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Inter-comparison of Evapo-transpiration Estimates for Summer Mung under Various Soil Moisture Regimes in Central India

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Abstract

To assess the reliability of climatic estimates of evapo-transpiration (ETc) for summer mung crop growth period, the computed values were compared with field estimated values of evapo-transpiration (ET) under varying soil moisture regimes. The relative values of climatic estimates were significantly higher than the field estimates even under optimum soil moisture conditions. In general, the ET/ETc ratios suggested that the climatic estimates overestimated 'ET' rate during peak crop growth period. The ratio with Pan evaporation method deviated to the greatest extent followed by Christiansen method, and the ratios with Radiation or Modified Hargreaves deviated the least. To summarize the nature of relationship and the significance of various estimates, it was apparent that both types of ET estimates were in exponential relationships with summer mung crop as: [$Y = a \times e^{b \times ET}$].

***Key Words**: - Field estimates, Climatic estimates and ET/ETc ratio*

Introduction

To estimate the crop evapo-transpiration (ETc) according to localized atmospheric condition, various climatological models have been developed by many Scientists. They vary in terms of ecologic data requirement and accuracy. Some researchers have also compared these empirical estimates with field estimates of evapo-transpiration (ET) to test their accuracy and precision. However, in general, the modified Penman model have been found to be more reliable if appropriate crop coefficient values are available for the given crop and climatological situation. But in summer season high evaporative conditions (HED) normally prevail and the aerodynamic factors of 'ET' remained dominant over the energy factors. Therefore, there is urgent need of time to predict precise estimate of ET for summer grown crops for efficient irrigation planning to achieve maximum production. The present investigation is the first effort for the localized environmental condition of Central India, to compare most common and widely used seven climatic estimates of ETc to actual field estimates of ET for summer mung crop under varying soil moisture regimes.

Materials and Methods

The field estimated values of evapotranspiration for summer mung crop growth period (First week of April to last week of June) under different soil moisture regimes (T_1-drier, T_2-medium, T_3-moderate, T_4-medium-moderate and T_5-moderate-moist) computed by root water uptake method were taken as the actual evapotranspiration (ET). The climatic estimates of crop evapotranspiration (ETc) were estimated using seven widely accepted standard climatological models (Modified Penman, Blaney-Criddle, Thornthwaite, Radiation, Modified Hargreave's, Christiansen and pan-evaporation method) for corresponding growth period of summer mung crop. Both set of data are presented in Table-1.

Table 1 Field and climatic estimates of ET (mm/day) for summer mung growth period

DAS	Field estimates of ET					Climatic estimates of ETc						
	T_1	T_2	T_3	T_4	T_5	M-Pen	BL& CR	Thorn	Rad.	M Harg.	Christ.	Pan-E
05	2.30	2.30	2.30	2.30	2.30	2.27	2.24	2.30	2.70	2.23	2.01	3.38
14	3.80	4.10	4.10	3.80	3.80	4.54	4.49	4.59	5.39	4.46	4.01	7.21
22	3.52	2.48	2.89	3.73	2.83	7.61	7.39	9.40	9.23	6.89	6.14	10.49
33	2.68	1.71	2.10	4.01	4.47	10.25	9.94	12.86	12.46	9.22	8.20	16.15
47	3.11	2.47	3.33	4.22	4.27	6.20	6.09	7.92	8.11	5.69	4.86	11.17
57	2.34	2.26	3.30	2.44	3.25	2.15	2.15	2.83	2.88	2.03	1.63	4.32

The ratios (ET/ ETc) amongst the field estimates (ET) to each of the climatic estimates (ETc) for concurrent crop growth period under different soil moisture regimes were calculated (Table-2). 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)

Results and Discussion

Periodic behavior of Field and Climatic estimates of ET

The field estimates (Table-1) of evapotranspiration (ET) tended to increased very sharply with plant age and within the period of 25 DAS; they attained peak value (about 4 mm/day). This peak value of 'ET' continued longer during crop growth period if soil moisture conditions have not significantly restricted the water supply to the plant root (T_4& T_5). However it may decrease significantly at any crop growth stage under stress condition (T_2). Such a behavior of 'ET' is attributed to the prevailing high 'AED' during growth period and its interaction to the soil factor. The soil evaporation also contributes greatly to the 'ET' in summer season. Other regimes showed irregular behaviours (alternate decrease & increase) during subsequent growth period of summer mung. In general, their values ranged between 2 to 3 mm/day.

Table 2 ET/ETc ratio of summer mung for different moisture regime

T_1 -Irrigations (5.0 & 5.0 cm) at 12 & 43 DAS- Drier							
DAS	M'PEN	BL&CR	THORN	CHRIST	RAD	M'HAR	PAN.E
5	1.01	1.03	1.00	0.85	1.03	1.14	0.68
14	0.84	0.85	0.83	0.71	0.85	0.95	0.53
22	0.46	0.48	0.37	0.38	0.51	0.57	0.34
33	0.26	0.27	0.21	0.22	0.29	0.33	0.17
47	0.50	0.51	0.39	0.38	0.55	0.64	0.28
57	1.09	1.09	0.83	0.81	1.15	1.44	0.54
T_2 –Irrigation (3.0 & 7.5 cm) at 12 & 43 DAS- Medium							
5	1.01	1.03	1.00	0.85	1.03	1.14	0.68
14	0.90	0.91	0.89	0.76	0.92	1.02	0.57
22	0.33	0.34	0.26	0.27	0.36	0.40	0.24
33	0.17	0.17	0.13	0.14	0.19	0.21	0.11
47	0.40	0.41	0.31	0.30	0.43	0.51	0.22

57	1.05	1.05	0.80	0.78	1.11	1.39	0.52
T_3- Irrigation (3.0 , 7.5 & 5.0 cm) at 12, 43 & 54 DAS- Moderate							
5	1.01	1.03	1.00	0.85	1.03	1.14	0.68
14	0.90	0.91	0.89	0.76	0.92	1.02	0.57
22	0.38	0.39	0.31	0.31	0.42	0.47	0.28
33	0.20	0.21	0.16	0.17	0.23	0.26	0.13
47	0.54	0.55	0.42	0.41	0.59	0.69	0.30
57	1.53	1.53	1.17	1.15	1.63	2.02	0.76
T_4- Irrigation (5.0 & 5.0 cm) at 12 & 27 DAS- Medium moderate							
5	1.01	1.03	1.00	0.85	1.03	1.14	0.68
14	0.84	0.85	0.83	0.71	0.85	0.95	0.53
22	0.49	0.50	0.40	0.40	0.54	0.61	0.36
33	0.39	0.40	0.31	0.32	0.43	0.49	0.25
47	0.68	0.69	0.53	0.52	0.74	0.87	0.38
57	1.13	1.13	0.86	0.85	1.20	1.50	0.56
T_5- Irrigation (5.0, 5.0,5.0 & 5.0 cm) at 12, 27, 43 and 54 DAS- Moderate moist regime							
5	1.01	1.03	1.00	0.85	1.03	1.14	0.68
14	0.84	0.85	0.83	0.71	0.85	0.95	0.53
22	0.37	0.38	0.30	0.31	0.41	0.46	0.27
33	0.44	0.45	0.35	0.36	0.48	0.55	0.28
47	0.69	0.70	0.54	0.53	0.75	0.88	0.38
57	1.51	1.51	1.15	1.13	1.60	1.99	0.75

The climatic estimates (Table-1) of crop evapotranspiration (ETc) ranged between 2 to 3.5 mm/day initially and progressively increased with plant age till the attained at about 35 DAS, and instantaneously started declining with advancing crop age. The maximum difference amongst the estimates was recorded at their peak values. The highest value ETc (maximum 16.5 mm/day) was noted, if it was predicted by Pan-evaporation method, followed by Christiansen method, because both estimates include the advective effect[4]. Other climatological estimates were at par during the various periods of crop growth. The minimum values (max.8.0) were observed in M' Hargreaves estimates.

The evapotranspiration estimates of summer mung crop indicated that the relative values of climatic estimates were significantly higher than field estimates even under optimum soil moisture conditions. Since in summer months high evaporative conditions (HED) normally prevail and the aerodynamic factors of 'ET' remained dominant over the energy factors, thus the ETc rate increased significantly[1]. These observations are also supported by the fact that the Pan-E and Christiansen estimates which include the advective effect, occupied the higher positions, and the lower positions are occupied by the estimates through M'Hargreaves and Radiation methods.

Table 3 Statistical parameters for Summer Mung crop

ETc\ET	't calculated' : d. f. = 4					S.S. Error				
	T_1	T_2	T_3	T_4	T_5	T_1	T_2	T_3	T_4	T_5
M'PEN	0.515	0.137	0.180	0.901*	0.628	0.267	0.309	0.307	0.135	0.242
BL&CR	0.518	0.133	0.174	0.904*	0.634	0.262	0.304	0.302	0.131	0.237
THORN	0.444	0.233	0.193	0.880*	0.653	0.300	0.325	0.328	0.159	0.253
CHRIST	0.536	0.104	0.165	0.907*	0.629	0.251	0.296	0.293	0.125	0.231
RAD	0.548	0.083	0.177	0.899*	0.600	0.257	0.307	0.303	0.135	0.246
M'HAR	0.495	0.165	0.165	0.908*	0.659	0.266	0.302	0.302	0.129	0.231
PAN.E	0.465	0.166	0.112	0.922**	0.753	0.258	0.287	0.289	0.113	0.192
	Regression Coefficient 'b'					Constant 'a'				
M'PEN	0.230	-0.047	-0.068	0.303	0.207	0.977	6.201	7.519	0.434	0.890
BL&CR	0.228	-0.045	-0.065	0.299	0.206	0.977	6.021	7.211	0.440	0.886
THORN	0.213	-0.086	-0.078	0.318	0.231	1.294	9.192	9.510	0.455	0.863
CHRIST	0.229	-0.034	-0.059	0.291	0.198	0.927	5.389	6.639	0.447	0.900
RAD	0.242	-0.028	-0.066	0.298	0.195	0.739	4.533	6.060	0.368	0.801
M'HAR	0.218	-0.056	-0.061	0.300	0.214	1.320	8.098	8.903	0.550	1.047
PAN.E	0.194	-0.053	-0.039	0.289	0.232	2.034	10.464	10.039	0.785	1.186
't' 5% = 0.811 d.f = 4					REGRESSION EQUATION: $ETc = a \times e^{b \times ET}$					
't' 1% = 0.917					*Significant, ** Highly Significant					

Comparison of Field and Climatic estimates of evapotranspiration

For better comparison of both types of estimates, the ratios (ET/ETc) were computed (Table-2) for each soil moisture regime of summer mung crop growth period. In general, the ET/ETc ratios suggested that the climatic estimates overestimated 'ET' rate during peak crop growth period of summer mung. It is due to inadequate data available for this crop growth period. The ET/ETc ratios normally approached unity under all soil moisture conditions only during early crop growth period. These ratios increased significantly near crop maturity which was attributed to the underestimates of 'ETc' during this period by the predictive methods[3]. The ratio with Pan evaporation method deviated to the greatest extent followed by Christiansen method, and ratios with Radiation or Modified Hargreaves deviated the least.

The comparisons of different moisture regimes with each method of climatic estimates (Table-2 & 3) further suggested that the Pan-evaporation method found to be more précised to predict the actual field values for moderate soil moisture regimes. It is attributed to the better integration of the erratic climatological situations, and dominant aerodynamic factors normally prevailed during summer season, by Pan-E[2] also mentioned that the aerodynamic factors are more dominant under arid situations.

Relationship between Field and Climatic estimates of evapotranspiration

The statistical analysis (Table-3) for both type of estimates for summer mung crop revealed that the field estimates ET of moderate moisture regime (T_4) had significant correlation with empherical/ climatic estimates, which was maintained up to pod formation stage. The Pan-E registered the highest t value significant at 1% level. The correlation coefficients value of other regimes were non-significant, It signified that other empherical/climatological methods of ETc prediction of summer mung crop indicating less reliability for agro-climatic conditions of Central India. To summarize the nature of relationship and the significance of various estimates, it was apparent that both types of ET estimates were in exponential relationships with summer mung crop as: [$Y = a \times e^{b \times ET}$]. That was attributed to the particular behavior of ET rate of summer mung crop i.e. an instantaneous initial increase followed by relatively static ETc rate, while other factors were not interacting with crop evapotranspiration.

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