https://doi.org/10.29321/MAJ.10.A02858

Madras agric. J. 67 (7) : 436—440, July, 1980

Calculation of Evapotranspiration in Rice*

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An investigation was carried out during 1971 to 1973 at the Tamil Nadu Agricultural University, Coimbatore, to calculate the evapotranspiration in rice by different formulae. It was found that the modified formula of $Q = 0.24\ S$ using the Bellani spherical pyranometer was the best from the point of accuracy, simplicity and time.

Meteorological parameters play a greater role in evapotranspiration of a crop, especially when the plant cover is adequate and the moisture supply is not limiting. Penman (1948) and Thornthwaite (1948) stated that when water supply is abundant, evapotranspiration is a physical phenomenon governed by the incident energy at a place and is not a physiological process. Many indirect methods of estimation of evapotranspiration have been attempted using meteorological parameters (Blaney and Criddle, 1950; Christiansen, 1968). However, Christiansen (1968) had pointed out that any formula developed should be simple, use all the climatic parameters affecting evapotranspiration and be applicable in a wide variety of situations.

Keeping this in view an attempt was made to compare the calculated evapotranspiration by the different formulae with the actual measured evapotranspiration and to develop a formula based on the meteorological factors that would fit better under the experimental conditions.

MATERIAL AND METHODS

The experiment was conducted in the wetlands of the Tamil Nadu Agricultural University, Coimbatore, during the years 1971 to 1973. Coimbatore is situated at 11° N 77° E at an altitude of 498 metres above mean sea level. The average rainfall is 613.6 mm received in 49.8 rainy days.

The treatments were : Water management treatments : I_1 - maintaining 5cm water depth daily throughout the crop growth I_2 - maintaining 5 cm water depth daily throughout the crop growth with stoppage of water for five days only at the end of the tillering stage, I_3 - maintaining saturation daily throughout the crop growth period, I_4 - maintaining 5 cm of water depth daily for four days and afterwards stoppage of water for four days and I_5 - maintaining 5 cm of water depth daily for eight days and afterwards stoppage of water for

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* Part of the Ph. D. Thesis of the first author submitted to the Tamil Nadu Agricultural University, Coimbatore.

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eight days. The varieties tried were V_1 - Kannaki (IR 8 × TKM 6) and V_2 - Bala (N. 22 × T (N) $_1$). The N levels tested were No-0 kg, N_1 - 60 kg, N_2 - 120 kg, N_3 - 180 kg and N_4 - 240 kg N/ha. A common dose of 60 kg each of P_2O_5 and K_2O/ha was applied uniformly to all the plots.

The experiment was laid out in split plot design with water management and variety allotted to the main plot and N levels to the sub plots, replicated thrice. In all, two monsoon (wet) and two summer (dry) crops were taken.

In order to estimate the evapotranspiration and effective rainfall, the drum culture technique evolved by Dastane *et al.* (1966), but slightly modified, was adopted. Empty earthern pots of 45 cm height and 45 cm diameter with and without bottom were buried at 30 cm deep in the soil so that 15 cm protruded outside the soil The pots were made leak proof by coating inside and outside with wax and black paint. The meteorological parameters recorded at the agrometeorological observatory of the university farm were utilised for calculation of evapotranspiration. Daily values of evapotranspiration were measured at 0800 hours. Mc Culloch's (1965) Tables for easy computation of Penman's (1948) values as furnished by Dastane (1972) were utilised in the calculation. The 'K' factor viz., the monthly consumptive use coefficient as given by Dastane (1972) was used in the calculation of Blaney and Criddle (1950) formula. Thornthwaite (1948), Ivanov (1966) and Johnson (1965) formulae were also used for calculation of evapotranspiration.

RESULTS AND DISCUSSION

The Thornthwaite formula gave very low values and was found to be the least accurate of the methods. Dastane (1972) found that the Thornthwaite formula underestimated the evapotranspiration. Similar results were obtained in the present investigation also and hence are not presented.

The formula proposed by Johnson (1965) also gave low evapotranspiration values compared to the actual evapotranspiration and hence a modified formulae was arrived at. The modified formula is, $Q = 0.24\ S$. The solar radiation measured by the Bellani Spherical Pyranometer was used.

In order to assess which of the formulae is best suited for calculating the evapotranspiration, the actual measured evapotranspiration for individual water management treatments was divided by the evapotranspiration obtained with the formulae. The ratios between the actual evapotranspiration and calculated with Ivanov, Blaney and Criddle, Penman and the modified formulae are presented in the Table. It is seen from the Table that the ratio between the actual evapotranspiration and calculated Ivanov and Blaney and

Criddle showed rather consistent pattern, but the ratio in the monsoon season was higher than that in summer. The ratios for the two varieties also varied. Except for the I_3 treatment, actual evapotranspiration was greater than that estimated in both the methods since neither method considered the radiation and humidity conditions. Doorenbos and Pruitt (1975) clearly showed the need for adjustment of Blaney and Criddle estimate under different general ranges of sunshine and humidity. The ratios obtained between actual evapotranspiration and that calculated with Penman and modified formula were close.

The perusal of the data in the Table showed that in I_3 treatment the ratios were almost near unity both in summer and in monsoon seasons and in both the varieties. However, under I_1 treatment the ratios ranged from 1.16 to 1.31. This is not in conformity with the concept that Penman formula gives the value of evaporation that could be obtained under non-limiting water conditions. This difference may be due to the effect of plant canopy effect under which the actual evapotransipiration was estimated. Compared to other formula gave the best estimate with smaller range of errors. Much of the evidence reviewed by Penman (1965) supported his hypothesis that vegetation, with its roots in moist soil and with leaves forming a complete canopy, transpired to a maximum or potential rate determined primarily by weather. It might be emphasised, however, that such relationships between climate and growth are conditioned by adequate water supply to the roots. Penman formula is perferred as it offers the possibility of analysing the relative importance of the various climatic factors in determining the rate of water loss under the nonlimiting soil moisture conditions. Penman formula gave the best fit under non-limiting water supply conditions (Stanhill, 1965).

The modified formula takes into account the solar radiation as measured by the Bellani Spherical Pyranometer. The rate and amount of evaporation are governed by the energy supply to the evaporating surface. As long as the soil surface remains wet, water is lost from a bare soil through the process of evaporation at approximately the same rate as from an open water surface (Marshall, 1959). The rate ot transpiration is governed by the radiant energy received at the leaf surfaces with the important exception that regulation of water loss could be affected by stomatal movement induced by water deficits in guard cells (Mongelard and Nickell, 1972).

There was not much difference in the ratios in both the seasons. The values ranged form 1.00 to 1.33 and 1.02 to 1.32 in monsoon and summer, respectively. As in the case of Penman formula, in I_3 treatment the ratios were near unity Indicating that the formula represented the actual evapotranspiration of the plant. In I_1 treatment the

TABLE Ratio between actual evapotranspiration and calculated evapotranspiration.

Water management treatment	Kannaki (V_1)						Bala (V_2)					
	Monsoon			Summer			Monsoon			Summer		
	1971	1972	Mean	1972	1973	Mean	1971	1972	Mean	1972	1973	Mean
					IVANOV FORMULA							
I_1	1.29	1.40	1.35	1.18	1.07	1.13	1.44	1.31	1.37	1.09	1.25	1.17
I_2	1.30	1.34	1.32	1.12	1.03	1.08	1.42	1.27	1.34	1.04	1.20	1.12
I_3	1.15	1.19	1.17	0.96	0.89	0.92	1.18	1.15	1.17	0.92	1.01	0.96
I_4	1.32	1.38	1.35	1.11	1.02	1.07	1.44	1.30	1.37	1.01	1.19	1.10
I_5	1.27	1.35	1.31	1.09	1.02	1.06	1.41	1.28	1.35	1.01	1.16	1.09
Mea	1.29	1.33		1.09	1.01		1.38	1.26		1.01	1.16	
					BLANEY AND CRIDDLE FORMULA							
I_1	1.09	1.26	1.18	1.30	1.29	1.30	1.11	1.22	1.16	1.33	1.32	1.32
I_2	1.10	1.20	1.15	1.24	1.25	1.24	1.09	1.18	1.14	1.26	1.26	1.26
I_3	0.96	1.07	1.02	1.05	1.07	1.06	0.91	1.07	0.99	1.12	1.06	1.09
I_4	1.11	1.24	1.17	1.22	1.24	1.23	1.11	1.21	1.16	1.22	1.25	1.24
I_5	1.07	1.21	1.14	1.20	1.23	1.22	1.08	1.19	1.14	1.23	1.22	1.23
Mean	1.07	1.20		1.20	1.02		1.06	1.18		1.23	1.26	
					PENMAN FORMULA							
I_1	1.16	1.18	1.17	1.17	1.30	1.23	1.19	1.21	1.20	1.14	1.31	1.23
I_2	1.16	1.12	1.14	1.11	1.25	1.18	1.18	1.17	1.17	1.09	1.25	1.17
I_3	1.03	1.00	1.01	0.94	1.08	1.01	0.98	1.06	1.02	0.97	1.05	1.01
I_4	1.18	1.16	1.17	1.09	1.24	1.17	1.19	1.20	1.20	1.05	1.24	1.15
I_5	1.14	1.13	1.13	1.08	1.24	1.16	1.17	1.19	1.18	1.06	1.21	1.14
Mean	1.13	1.12		1.08	1.22		1.14	1.17		1.06	1.21	
					MODIFIED FORMULA							
I_1	1.18	1.26	1.22	1.26	1.32	1.29	1.22	1.33	1.28	1.26	1.30	1.28
I_2	1.18	1.19	1.19	1.19	1.26	1.23	1.21	1.29	1.25	1.19	1.25	1.22
I_3	1.04	1.06	1.05	1.02	1.09	1.06	1.00	1.17	10.9	1.06	1.04	1.05
I_4	1.19	1.24	1.22	1.18	1.26	1.22	1.22	1.33	1.27	1.16	1.24	1.20
I_5	1.16	1.21	1.18	1.16	1.25	1.21	1.19	1.31	1.25	1.17	1.21	1.19
Mean	1.15	1.19		1.16	1.24		1.17	1.29		1.17	1.21	

ratios ranged from 1.18 to 1.33. This showed the great similarity in the predicted evapotranspiration between Penman formula and the modified formula.

Among the six empirical methods tested for calculating evapotranspiration in rice, it was found that the modified formula, Q = 0.24 S, where Q, is the evapotranspiration in m^3/ha/day and S is the measured solar radiation in cal/cm^2/day using Bellani Spherical Pyranometer, was the best for calculation of evapotranspiration taking into account, the accuracy, simplicity and time consumed. The next best was Penman formula which required large volume of data and tedious calculations

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