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Evaluation of Evapotranspiration Estimates and Crop Coefficients of Gram under Different Soil Moisture Regimes in Central India

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Abstract

Reference Evapotranspiration (ETo) for gram growth period were determined by standard empirical estimates (Modified Penman, Blaney-Criddle, Radiation, Modified Hargreave's, Christiansen and Pan-evaporation methods). ETo values were fairly low (< 4 mm/day) and constant during early 55 DAS, thereafter, increased till crop maturity. Values of field and climatic estimates of evapotranspiration (ET&ETc) under various moisture regimes increased with plant age up to 50 DAS and registered stability till 75 days period (except drier regimes). The ET/ETc ratios were fairly higher during initial crop growth and continued to decrease with plant age up to 30 DAS. Whereas, in drier regimes the values attended closer to unity, during peak rate of ET. Under moderate moist regimes the ratio stabilized closer to the value of 1.5, which decreased sharply near maturity. In general, the ET/ETc ratios of field estimates with Radiation estimates were closer to the unit value than the other climatic estimates, in all regimes. The crop coefficients (Kc) for the actual field conditions, and variable moisture regimes seems to be most realistic, particularly the radiation estimates which gave crop coefficients closer to the field estimates of gram crop.

***Key Words**:- Reference evapotranspiration, Crop evapotranspiration, ET/ETc ratio, Crop coefficient (Kc).*

Introduction

Gram (*Cicer arietinum*) is a premier protein rich pulse crop of India grown in rabi season under different agro climatic conditions. Soil water status is a prime factor that controls gram crop production. The yield is greatly dependent on moisture regimes particularly in dry land farming. Optimum quantity of water is required at specific time to meet out the water demand of the gram crop[4]. The crop yields and their seasonal water use are influenced either independently or differentially by crop management and the other environment conditions[1].

The knowledge of crop water use in a watershed is a crucial part for effective irrigation planning and judicious water management. Empirical estimates are generally used for actual crop evapotranspiration estimation but their precision relies on comparison with field measured values of ET. Though comparisons under limited field situations are available, but they are scanty and unsystematic with respect to gram crop. Also, site specific crop coefficient need to be work upon which is required in estimating actual crop evapotranspiration[5]. Therefore, objectives of this study are to predict reliable estimates of actual evapotranspiration and appropriate crop coefficients of gram crop grown under different soil moisture regimes in central India.

Materials and Methods

The soil moisture profiles were determined from the gram fields of various soil moisture regimes (dry, moderate, and moist). These values were used in the computation of the actual 'ET' rates for different crop growth periods using the predetermined field estimated hydraulic properties (Kauraw and Gupta, 1985). The computed ET rates were taken as the field estimates and were used for comparisons with following most commonly accepted empirical/climatic estimates (Modified Penman, Blaney-Criddle, Radiation, Modified Hargreave's, Christiansen and Pan-evaporation methods) of evapotranspiration. For this purpose the available measured climate data (max.-min. temperature, max.-min. relative humidity, wind velocity, sunshine hours and pan-evaporation) of corresponding gram growth period (First week of December to Second week of March) have been collected from Department of Physics and Agrometerology, JNKVV, Jabalpur (M.P.) India.

After determining the reference evapotranspiration (ETo) by above methods[2]. The ETc rate was predicted using the crop coefficient (Kc) values obtained for different crop growth stages (Table-1). Thus, ETc=Kc*ETo

To Interpret and gain understanding of the complex behavior of both type of estimates the available data were analyzed statistically and obtained statistical parameters are tabulated (Table-3). To evaluate appropriate field estimated gram crop coefficients (Kc) under various soil moisture regimes for central India, the Kc was calculated as ET/ETo (Table-4) and compared with reference values.

Results and Discussion

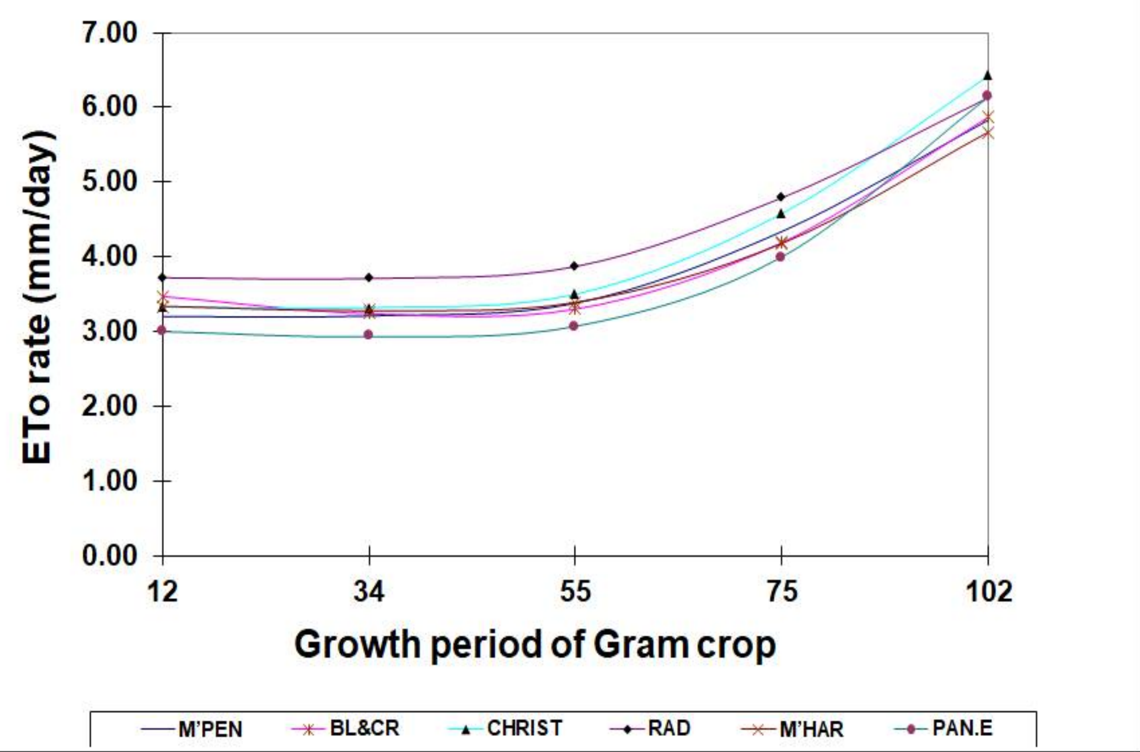
Reference evapotranspiration

The atmospheric evaporative demands in terms of reference evapotranspiration (ETo) values were fairly low (less than 3.90 mm/day) and constant during early 55 DAS period. Thereafter it registered a significant increase and attained the value higher than 4.5 mm/day during pod development stage and approached 6 mm/day at the harvest stage (Table-1). Such a nature of ETo is attributed to the increasing temperature, reducing maximum relative humidity and partially to the increasing wind velocity during later crop growth period[1]. The relative magnitude of ETo estimates during different crop growth periods also suggested that up to 75 days period the values for Radiation (4.79 mm/day) and Pan-E estimates (4 mm/day) were the highest and lowest at pod development stage, respectively. However, Christiansen estimates approached maximum ETo rates (6.42 mm/day) near gram crop maturity (Fig.01). This sudden increase at harvest stage in both ETo estimates is due to advective effect[5].

Table 1 Reference crop Evapotranspiration (ETo) for gram crop (mm/day)

DAS	M'PEN	BL&CR	CHRIST	RAD	M'HAR	PAN.E	Reference Kc values
12	3.2	3.47	3.33	3.72	3.34	3	0.3
34	3.21	3.24	3.32	3.71	3.28	2.93	0.67
55	3.38	3.3	3.5	3.87	3.39	3.07	1.14
75	4.34	4.19	4.58	4.79	4.18	4	0.9
102	5.83	5.87	6.42	6.13	5.67	6.14	0.27

Fig.1 Reference Crop Evapotranspiration (ETo) for Gram crop

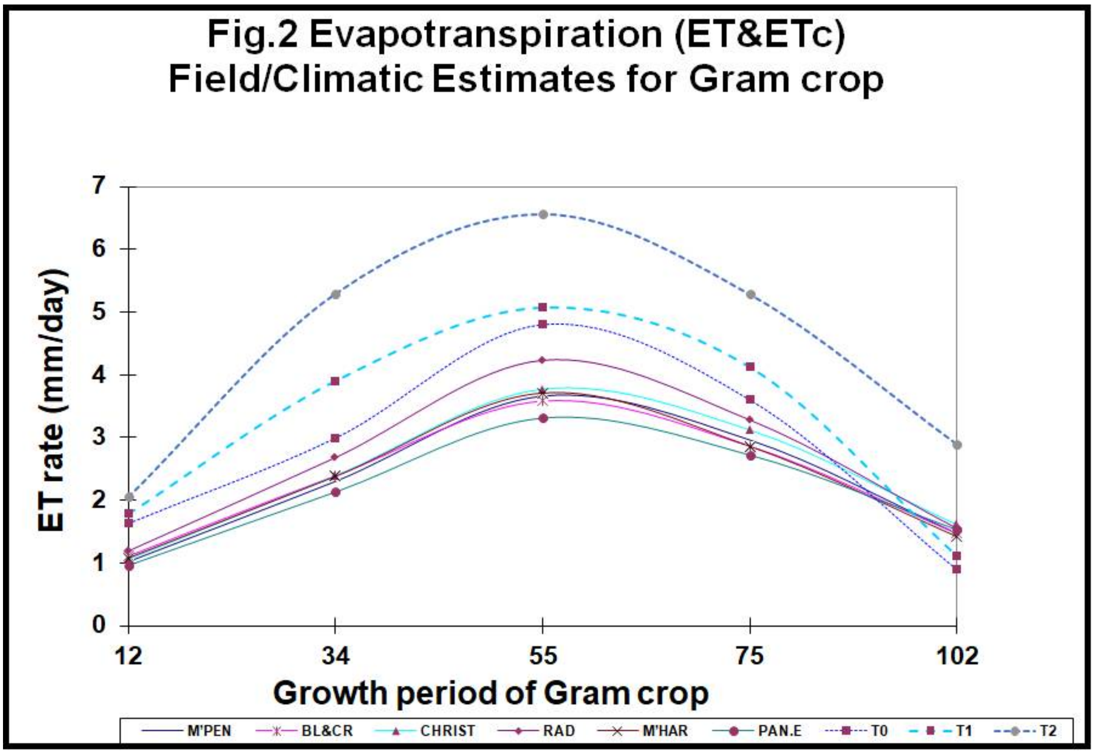


Crop evapotranspiration

The evapotranspiration (ET) data of gram crop (Table 02) emphasized that the ET values of field estimates(5.2 to 7.6 mm/day) and climatic estimates increased (3.5 to 4.5 mm/day) approached the peak rate at plant age about 50 days after sowing and registered stability till 75 days period (except drier regimes). Thereafter, it registered a sharp decrease with plant growth in all the cases (Fig. 02). However, the magnitude of decline in the field estimated ET values were relatively smaller in drier regimes than in moist regimes[6].

Table 2 Evapotranspiration (mm/day) for irrigated gram crop

	CLIMATIC ESTIMATES (ETc)						FIELD ESTIMATES (ET)		
DAS	M'PEN	BL&CR	CHRIST	RAD	M'HAR	PAN.E	Dry	Modrate	Moist
12	1.02	1.11	1.06	1.19	1.08	0.96	1.63	1.78	2.05
34	2.3	2.39	2.39	2.68	2.38	2.13	2.99	3.9	5.29
55	3.66	3.58	3.77	4.23	3.71	3.31	4.8	5.07	6.56
75	2.96	2.86	3.12	3.28	2.86	2.72	3.6	4.12	5.28
102	1.47	1.47	1.61	1.55	1.42	1.53	0.89	1.11	2.89



Comparisons of Field and Climatic estimates

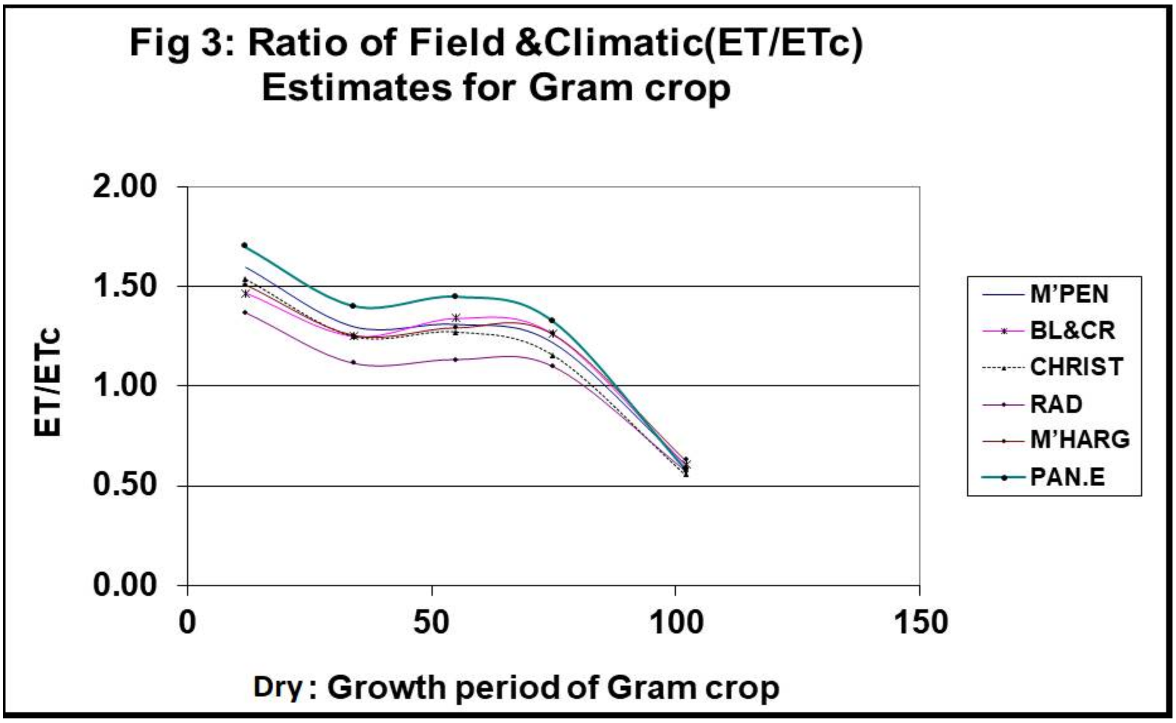
The ratios amongst the field estimates (ET) under different moisture regimes (dry, moderate and moisture) to each of the climatic estimates for current crop growth period were plotted (Fig 3 to 5). The behavior of ET/ETc ratios corresponding to various climatic estimates were generally identical in different moisture regimes and throughout the crop growth period. The ratio (ET/ETc) of field and climatic estimates were fairly higher during initial plant age and continued to decrease up to 25 or 30 DAS. Thereafter, in drier regimes (Fig. 3), the ratio have got fairly stabilized closer to unity, during peak rate of ET. Later, it decreased marginally with crop maturity. In moderate moisture regimes (Fig. 4), the ratio stabilized closer to the value of about 1.5 and decreased sharply near crop maturity. However, in case of moist moisture regimes (Fig. 5), the ET/ETc ratio registered a second increase during peak rate of ET. Yet a sharp decrease of the ratio was noticed at about the pod development stage of crop growth.

The ET/ETc ratios for gram crop (Fig.3 to 5) also indicated that in general, ETc values are predicted more precisely under drier moisture regimes by any of the climatic estimates. It was ascribed to the dependence of crop coefficient values on the data from drier environment under which the gram crop is normally grown[6]. Amongst the different empirical methods, the Radiation method estimated field values more precisely during all the stage of crop growth period (ET/ETc values more nearer to the unity) and the Pan-E deviated the most. Remaining climatic estimates (Blany-Criddle, Modified Hargreaves, Christiansen and Modified Penman methods)were observed to the identical with each other irrespective of soil moisture regimes. It was attributed to the integrated effect of most of the climatic parameters[1] in the estimates of Radiation method.

The values of correlation and regression coefficients along with the standard error of estimates for the climatic and field estimates of gram crop evapotranspiration (Table-3) shows a linear correlation amongst themselves as [y=a+bx][3]. It means, the magnitude of change in ET rate was slow and static[4]. The correlation coefficients for dry as well as moist regimes were highly significant for most of estimates. However the relative positions of the various estimates were different in drier regimes (Radiation 0.963, Pan –E 0.922) than the moisture regimes (Radiation 0.973, Pan-E (0.964).

Table 3 Correlation between Field and Climatic Estimates

	M'PEN	*BL&CR*	*CHRIST*	*RAD*	*M'HAR*	*PAN.E*	*Dry*	*Modrate*	*Moist*
M'PEN	**1.000**	0.998	0.999	0.998	0.997	0.998	0.947	0.932	0.967
BL&CR	0.998	**1.000**	0.996	0.999	0.999	0.994	0.956	0.947	0.978
CHRIST	0.999	0.996	**1.000**	0.994	0.994	0.999	0.935	0.921	0.964
RAD	0.998	0.999	0.994	**1.000**	1.000	0.992	0.963	0.949	0.973
M'HAR	0.997	0.999	0.994	1.000	**1.000**	0.992	0.960	0.947	0.975
PAN.E	0.998	0.994	0.999	0.992	0.992	**1.000**	0.922	0.908	0.964
Dry	0.947	0.956	0.935	0.963	0.960	0.922	**1.000**	0.984	0.928
Modrate	0.932	0.947	0.921	0.949	0.947	0.908	0.984	**1.000**	0.954
Moist	0.967	0.978	0.964	0.973	0.975	0.964	0.928	0.954	**1.000**



Crop Coefficients (Kc)

The periodic behavior of field estimated crop coefficients of gram crop corresponding to various soil moisture regimes with different climatic estimates as well as reference crop coefficients was not symmetric. In general, the differences between field estimated crop coefficients and the reference crop coefficients were maximum during peak rate of ET under drier regimes. During early plant age the reference crop coefficients was about 0.2, whereas field measured values ranged between 0.6 to 0.7 (Pan-E). At peak rate of ET (after 50 days), the reference crop coefficients was 1.2, and the field estimated crop coefficients values recorded minimum in case of Radiation (1.69) followed by the Christiansen (1.87), M'Hargreaves(1.93), M'Penman (1.94), Blaney & Criddle (1.98) and maximum in case of Pan-E (2.13)[2]. After 80 DAS, the magnitude as well as the nature of reference and field estimated crop coefficients were quite identical (Sriniwas and Tiwari,2018). Similar trends were also observed in case of moderate and moisture regimes (Table 04).

Table 4 Crop Coefficient (Kc) for gram crop estimated from field values

DRY						
DAS	M'PEN	BL&CR	CHRIST	RAD	M'HAR	PAN.E
12	0.509	0.470	0.489	0.438	0.488	0.543
34	0.931	0.923	0.901	0.806	0.912	1.020
55	1.420	1.455	1.371	1.240	1.416	1.564
75	0.829	0.859	0.786	0.752	0.861	0.900
102	0.153	0.152	0.139	0.145	0.157	0.145
MODRATE						
12	0.556	0.513	0.535	0.478	0.533	0.593
34	1.215	1.204	1.175	1.051	1.189	1.331
55	1.500	1.536	1.449	1.310	1.496	1.651
75	0.949	0.983	0.900	0.860	0.986	1.030
102	0.190	0.189	0.173	0.181	0.196	0.181
MOIST						
12	0.641	0.591	0.616	0.551	0.614	0.683
34	1.648	1.633	1.593	1.426	1.613	1.805
55	1.941	1.988	1.874	1.695	1.935	2.137
75	1.217	1.260	1.153	1.102	1.263	1.320
102	0.496	0.492	0.450	0.471	0.510	0.471

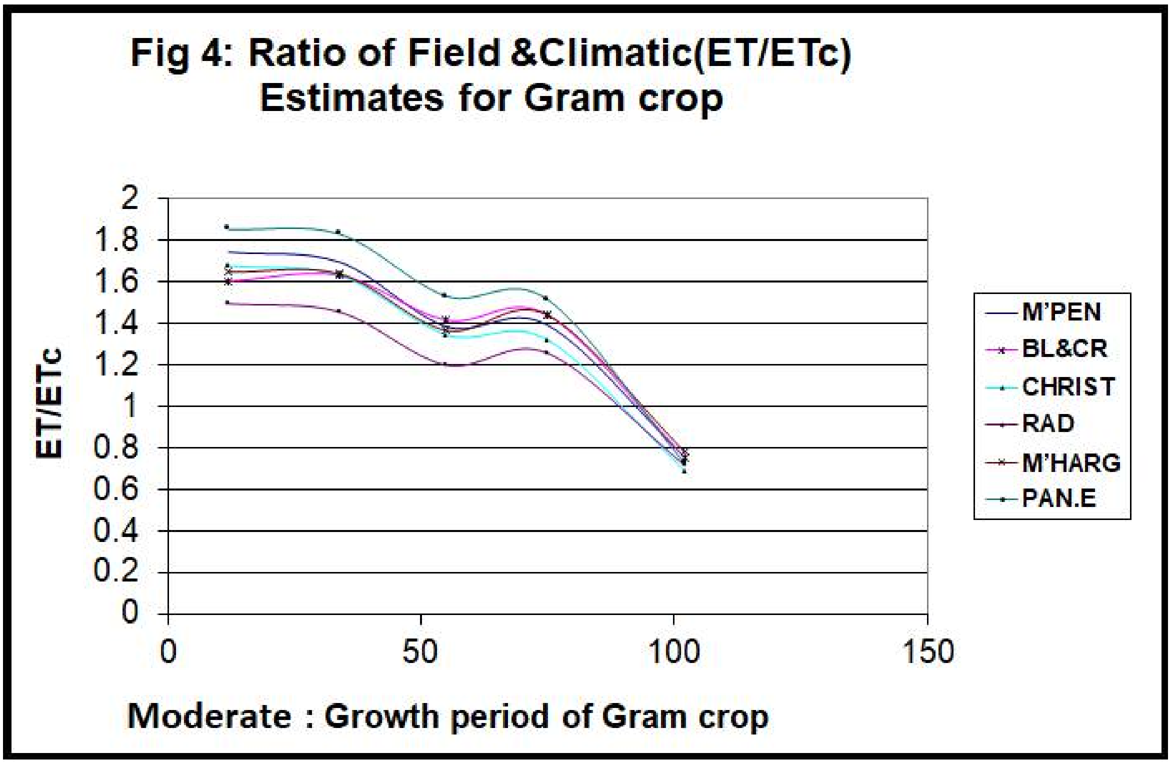


Fig 4: Ratio of Field &Climatic(ET/ETc) Estimates for Gram crop
ET/ETc
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
50
100
150
Moderate : Growth period of Gram crop
M'PEN
BL&CR
CHRIST
RAD
M'HARG
PAN.E

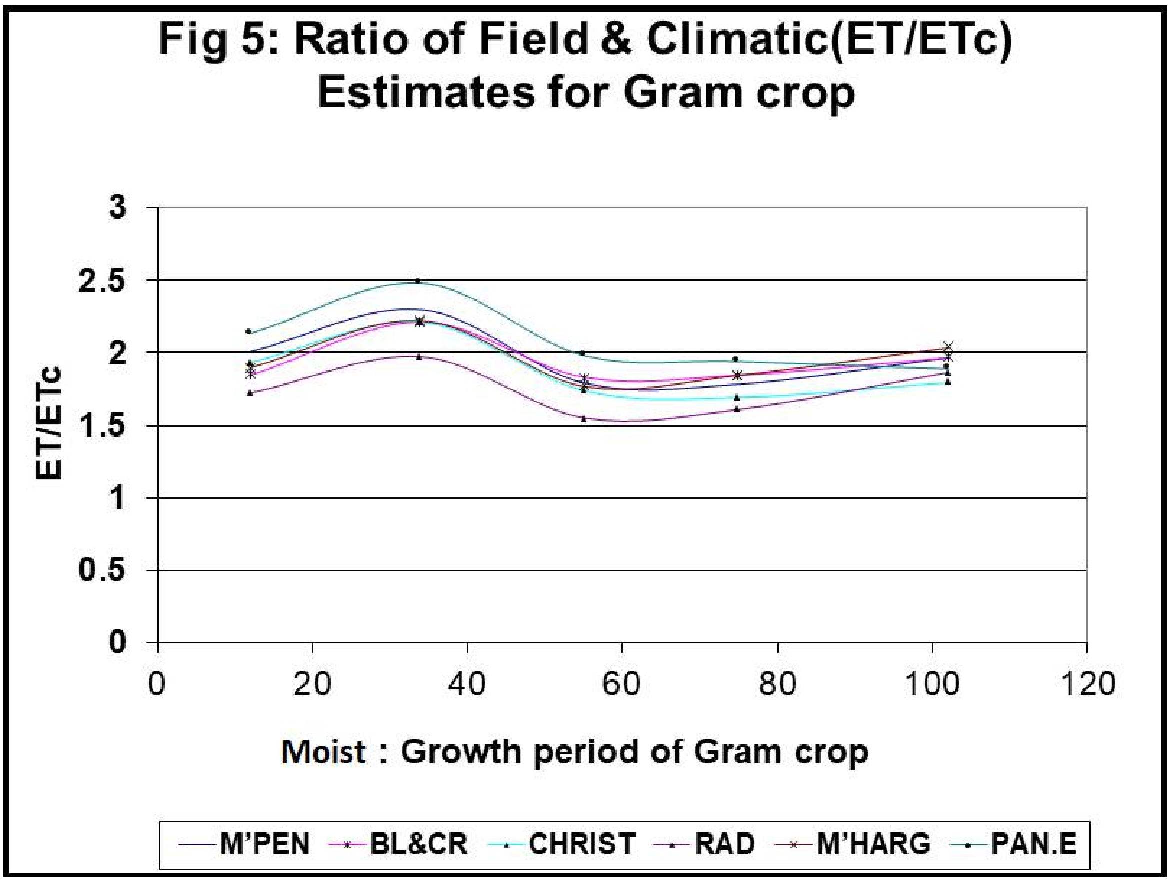


Fig 5: Ratio of Field & Climatic(ET/ETc) Estimates for Gram crop
ET/ETc
3
2.5
2
1.5
1
0.5
0
0
20
40
60
80
100
120
Moist : Growth period of Gram crop
M'PEN
BL&CR
CHRIST
RAD
M'HARG
PAN.E

A comparison of reference crop coefficients and those recorded with different soil moisture regimes for various methods of climatic estimates suggested that at peak rate of crop growth period of gram crop, the field estimated crop coefficients of Radiation estimate were quite similar and closer to the reference crop coefficient. The differences amongst the crop coefficients evaluated under different moisture regimes were minimum for Radiation estimates. The deviations were more pronounced in case of Pan-evaporation estimates. The magnitude and behavior of crop coefficients for M'Penman, Blaney and Criddle, M'Hargreaves and Christiansen estimate were quite similar[4].

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