Determination of Crop Co-efficient Values for Jute (*Corchorus olitorius* L.)

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Abstract

Site specific calibration of crop coefficient (K_c) values is essential for irrigation scheduling of any crop. In order to determine the values of K_c for jute, an experiment was conducted at the Irrigation and Water Management Division of Bangladesh Agricultural Research Institute (BARI), Gazipur. An improved jute variety BJRI Tosa-2 (O-9897) was used in this experiment. The study examined growth and yield of the jute in terms of four irrigation treatments distributed over 7-28 days intervals. The treatments were so designed that drainage was allowed between the consecutive irrigations. Irrigation at 14days interval produced the highest dry fiber yield (3.93 t/ha) and was considered to be suitable for estimating seasonal crop evapotranspiration and K_c values. The seasonal crop ET was 549.13 mm under this treatment. The K_c values of jute at initial, development, mid-season and late season stages were found to be 0.72, 1.39, 1.26 and 0.46, respectively. As there is no FAO-recommended K_c value for this crop, this locally calibrated values can be used for similar climatic conditions of Bangladesh and elsewhere. Therefore, based on K_c value, it can be recommended that jute can be irrigated by equal amount of water needed for crop evapotranspiration (ET_c) for different growth stages (141.05, 142.57, 167.34, and 84.30 mm) to get maximum dry fiber yield.

1. Introduction

Jute (*Corchorus olitorius*) is an important crop of Bangladesh. It also goes by the name of "Golden Fiber" due to its golden brown colour and its importance as a cash crop. In terms of area and production, its position is first (0.67Mha and 2.03 t/ha) among the other fiber crops of the country (BBS, 2014). In Bangladesh, jute is cultivated during the kharif season and water is an essential element if higher yield and quality of fiber is sought. Since jute cultivation is completely reliant on rainfall, irrigation scheduling was not a priority for the

researchers of Bangladesh. However, recent changes in the rainfall pattern of the country has posed several risk factors that may cause severe damage to this industry. As a result, scientists are now interested in customizing the irrigation schedule for this crop in Bangladesh. In order to achieve this, crop co-efficient data is necessary, especially for regional water allocation plan for irrigation water. This research was therefore carried out to contribute towards this area of concern.

Crop coefficient (K_c) value of jute is a pre-requisite for accurate measurement of crop water

requirement at different stages of growth. It is the ratio of Crop evapotranspiration (ET_c) to the reference evapotranspiration (ET_0) of alfalfa grass. Crop coefficient values for a number of crops grown under different climatic conditions have been suggested by Doorenbos and Pruitt (1977). The values of K_c changes with the growth stages of a crop. Several researchers (Pruitt *et al.*, 1972; Jensen, 1974; Doorenbos and Pruitt, 1977; Burman *et al.*, 1980; Wright, 1982; Pruitt *et al.,* 1987) have devised experimental procedures for the determination of crop coefficient value. The values of K_c also vary with location, cultivar, soil and weather conditions. Therefore, site specific determination of crop coefficient (K_c) values is very important (Tyagi *et al.,* 2000) for successful irrigation management of a crop. However, such information have not yet been surfaced for jute cultivation in the country. Although several agronomic experiments were conducted with jute in Bangladesh, none of them reported the crop coefficient values (Alam *et al.,* 2011; Begum and Kumar, 2014; Nizam *et al.,* 2015; Billah *et al.,* 2016). This research aims to generate information towards fulfilling this research gap in the country.

Despite several efforts, a standard irrigation scheduling and water management technique for jute could not be developed in Bangladesh. Growers therefore, depend on the rainfall and their indigenous knowledge base. However, for better production of jute in the country, a proper irrigation schedule is absolutely necessary. In this regard, this research was carried out on Lysimeter to determine the crop coefficient values of jute at different growth stages, which can be used as a reference value for the country.

2. Materials and Methods

The experiments were conducted in a micro-lysimeter at the research farm of Bangladesh Agricultural Research Institute, Gazipur, during the summer season of 2016. It was a warm-dry climate, with average temperature of 30.73°C. The average relative humidity, wind speed, and sunshine hour were 80%, 16 km/hr, and 5.37, respectively. The highest rainfall was recorded in July (Table 1) and it was 42.11% of the total rainfall during the entire growing season. The soil of experimental field was silty clay loam, with field capacity and bulk density of 29.5% and 1.5 g/cm^3, respectively.

A hybrid jute variety (BJRI Tosa-2 (O9897))was selected for the lysimeter experiment. Seeds were sown in a 1m^2 micro-lysimeter at a spacing of 0.30 m × 0.10 m on 18April 2016. Seeds were treated by using Vitavax 200 (0.4% of seed weight) before sowing according to Islam *et al.* (2001). The same crop was also sown in field plots adjacent to the lysimeter tanks with the objective of creating favorable atmospheric condition (Figure 1).

Table 1. Mean monthly weather data during the crop growing period

Month	Temperature (°C)		Relative humidity (%)	Wind speed (km/hr)	Sunshine hour	Rainfall (mm)
	Max	Min				
April*	36.46	27.87	78	21	7.55	0
May	33.27	31.31	80	14	6.16	372
June	33.91	26.46	79	15	5.10	134
July	32.23	26.4	84	14	3.12	395
August**	32.65	26.72	80	16	4.92	37

*mean was calculated from date of sowing to 30 April
**mean was calculated from 1st day to 10th August
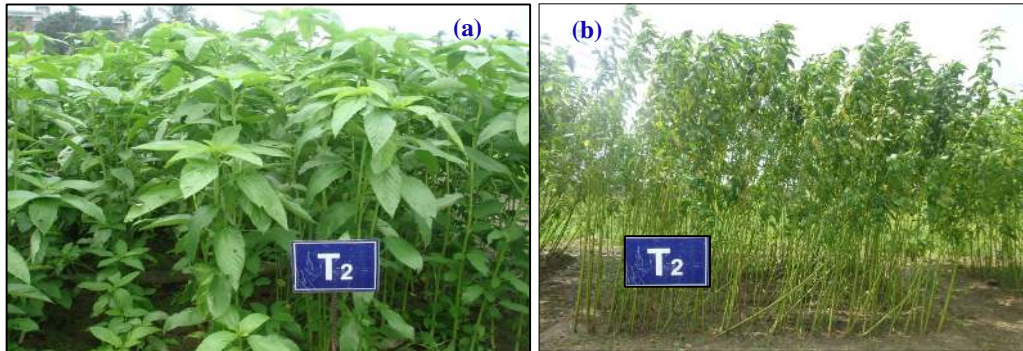
Fig. 1. Photographic view of jute plants under treatment T_2 grown in the lysimetertank which was surrounded by same crop at the experimental field for creation of favorable atmospheric condition. The age of the plants was 26 days (a) and 98 days (b) at the time of taking the photograph

Recommended fertilizer doses were applied at the rate of N_{75}, P_{12}, K_{39}, S_{15}, Zn_3 kg/ha, and cowdung of 5 t/ha (FRG, 2012). Half of N and total amount of the other fertilizers were applied at the time of final land preparation, and the rest of N was top dressed at 40-45 days after sowing (DAS) under moist soil condition. Post-sowing irrigation of 112 mm was applied at 7 and 10 DAS for ensuring proper crop establishment. Intercultural operations (weeding and thinning at 14 and 21 DAS) and pesticide application (Ripcord @1 ppm at 30, 41, 58, 73, 80 and 84 DAS) were applied according to necessity. Irrigation treatment was started at 25 DAS and the crop was harvested on10 August 2016.

The micro-lysimeter in this study contains 4-tanks, and it is in fact a one meter square where jute was grown in a condition that is hydrologically separated from the surrounding environment (Michael, 2014). According to Khan *et al*. (1993), growing crops in such a condition does not need any replication. Similar system was also used by other researchers (Mila *et al.,* 2016a; Mila *et al.,* 2016b) for estimating crop coefficient values of sunflower and soybean at Gazipur. The crop was irrigated according to the following design. Four treatments were used as follows:

T_1 = Irrigation at 7 days interval, allowing drainage until receiving the next irrigation
T_2 = Irrigation at 14 days interval, allowing drainage until receiving the next irrigation
T_3 = Irrigation at 21 days interval, allowing drainage until receiving the next irrigation
T_4 = Irrigation at 28 days interval, allowing drainage until receiving the next irrigation

Irrigation was applied more than field capacity to the Lysimeter tank for the assurance of drainage. In addition, the jute plots adjacent to the tanks were also irrigated. Drainage water from the lysimeters was measured by graduated cylinder. The crop evapotranspiration, ET_c, was calculated from the applied irrigation, rainfall and drainage quantities by following water balance equation (Eq. 1) (Itier *et al*., 1997). Prior to irrigation, soil moisture was measured to determine the depleted soil water during a particular time period. The crop evapotranspiration for the specific period was calculated as:

$$\text{Crop ET} = W_a - (D_w \pm \Delta S_s) \dots\dots\dots\dots\dots (1)$$

Where, Crop ET is crop evapotranspiration during a specified time period (mm), W_a is applied water plus rainfall during the time period (mm), D_w is drainage water during the time

period (mm) and ΔSs is stored soil moisture during the time period (mm).

There are several methods for determining reference evapotranspiration, ET_0. Among them, Penman-Monteith method has been recommended for empirical determination of ET_0 using climatic data of temperature, humidity, sunshine duration and wind speed (Allen *et al.,*1998; Michael, 2014). According to Smith *et al.* (1992), FAO Penman-Monteith method gives more consistent ET_0 estimates and has been shown to perform better than other methods. In this study, reference evapotranspiration, ET_0, was estimated by using CROPWAT software that uses Penman-Monteith model to calculate ET_0. This model requires only insertion of location (latitude, longitude and elevation), and climate data (maximum and minimum air temperature, humidity, sunshine hour and wind speed).

The crop coefficient, K_c for different growth stages was estimated by using the following formula:

$$ET_c = K_c \times ET_0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

The internationally recognized crop growth stages for the calculation of crop coefficients are initial, development, mid-season and late season stages (Allen *et al.*, 1998). The duration of each stage depends on the length of growing season of a particular crop and climate (Doorenbos and Pruitt, 1977; Smith *et al.,* 1992). In this experiment, the duration of crop with respect to different growth stages is provided in Table 4.

After 112 days of sowing, plant population, plant height, and base diameter of jute crop were collected. After harvest, data on green weight with leaves/m^2 was collected. The plants were staked in a shady place to remove the leaves. The bundle of green stem was kept under water for rotting. It required 12 days to complete the rotten process. The fiber was then detached from the rotten stem and dried in sun. The data on dry fiber and stalk/m^2were recorded.

3. Results and Discussion

3.1 Irrigation effect on growth and yield

The growth, yield and yield contributing parameters of jute variety BJRI Tosa-2 (O-9897) for various irrigation treatments are listed in Table 2. Treatment T_2 (irrigation at 14 days interval) produced the highest plant height, base diameter, green weight with leaves/m^2, dry fiber and dry stalk/m^2 in comparison to the other three treatments. This treatment received 7 irrigations whereas T_1 (irrigation at 7 days interval) received 13 irrigations. This was due to the fact that treatment T_2, took maximum 7 to10 days to get completely drainage and rest of days (4-7 days) its root zone was becoming dry prior to receiving next irrigation. This interval seems much more favorable for plant growth and yield followed by treatment T_1 (irrigation at 7 days interval). On the other hand, watering at 28 days interval (treatment T_4) seems too long to provide adequate moisture to plants for normal growth and yield of fiber. There might have some sorts of water stress in the tank that affected crop growth and fiber yield. Consequently, the lowest dry fiber yield was obtained in T_4 followed by T_3 (irrigation at 21days interval) that produced the lowest green weight with leaves and dry stalk yield among all treatments.

Doorenbos and Pruitt (1977) suggested for calculating the crop coefficients at different growth stages by considering the best growing plants producing the highest yield. Therefore, treatment $T_2$was selected for determining the crop co-efficient values in this study. It was noted that the soil moisture fluctuation for different treatments during the growth period was not so high since every treatment received the same amount of rainfall (938 mm) during the crop season (Figure 2). In treatment T_1, T_2 and T_3, soil moisture sometimes exceeded the field capacity due to high rainfall. In treatment T_4, soil moisture was within the limit of available moisture due to higher irrigation interval than the other treatments.

Table 2. Effect of irrigation on growth, yield and yield contributing parameters of jute

Treatments	Plant population	Plant height (m)	Base diameter (mm)	Green weight with leaves(t/ha)	Dry fiber yield (t/ha)	Dry stalk yield (t/ha)
T_1	17	3.49	21.6	77.5	3.31	11.81
T_2	21	3.62	22.3	78	3.93	11.94
T_3	18	3.35	20.2	61	2.75	6.92
T_4	16	3.33	21.6	68	2.6	7.4

Table 3. Seasonal water use or Seasonal ET of jute for treatment T_2 grown in the lysimeter tank

Days after sowing	Irrigation (mm)	Rainfall (mm)	Drainage* (mm)	Stored soil moisture,**ΔS_s (mm)	Crop ET (mm)
25	70	206	180.00	5.724	101.72
39	0	182	94.00	-7.86	80.48
53	50	87	42.5	3.312	97.81
67	80	144	145.26	16.01	94.75
81	0	148	65.35	-10.44	72.21
95	0	223	172.97	13.58	63.61
109	40	24	20	-5.46	38.54
Seasonal water use					549.13

* Drainage was calculated by collecting volume of water after irrigation application.

**Stored soil moisture was calculated by subtracting before and after irrigation moisture at the tank.
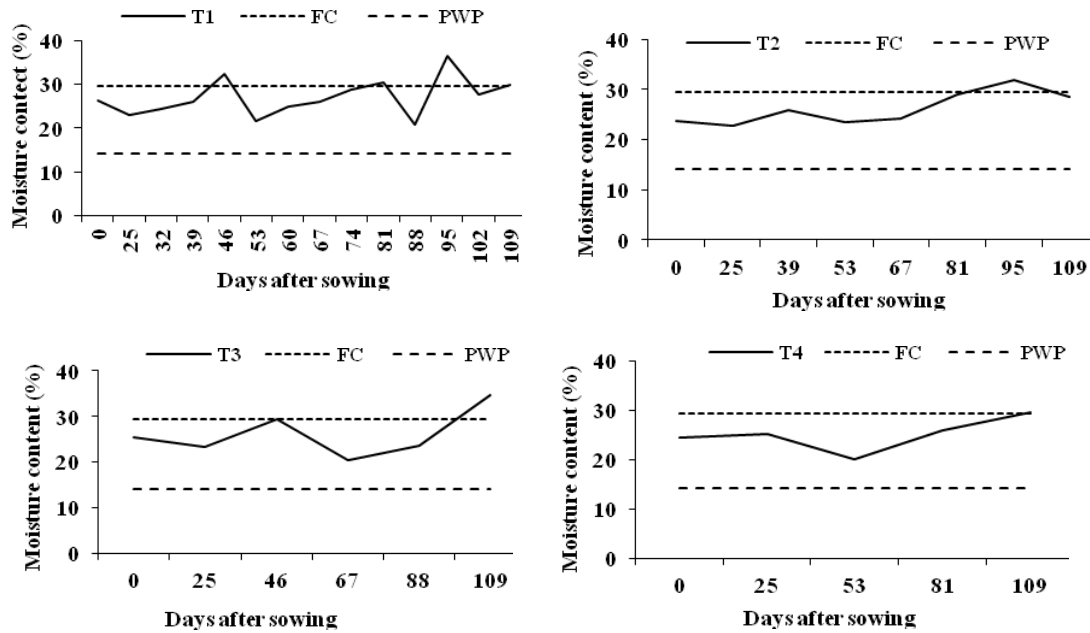
Fig. 2. Soil-moisture content under different treatments during the crop period

3.2 Seasonal water use

Table 3 represents irrigation, rainfall, soil moisture andcrop evapotranspiration values of treatment T_2 where irrigation interval was 14 days. Irrigation was started from 25 DAS until 109 DAS by maintaining irrigation interval of 14 days. No irrigation was applied at 39, 81 and 95 DAS due to heavy rainfall before these days. The crop was harvested after 6 days of last irrigation. Total evapotranspiration during the crop period was 549.13 mm. The negative soil moisture storageindicates that the plants extracted water from the initial soil moisture content. By contrast, the positive sign indicates that more water was stored in soil in excess of initial water content.
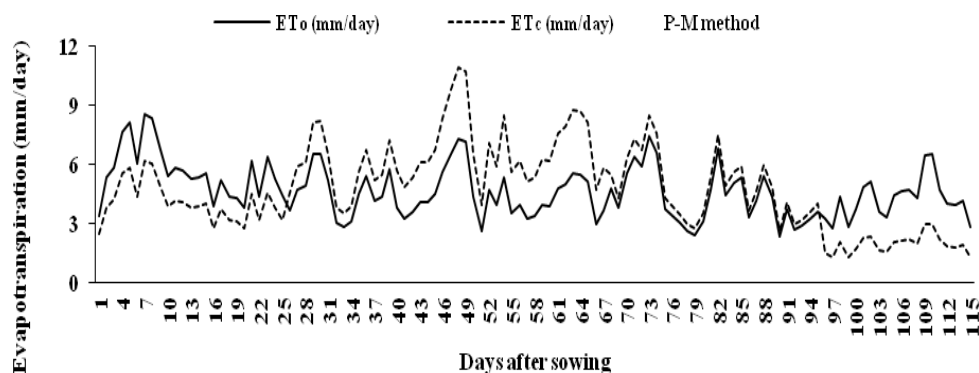
3.3 Crop coefficient, K_c

Evapotranspiration (ET_c and ET_0) and crop coefficient vary according to the crop growth stages (Figure 3 to 4). At the initial stage, ET_c

was 2.45 mm/day. It fluctuated and reached the peak value of 10.89 mm/day at 48 DAS, after which it sharply fell to 9.10 mm/day. On the other hand, ET_o values fluctuated within the range of 2.35 to 8.55 mm/day. At the primary stage, $ET_0$was 3.40 mm/day which gradually fell during the mid-season, and again rose up to 6.48 mm/day till the period of harvest (Figure 3). Table 4 shows crop evapotranspiration (ET_c) and reference crop evapotranspiration (ET_0) value different growth stages. Finally, K_c values were found to be 0.72, 1.39, 1.26 and 0.46 at the four consecutive growth stages. These are the first reported values of crop coefficients for jute in Bangladesh. These values indicate how water requirement of jute needs to be distributed across the growth season. Therefore, based on K_c value, tabulated ET_c values for different growth stages can be considered for the irrigation amount of this crop.

Table 4. Crop co-efficient values of jute

Crop growth stages	Duration (Days)	*ET_c (mm)	ET_0(mm)	K_c
Initial	25 (1-25 days after sowing)	141.05	101.56	0.72
Development	31 (26-56 days after sowing)	142.57	198.88	1.39
Mid-season	39 (57-95 days after sowing)	167.34	210.13	1.26
Late season	20 (96-115 days after sowing)	84.30	38.78	0.46

*Irrigation amount of jute for different growth stages will be equal to the ET_c of different growth stages.

Figure 3. Cropevapotranspiration (ET_c) of jute and reference evapotranspiration (ET_0) during the growing period of jute

4. Conclusions

Seasonal crop evapotranspiration and crop coefficient values of jute was carried out by doing an experiment on Lysimeter at the research field of Irrigation and Water Management Division, Bangladesh Agricultural Research Institute, Gazipur. Result showed that irrigation at 14 days interval, including drainage within two consecutive irrigations, gave the highest yield of jute in this semi-arid region. Seasonal crop evapotranspiration of jute was 549.13mm when irrigation was provided at 14 days interval. The crop coefficient values of jute (O9897) were 0.72, 1.39, 1.26 and 0.46 at the initial, development, mid-season and late season stages, respectively. These locally calibrated crop co-efficient values can be used reliable information for planning and distribution of regional water resources for irrigation manager. Therefore, based on K_c value, it can be recommended that jute can be irrigated by 141.05, 142.57, 167.34, and 84.30 mm of water at the initial, development, mid-season and late season stages to get maximum dry fiber yield.

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