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Short communication

Developement of crop coefficient curves for different growth periods of *kharif* groundnut

DEEPA ASOKAN, S. R. BHAKAR, DEEPESH MACHIWAL, H. K. JAIN and R. C. PUROHIT

Department of Soil and Water Engineering, College of Technology and Engineering, MPUAT, Udaipur.

Groundnut is one of the main irrigated crops in the Udaipur (arid and semiarid) region of the Rajasthan state of India. The rapid decline of water table in these regions, however, has led to an urgent need for a reduction of irrigation to make agriculture in these regions sustainable. A detailed investigation on the water requirements is required for the efficient management of the scarce water resources in this region. A crop coefficient is required to estimate the crop water requirement by the FAO method. For most of the agricultural crops, a relation can be established between evapotranspiration and climate by the introduction of the crop coefficient (K_c), which is the ratio of crop evapotranspiration (ET_C) and reference evapotranspiration (ET_0) (Doorenbos and Pruitt, 1977). Doorenbos and Kasam (1979), and Jensen *et al*. (1990) reported different crop coefficients for various crops. The empirical information about crop coefficients for groundnut growing in arid and semiarid region of Udaipur is not yet available.

Reference evapotranspiration can be estimated by different methods (Kang *et al.*, 1994). The Penman-Monteith equation with its new definition of ET_0 is recommended by the FAO for calculation of crop water requirements (Allen *et al.*, 1998). The objectives of the present study were to develop crop coefficient curves for kharif groundnut.

Meteorological data recorded at Agro meteorological observatory at the instructional farm of College of Technology and Engineering (CTAE) Udaipur were collected for period of 1978-2009. The area comes under the sub humid region of agro-climatic zone IV A of the Rajasthan state and is situated at 24° 35' N latitude 73° 42'E longitude and at an altitude of 582.17 m above mean sea level. The annual rainfall in the region is 662.5 mm and more than 80% of this amount is received as a part of south – west monsoon during June to September. The crop coefficient curves were developed for groundnut by FAO-56 curve method, modified FAO-56 curve method and quadratic curve method. The best method was decided by using the criterion of correlation coefficient at one percent level of significance, standard error and nearness to 1:1 line between measured and predicted crop evapotranspiration.

FAO-56 curve method

The crop coefficient curves for kharif groundnut (K_{CKG}) was developed using the FAO-56 method (Allen *et al.*, 1998) proposed three values of crop coefficients for three important stages for development of crop coefficient curve. The crop coefficient for initial stage is referred as K_{cini} Similarly crop coefficient for mid stage and late stages are designated as K_{cmid} and K_{cend} respectively. The K_{cini} value for groundnut crop was found to be 0.4.

The value of K_{cmid} varied with the climatic condition and crop height. For specific adjustment in climates where value of minimum relative humidity differ from 45 per cent or where U_2 is larger or smaller than 2.0 m s^{-1}, K_{cmid} value was determined from the following expression:

$$K_{cmid} = K_{cmid\,(TAB)} + [0.04(U_2 - 2) - 0.004\,(RH_{min} - 45)]\,(h/3)^{0.3} \quad ...(1)$$

where,

$K_{cmid\,(TAB)}$ = Tabulated value of $K_{C\ mid}$

U_2 = Mean value of daily wind speed at 2m height during mid season growth stage for 1 m $s^{-1} \leq U_2 \leq$ 6 m s^{-1}, m s^{-1}

RH_{min} = Mean value of daily minimum relative humidity during the mid season growth stage for 20 % $\leq RH_{min} \leq$ 80%, percent

h = Mean plant height during mid season stage for 0.1 m $\leq$ h $\leq$ 10m, m

During the mid season stage, mean wind speed was 1.29 m sec^{-1}. Mean value of minimum relative humidity was 55.03 per cent and height of the crop was 20.30 cm. The K_{cmid} value for groundnut crop was worked out to be 1.03.

The value of K_{cend} reflects crop and water management practices. The K_C value was determined from the following expression:

$$K_{cend} = K_{cend(Tab)} + 0.04(U_2 - 2) - 0.004(RH_{min} - 45)](h/3)^{0.3} \quad ...(2)$$

where,

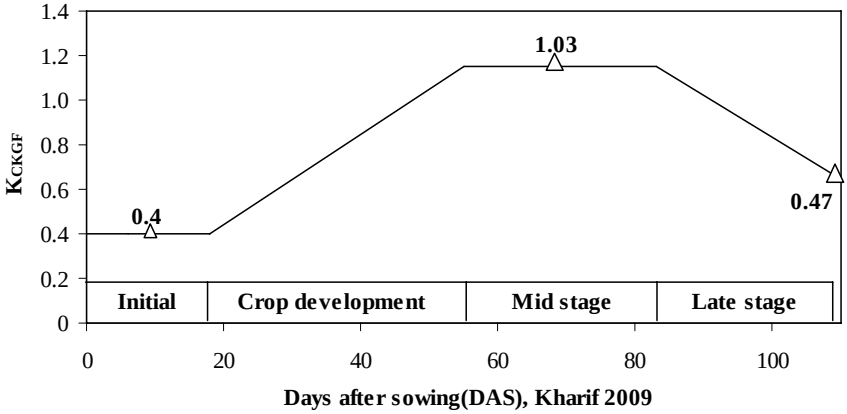

Fig. 1: Development of crop coefficient curve for kharif groundnut by FAO-56 (K_{CKGF}) curve method.

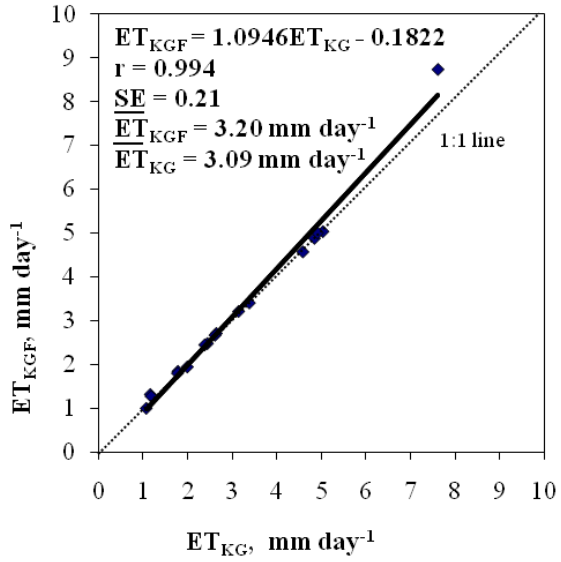

Fig. 2: Relationship between estimated groundnut evapotranspiration by FAO-56 curve method (ET_{KGF}) and measured groundnut evapotranspiration (ET_{KG})

$K_{cend\ (TAB)}$ = Tabulated value of K_{Cend}

U_2 = Mean value of daily wind speed at 2m height during end season growth stage for 1 m $s^{-1} \leq U_2 \leq 6$ ms^{-1}, ms^{-1}

RH_{min} = n value of daily minimum relative humidity during the end season growth stage for 20 % $\leq RH_{min} \leq$ 80%, percent

h = Mean plant height during end season stage for 0.1 m $\leq$ h $\leq$ 10 m, m

The equation 2 is only applied when the tabulated value of K_{Cend} exceeds 0.45. The K_{Cend} value for groundnut crop was worked out to be 0.47

A comparison was made between the crop evapotranspiration estimated by FAO–56-curve method and the measured crop evapotranspiration by soil moisture depletion method for groundnut. The relationship was plotted in Fig. 2. There existed a linear relationship between crop evapotranspiration estimated from FAO-56 curve method and a measured crop evapotranspiration by soil moisture depletion method. The correlation coefficients were found to be 0.994, significant at 1 per cent level. The standard error was found to be 0.21 mm day^{-1}.

The FAO –56 curve methods underestimated the ET_{KG} values by 3.55 percent. Therefore, this method does not appear to predict groundnut evapotranspiration very accurately under climatic conditions of Udaipur.

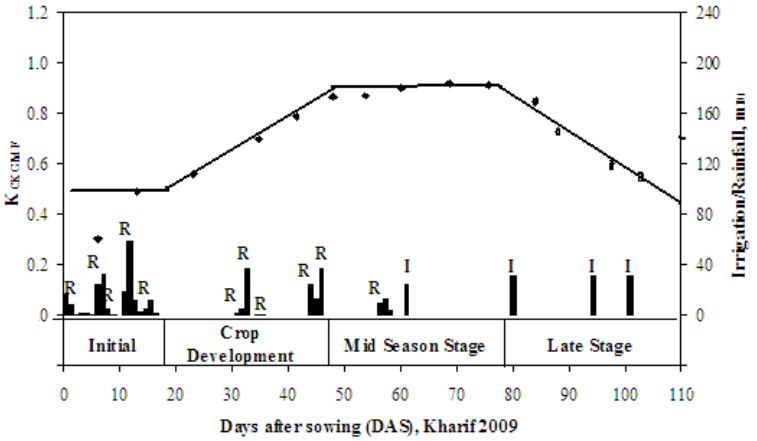

Fig. 3: Daily K_{CKG} values, modified FAO-56 curve (K_{CKGMF}) and amount of irrigation and rainfall during growing season of groundnut crop at Udaipur

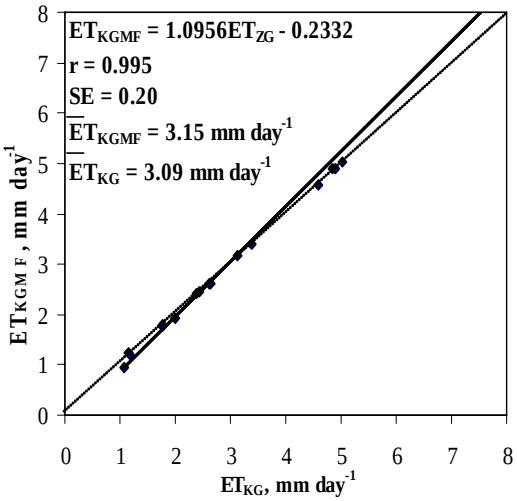

Fig. 4: Comparison between estimated groundnut evapotranspiration by modified FAO-56 curve method (ET_{KGMF}) and measured evapotranspiration (ET_{KG}) for groundnut crop at Udaipur

Modified FAO –56 curve method

The FAO–56 curve method was modified by using actual values of the crop coefficient of groundnut (K_{CKG}). This method was therefore, designated as modified FAO–56 curve method. Crop coefficient values were calculated as ratio the of measured crop evapotranspiration (ET_{KG}) by soil moisture depletion method to estimate reference evapotranspiration (ET_0) by ET_0 Calculator using Penman-Monteith method. Fig. 3 shows the daily K_{CKG} values during growing season of groundnut crop. The growing season of the groundnut crop was divided into four stages such as initial stage, 20 days (11th July to 30th July), crop development stage, 28 days (31th July to 27th August), mid season stage, 36 days (28th August to 2nd October), and late season stage 32 days (3rd October to 3rd November). The crop coefficient for the initial stage was determined by taking the mean of K_{CKG} values for 20 days. The K_{CKG} for initial stage were found to be 0.38, which is shown by a horizontal line in Fig. 3. As the crop developed and shaded more and more of the ground, evaporation became restricted and transpiration gradually becomes the major process. Fig. 3 shows that the K_{CKG} value increases during the crop development stage to the beginning of the mid season. The midseason stage runs from full effective cover to the last of start of the maturity. The start of maturity was indicated by senesce of groundnut leaves. It is evident from Fig. 3 that at mid season stage the value of K_{CKG} was higher than other stages of groundnut crop. Allen *et al.*, (1998.) indicated that some crop coefficient

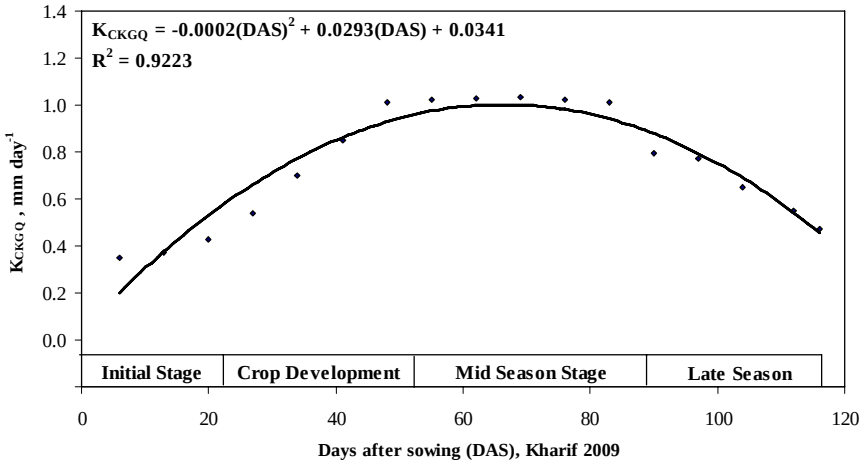

Fig. 5: Development of crop coefficient curve for groundnut by quadratic curve (K_{CKGQ}) method

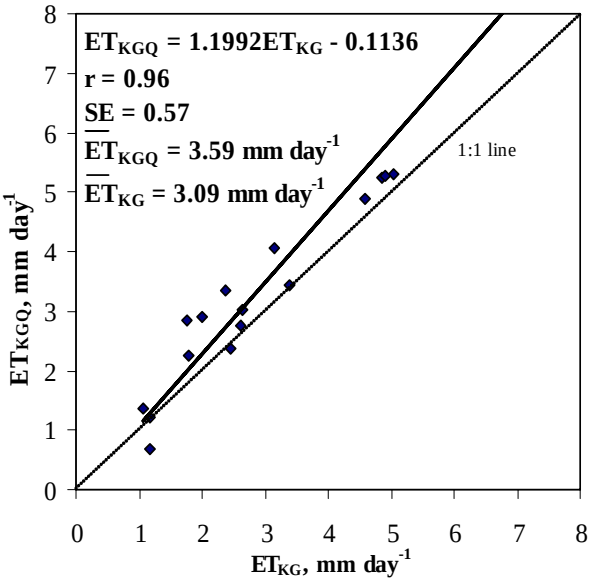

Fig. 6: Relationship between estimated groundnut evapotranspiration by quadratic curve method (ET_{KGQ}) and measured evapotranspiration (ET_{KG}) for groundnut crop at Udaipur

values might be higher following wetting of soil by irrigation or rainfall. These higher values may be neglected while constructing crop coefficient curves. The K_{CKG} value for mid season stage were found to be 1.03.

The K_{CKG} values were reduced during the late season stage. The reduction is linear from the end of mid season stage to the end of maturity. The K_{CKG} values at the end of late season were found to be 0.46.

The comparison was made between crop evapotranspiration estimated by the modified FAO-56 curve method (ET_{KGMF}) and measured evapotranspiration ET_{KG} by soil moisture depletion method for groundnut respectively. Fig. 4 shows linear relationship between crop evapotranspiration estimated from modified FAO–56 curve method (ET_{KGMF}) and measured crop evapotranspiration (ET_{KG}) by soil moisture depletion method. The correlation coefficient was found to be 0.995, which are significant at 1 percent level. The standard error was found to be 0.20 mm day^{-1}. The modified FAO–56 curve method underestimates the groundnut evapotranspiration values by 1.94 per cent.

Quadratic curve method

The quadratic crop coefficient curve for groundnut was

developed by fitting quadratic equation by least square method. The quadratic crop coefficient curve for groundnut is presented in Fig. 5. K_{CZGQ} values increased during initial stage and crop development stage. The K_{CKG} attains its maximum value at the mid season stage. The K_{CKGQ} value start decreasing during the late season stage till harvesting. The fitted quadratic equation is given as follows:

$$K_{CKGQ} = -0.0002\ DAS^2 + 0.0293\ DAS + 0.0341 \quad \ldots(3)$$

where,

K_{CKGQ} = quadratic crop coefficient for groundnut

DAS = days after sowing

The coefficient of determination (R^2) was found to be 0.9223. The comparison was made between crop evapotranspiration estimated by quadratic curve method (ET_{KGQ}) and measured evapotranspiration (ET_{KG}) by soil moisture depletion method for groundnut. Fig. 6 shows linear relationship between crop evapotranspiration estimated from quadratic curve method (ET_{KGQ}) and and measured crop evapotranspiration (ET_{KG}) by soil moisture depletion method. The correlation coefficient was found to be 0.96, which is significant at 1 per cent level. The standard error was found to be 0.57 mm day^{-1}. The modified FAO–56 curve method underestimates the groundnut evapotranspiration values by 13.93 percent.

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