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# Flax Crop Coefficients and Water use under sub-tropical environment

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## Abstract

*In present study, the actual water use (ETa) rates of flax crop growth period were determined under field conditions by root water uptake method. The crop water use (ETc) values were also estimated by different FAO's empirical evapotranspiration (ET) modals for corresponding flax growth period. Inter-comparison of both types of estimations revealed that the ETa & ETc values increased with plant age up to 62 DAS, thereafter, the value started declining as the crop advanced to the capsule formation stage and maturity. The ETa/ETc ratios were fairly higher during initial crop age and continued to decrease with plant age up to 22 DAS. The ratio attended relatively static value (1.3 to 1.7) during peak rate of water use. Later, it decreased marginally with crop maturity. The ETa/ETc ratios of Radiation estimates were closer to the unit value, whereas Pan –E estimates deviated maximum from unity. The field estimated crop coefficients (Kc) values were quite higher than the FAO's Kc values during all stages of flax crop growth period except late season stage. The field estimated Kc values corresponding to Radiation estimate were much closer to the FAO's Kc values during all growth stages of flax crop growth period.*

***Key Words**:- Actual water use, Crop water use, ETa/ETc ratio, Crop coefficient (Kc).*

## Introduction

Flax is an economically important dry season oil seed and fiber crop of central India. Water requirement of flax is critical for physiological growth and capsule formation and is affected by water scarcity, thus effective water use rate (ET) is an important mean of increasing flax yield. The quantification of water loss through ET is pre-requisite for crop planning, irrigation scheduling and water management studies in agriculture sector[3]. In recent decades, many empirical models are developed for the prediction of crop water use (ETc). Precise estimates of ET are essential for maximum production of flax in sub-tropical environment. It also takes into account that the site specific crop coefficient (Kc) plays a great role in estimating actual crop evapotranspiration[8]. Only few comparisons of reference Kc and local Kc values under limited field situations for flax are available, but their comparisons always performed to ensure the quality of the new values[7].Thus the current study aims to determine correct value of crop coefficient and reliable crop water use (ETc) estimates for flax crop grown under field conditions in sub-tropical environment.

## Materials and Methods

The actual field values of water use (ETa) for flax (irrigated as pre-emergence) crop growth period (first week of December to third week of March) were determined by root water uptake method[6].The crop water use (ETc) values for corresponding flax crop growth period were also computed by multiplying the crop coefficients (Kc) values by the reference evapo-transpiration (ETo) values. For this purpose, ETo values of corresponding

flax crop growth period were predicted by different FAO's empirical evapotranspiration (ET) models (Modified Penman, Blaney-Criddle, Radiation, Modified Hargreave's, Christiansen and Pan-evaporation method) and presented in Table-1 with the FAO's crop coefficients (Kc) values[3].

**Table-1: Reference Evapotranspiration (ETo) in mm/day and FAO's crop coefficients (Kc) values for flax crop growth period**

| DAS | M'PEN (ETo) | BL&CL (ETo) | CHRIST (ETo) | RAD (ETo) | M'HAR (ETo) | PAN.E (ETo) | FAO's Kc values |
|---|---|---|---|---|---|---|---|
| 06 | 3.20 | 3.47 | 3.33 | 3.72 | 3.34 | 3.0 | 0.27 |
| 22 | 3.20 | 3.42 | 3.33 | 3.72 | 3.33 | 3.0 | 0.65 |
| 42 | 3.21 | 3.14 | 3.31 | 3.71 | 3.25 | 2.9 | 1.05 |
| 62 | 3.89 | 3.77 | 4.07 | 4.36 | 3.81 | 3.6 | 1.14 |
| 85 | 4.69 | 4.58 | 5.01 | 5.1 | 4.53 | 4.5 | 0.50 |
| 113 | 6.68 | 6.94 | 7.77 | 7.03 | 6.38 | 7.8 | 0.26 |

The obtained ETa values were taken as the standard for comparison with the ETc obtained by different empirical models (Fig.1).The ETa/ETc ratios were also plotted (Fig.2) for their better comparison. The growth stages (initial, development, mid and late season) specific crop coefficients (Kc) as the ratio of actual evapotranspiration (ETa) to reference evapotranspiration (ETo) were also developed for subtropical condition of Central India and compared with FAO's Kc values (Fig.3).

**Results and Discussions**

**Actual water use (ETa)**

The field measured actual water use (ETa) values of flax (table-2) increased with crop growth period and continued up to 62 DAS (2.32 to 6.74 mm/day). Fig.(1) also emphasized that the magnitude of increase in ETa values were instantaneously high (6.74 mm/ day) at capsule development stage (62 DAS). It is attributed to large leaf area index at this stage of growth as well as higher vapour pressure gradient between canopy air and atmospheric air was probably responsible for greater water use[5]. Thereafter, a sharp decline of ETa rate was noticed at midseason growth stage and continued till crop maturity. However, the magnitude of decline at the late season stage was more profound in comparison to all empirical estimates (ETc).

**Table 2: Actual water use (ETa) and Crop water use (ETc) values in mm/day for flax crop growth period**

| DAS | M'PEN (ETc) | BL&CL (ETc) | CHRIST (ETc) | RAD (ETc) | M'HAR (ETc) | PAN.E (ETc) | Actual Field values (ETa) |
|---|---|---|---|---|---|---|---|
| 06 | 0.86 | 0.94 | 0.9 | 1 | 0.9 | 0.81 | 2.32 |
| 22 | 2.08 | 2.22 | 2.16 | 2.42 | 2.16 | 1.95 | 3.24 |
| 42 | 3.26 | 3.3 | 3.48 | 3.9 | 3.41 | 3.05 | 5.54 |
| 62 | 3.89 | 4.3 | 4.64 | 4.97 | 4.34 | 4.1 | 6.74 |
| 85 | 2.58 | 2.52 | 2.76 | 2.81 | 2.49 | 2.48 | 2.74 |
| 113 | 1.74 | 1.8 | 2.02 | 1.83 | 1.66 | 2.03 | 1.21 |

**Crop water use (ETc)**

The data of flax crop water use (table-2) indicated that the empirically estimated ETc values sharply increased with advancing crop growth period (0.81 to 4.97 mm/day) and continued till it attained peak value at about 62 DAS (Fig.1). Thereafter, it registered a sharp decrease with crop maturity. The Radiation method was predicted maximum value (4.97 mm/day) of ETc, followed by Christiansen method (4.64 mm/day).However, other estimates rarely approached up to 4.35 mm/day. Modified Penman estimates occupied the lowest position (3.89 mm/day) at capsule development stage. Pan –E estimates normally predicted lower values of ETc during most of the flax growth period. Similar trend of ETc values over the flax crop growth period were reported in the past[1].

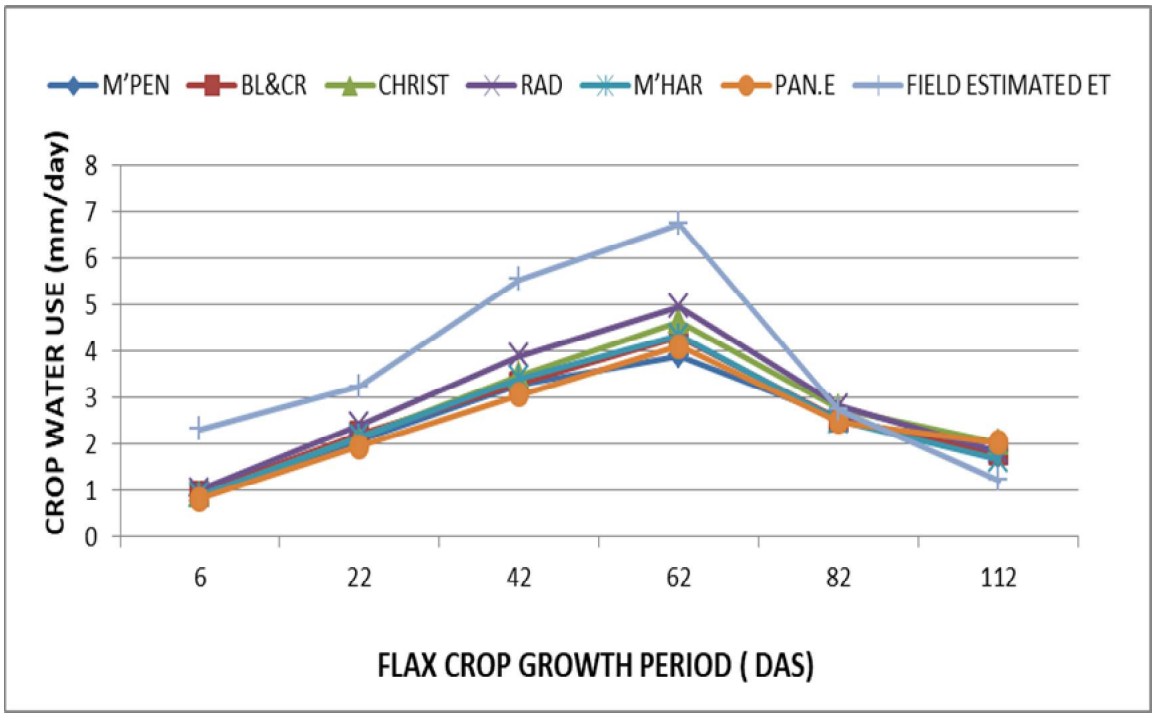


**Fig-01 Crop water use for Flax growth period**

**ETa/ETc Ratios**

To compare the behavior of two groups of estimates amongst themselves, and between the estimates, the ratios of ETa /ETc were plotted (Fig 2). The natures of ratios representing the various empirical estimates were generally identical throughout the crop growth period. The ratio (ET/ETc) of field and empirical estimates were fairly higher during initial crop age which continued to decrease up to 22 DAS. Thereafter, the ratio attended relatively static value (1.3 to 1.7) during peak rate of ET (22 to 62 DAS). Later, it decreased marginally with crop maturity[8]. Amongst the various empirical estimates, the Radiation estimates were much closer to unity (means closer to field estimates) than the other empirical estimates. The ETa/ETc ratio of Pan –E estimates deviated maximum from unity. Ratios corresponding to the rest of the empirical estimates i.e. Blany-Criddle, Modified Hargreaves, Christiansen and

Modified Penman methods occupied the next positions from Radiation estimates, and were interchanging during different flax growth stages[2].

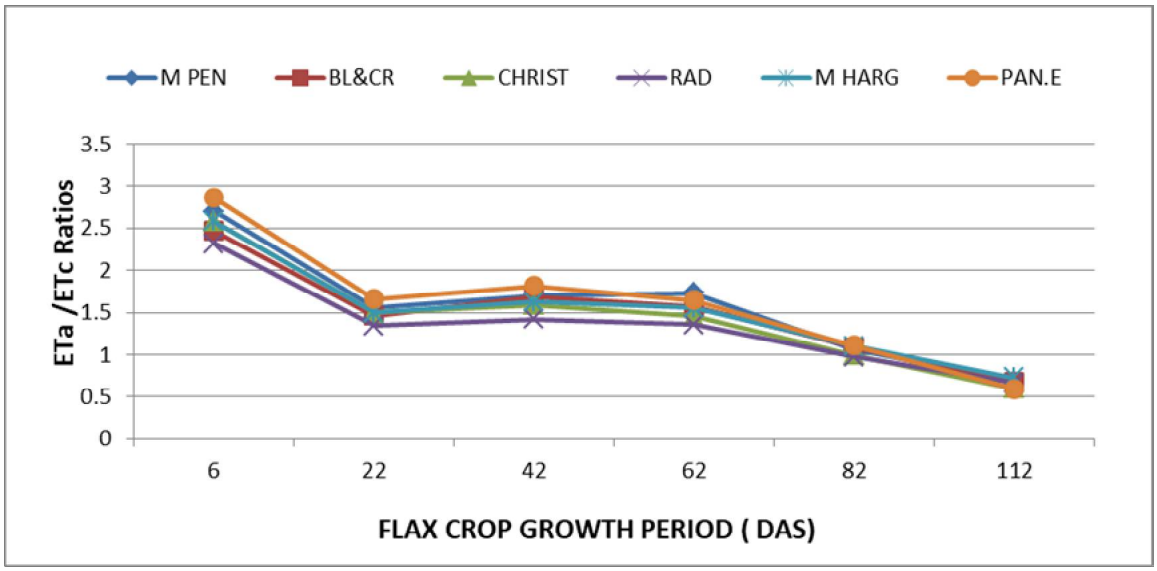


**Fig-02 ETa /ETc ratios for Flax growth period**

**Crop Coefficients (Kc)**

The field estimated flax crop coefficients (Kc) values (table-3) were quite higher (0.62 to 1.08) than the FAO's Kc values (0.27 to 0.65) during initial stage of crop growth covered the period from sowing through 22 DAS (Fig.3). It could be attributed to low leaf area index during this stage of growth. Yet, the nature of both types of coefficients was identical during this early crop growth period. During the crop development stage (22 to 42 DAS), the differences amongst field estimated and FAO's Kc values are continued to increase till they approached the peak values (1.49 to 1.91) when the crop attended full ground cover or the maximum growth rate. It could be mainly due to soil heat flux that contributed energy for crop ET during crop growth season which raised the Kc values[8]. In midseason stage (42 to 62 DAS), field estimated crop coefficients attended relatively static value (1.5 to 1.7). Subsequently, the differences amongst the crop coefficients (computed for various estimates) started declining as the crop advanced to the capsule formation stage. In late season stage (close to maturity), the field estimated crop coefficients values were merely equal or even less than the FAO's crop coefficients.

**Table-3 Crop coefficient for flax crop estimated from field values**

| PERIOD DAYS | M'PEN | BL&CR | CHRIST | RAD | M'HARG | PAN.E | FAO's VALUE |
|---|---|---|---|---|---|---|---|
| 06 | 0.73 | 0.67 | 0.70 | 0.62 | 0.69 | 0.77 | 0.27 |
| 22 | 1.01 | 0.95 | 0.97 | 0.87 | 0.97 | 1.08 | 0.65 |
| 42 | 1.73 | 1.76 | 1.67 | 1.49 | 1.70 | 1.91 | 1.05 |
| 62 | 1.73 | 1.79 | 1.66 | 1.55 | 1.77 | 1.87 | 1.14 |
| 82 | 0.58 | 0.60 | 0.55 | 0.54 | 0.60 | 0.61 | 0.50 |
| 113 | 0.18 | 0.17 | 0.16 | 0.17 | 0.19 | 0.16 | 0.26 |

A comparison of field estimated crop coefficients and the FAO's crop coefficients of flax crop clearly indicated that the field estimated crop coefficients corresponding to Radiation estimate were much closer to the FAO's crop coefficient during all crop growth stages. Field estimated crop coefficients values for Modified Penman estimate and Christiansen estimate showed much similarity, however, Modified Penman estimate was more symmetrical than Pan-evaporation estimates. Actual field estimated flax crop coefficients values of Radiation estimate was much similar to Modified Hargreaves estimate, as it also expressed more symmetry than Blaney–Criddle estimate during flax growth period.The differences amongst the FAO's and field estimated crop coefficient were maximum in case of Pan-evaporation method[1,4]. The result of this study can be used for similar environmental conditions and could help improve the link between crop coefficients and empirical approaches to assess the water requirement of flax crop over the growing season.

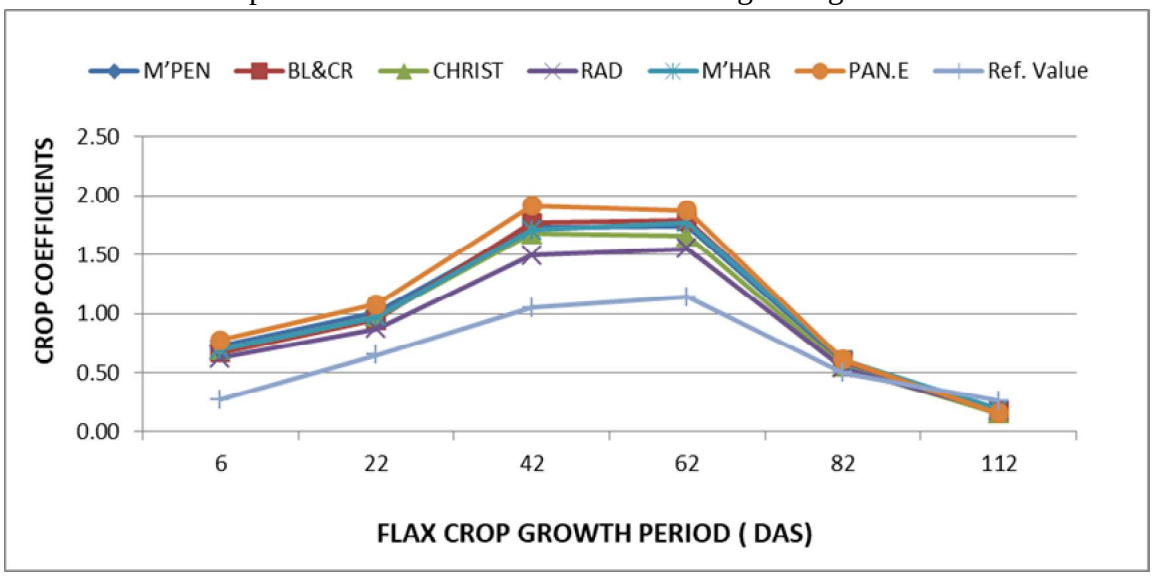


**Fig-03 Growth stage specific crop coefficients (Kc) for Flax growth period**

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