAF), Barrackpore in 2012 and 2013. The *tossa* jute (var. JRO 524) was sown in 6 check basins each with dimension of 4 m x 3 m, separated by a spacing of 1 m. Earthen ridge was constructed around each of the basins to facilitate retention of irrigation water and to prevent surface runoff. Measured quantity of water was applied to the crop in each basin using a 10 L capacity plastic bucket. The basins were irrigated 15 days after sowing (DAS) and thereafter at 5 days interval.

Jute growing period

Jute is cultivated in *zaid* season in West Bengal. Length of the growing period (LGP) of the crop is 110 days (sowing in mid-March and harvesting in mid-July). In the first 60-70 days of growth period, the crop experiences water scarcity due to high ET. This is in addition to scanty and erratic norwester rains before the onset of south-west monsoon on 11th June in the region (Barman *et al*., 2012). Again, during monsoon, the crop often suffers from waterlogging during the 2nd half of growing season.

Weather data

Weather data for the period of 2001-2010 was collected from the Agrometeorology Unit, CRIJAF, Barrackpore. The observatory is situated at 22°45' N latitude and 88°26' E longitude and at 3.14 m above mean sea level. Daily weather data were converted to weekly, monthly and seasonal frequency by simple mathematical means. Total amount of rainfall was considered as the input of water into the soils for a particular period.

Water requirement of jute crop

The ET_0 was estimated by using pan evaporation method. Pan co-efficient (K_p) was empirically derived by correlating pan evaporation data (E_{pan}) with reference ET (ET_o):

$$ET_0 = K_p * E_{pan} \quad \ldots(i)$$

For USWB class A pan, adopted in India, the values of K_p for different conditions of humidity, wind and pan environment were taken from Reddy and Reddy (2001).

The ET_c was estimated by root zone soil moisture depletion method (Michael, 2006). The ET_c was calculated from the change in root zone soil moisture content in successive samples from the following equation:

$$ET_c = \sum_{i=1}^{n} \{(\theta_{1i} - \theta_{2i})/100\} * (\rho/\Gamma) * D \quad \ldots(ii)$$

where, ET_c evapotranspiration from root zone for 7 days sampling interval (mm), n number of soil layers sampled in the root zone depth, D; θ_{1i} and θ_{2i} are gravimetric water content (%) at the time of 1st and 2nd sampling, respectively in the ith layer; the ratio ρ/Γ is called bulk specific gravity in which ñ is bulk density (Mg m^{-3}) and ρ is the density of water (Mg m^{-3}) and D is the depth of the ith layer (mm).

The 1st soil sampling was done 2 days after irrigation, in order to allow soil moisture content of the silty clay loam soil to come to field capacity, so that the subsequent water loss could be attributed essentially to ET_c. For each calculation of ET_c at 7 days interval, a correction was made by adding the ET_0 values for accelerated water loss during first 2 days after each irrigation event and before the first soil sampling (Odofin *et al*., 2011).

K_c was computed on weekly basis, 15 DAS as ratio of ET_c to ET_0 as:

$$K_c = ET_c / ET_0 \quad \ldots(iii)$$

Results and Discussion

Climatic condition at Barrackpore

Decadal climatic parameters of Barrackpore are presented in Table 1. Decadal average annual rainfall (2001-2010) was 1383.2 mm (ranges between 1057.6 and 1751.2 mm), 85.7% of which occurred during June-October (monsoon months). Number of rainy days (>2.5 mm rainfall in a day) varied from 65 to 97 in a year with an average of 80.9 and coefficient of variation (CV) of 15.6%. Mean maximum and minimum air temperatures were 31.2 and 20.6 °C, respectively. Average maximum and minimum relative humidity in atmosphere was 93.7 and 61.8%, respectively. On

Table 1. Climatic parameters at Barrackpore during 2001-2010

Year	Temperature (°C)		RH (%) at		Total rainfall (mm)	Bright sunshine (h)	Class A Pan evaporation (mm d^{-1})	Wind speed (km h^{-1})
	Maximum	Minimum	6:36 h	13:36 h				
2001	30.8	20.4	95.2	62.1	1446.6	5.96	2.88	3.45
2002	30.9	20.0	94.4	60.4	1545.5	6.50	3.03	3.84
2003	30.8	20.3	94.5	62.4	1537.7	6.10	2.90	3.35
2004	31.1	20.4	93.6	62.4	1455.1	5.89	3.08	3.83
2005	31.2	20.9	93.2	63.1	1239.9	6.36	3.12	4.14
2006	31.4	19.7	92.1	62.0	1389.6	6.42	2.97	3.56
2007	30.5	20.5	93.3	61.7	1751.2	6.06	2.91	3.43
2008	31.1	20.7	94.1	63.1	1333.8	6.76	2.97	3.27
2009	31.8	20.9	94.0	59.4	1057.6	6.49	3.36	3.11
2010	31.7	21.3	92.7	61.2	1074.8	6.12	3.37	3.57
Mean	31.2	20.6	93.7	61.8	1383.2	6.3	3.1	3.6
SD	0.40	0.47	0.94	1.15	215.76	0.28	0.18	0.31
CV (%)	1.29	2.28	1.01	1.87	15.60	4.48	5.83	8.60

an average, bright sunshine was 6.3 h d^{-1} with 4.48% CV. Average open pan evaporation was 3.1 mm d^{-1} and wind speed was 3.6 km h^{1}. The climate is classified as subtropical humid.

Weekly rainfall, E_{pan} and ET_0 during 2001-2010

Weekly total rainfall, E_{pan} and ET_0 data indicates the surplus and deficit of moisture for cultivation of jute crop at Barrackpore (Fig. 1). The weekly E_{pan} and ET_0 were greater than the weekly rainfall up to the standard meteorological week-20, became lower than the rainfall thereafter till week-44 and again higher up to the week-52. The LGP of the crop extends between week-13 to 29 during which it experienced water deficit up to the week-20 and surplus thereafter, till its harvest.

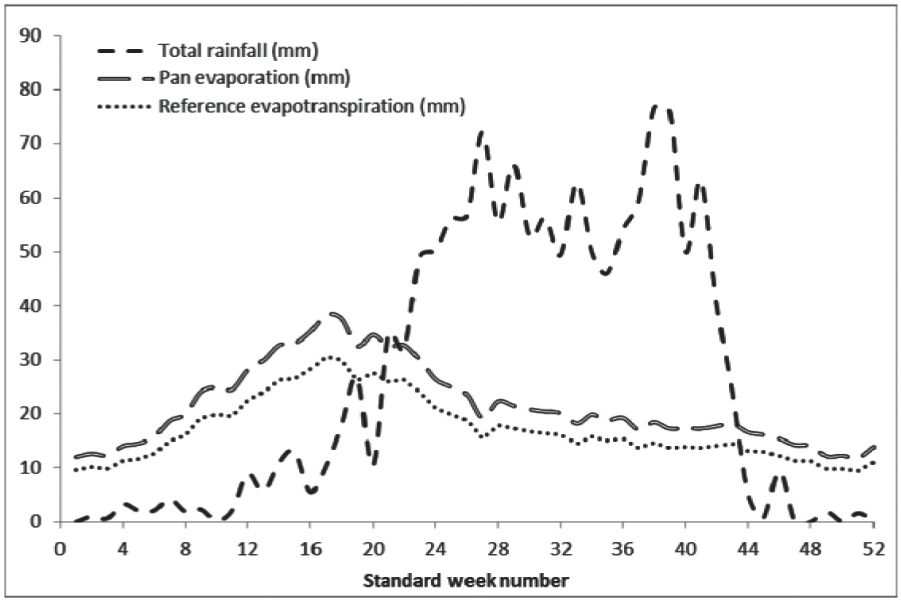

Fig. 1. Weekly distribution of rainfall, pan evaporation and ET_0 at Barrackpore (2001-2010)

Table 2. Pan coefficient (K_p) and reference evapotranspiration (ET_0) values in the standard meteorological weeks during early growth period of jute in 2013

Standard week No.	Wind velocity (km d^{-1})	Relative humidity (%)	K_p	Open pan evaporation (E_{pan}) mm d^{-1}	ET_0
15	120.0	65.0	0.80	6.4	5.12
16	108.0	73.5	0.85	5.2	4.42
17	86.4	72.5	0.85	4.9	4.16
18	201.6	71.5	0.80	5.5	4.40
19	216.0	71.5	0.80	6.5	5.20
20	127.2	80.0	0.85	4.7	3.99

Estimation of ET_0

The ET_0 in the year of 2013 was estimated on daily basis using Eq. (i) through pan coefficient (K_p) values for different wind velocity, ground cover and relative humidity, and is presented in Table 2. The ET_0 from week-15 to 20 was calculated which was the period of norwester rainfall. The ET_0 is higher in week-15 (5.12 mm d^{-1}) due to higher atmospheric evaporative demand, decreasing thereafter till week-18. The value in week-19 was higher (5.20 mm d^{-1}), but reduced to 3.99 mm d^{-1}.

Estimation of ET_c and K_c

Average weekly ET_c of the crop were measured in both 2012 and 2013 using Eq. (ii). The values ranged between 2.12 and 3.32 mm d^{-1} from week-15 to 20 (Fig. 2). The average weekly ET_c for JRO 524 was 2.72 mm d^{-1}. In this specific growth period, total ET_c was calculated as 114.24 mm.

The K_c values were computed on weekly basis using Eq. (iii), which showed exponential increasing trend between the week-15 and 20 in both the years of 2012 and 2013 (Fig. 3). The computed K_c values fall in similar line of estimation of some other studies conducted outside India (Fasinmirin and Olufayo, 2009; Odofin *et al*., 2011).

Irrigation at early growth period of jute

Jute requires about 418 mm water for its growth and development during its life cycle. In addition, 77 mm water is required for land preparation in respect of better germination of seed. Barman *et al*. (2012) calculated that the

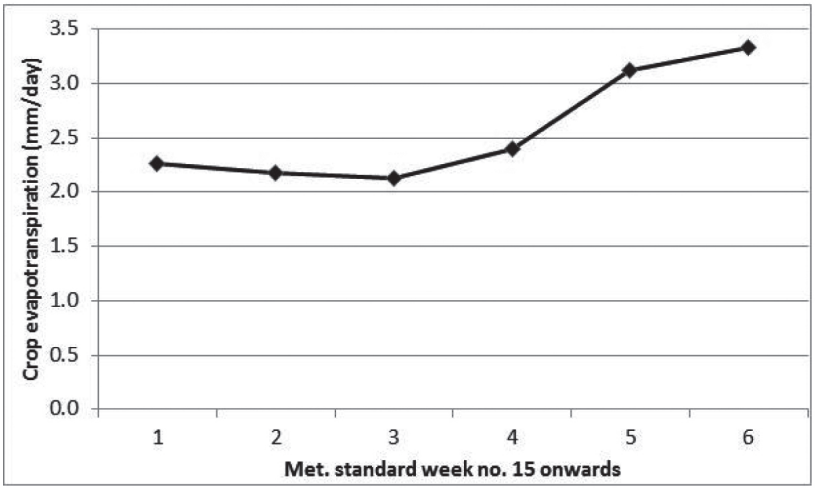

Fig. 2. Daily crop evapotranspiration (mm d^{-1}) during the week-15 to 20

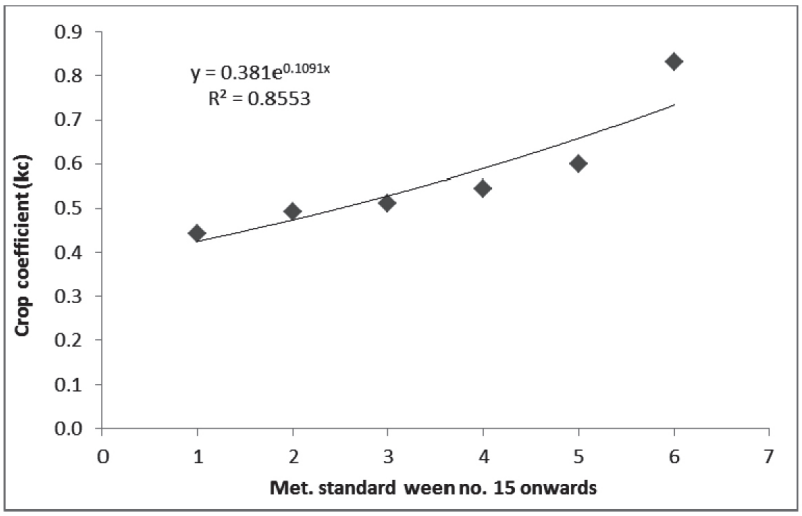

Fig. 3. Weekly crop coefficient (K_c) value during week number 15 to 20

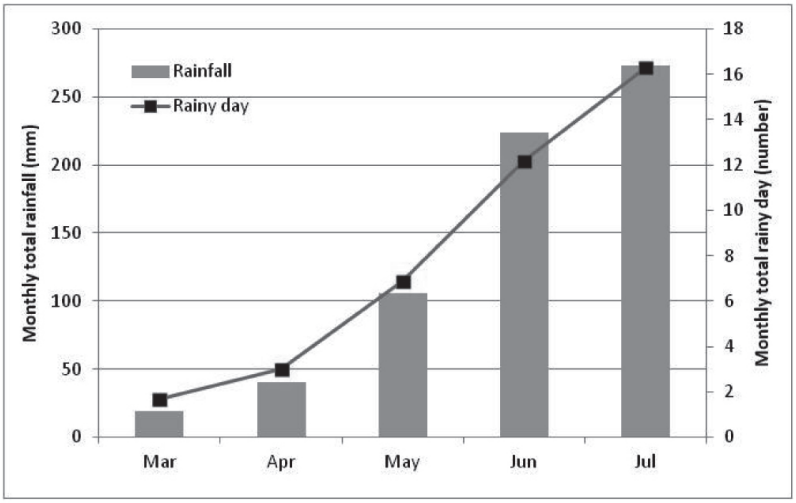

Fig. 4. Monthly distribution of rainfall and rainy days during life cycle of jute at Barrackpore

average rainfall during 10 to 15th week (5th March to 15th April) was 41 mm in the last decade (2001-2010). Therefore, the deficit of water during the land preparation and sowing was 36 mm, which could increase by evaporation and percolation losses depending on other factors. Thus, pre-sowing irrigation for the crop to supplement rain water would be required for better germination and crop growth. Indeed, the requirement of irrigation water would increase as because rainfall in the month of March-April showed a decreasing trend during the last decade. In the early growing period (week-15 to 20), ET_c was estimated at 114.24 mm, indicating similar amount of water required for irrigation @ 19 mm per week for better growth and development of the crop.

Conclusions

To the best of our knowledge, this is the first report on ET_c and K_c for *tossa* jute in the Gangetic alluvial zones of West Bengal, and the information will be useful for precise scheduling of irrigation during its early growth period. Although the pan evaporation is a crude method to estimate the reference evapotranspiration, it can be used to compute the crop coefficient value with minimum meteorological dataset at the initial level.

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