Research Article

ESTIMATION OF CROP EVAPOTRANSPIRATION OF Bt. COTTON UNDER SILVER BLACK PLASTIC MULCH USING VARIOUS APPROACHES

G. V. Prajapati[1*] and R. Subbaiah[2]

[1]*Centre of Excellence on Soil & Water Management, Junagadh Agricultural University, Junagadh, Gujrat, INDIA*

[2]*College of Agricultural Engineering and Technology, Anand Agricultural University, Godhra, Gujrat, INDIA*

**Corresponding author's E-mail: prajapti_girish@jau.in*

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ABSTRACT

Most fundamental requirement of scheduling irrigation is the determination of crop evapotranspiration (ET_c). Over estimation of crop evapotranspiration leads waste of scarce water and under estimation leads to the plant moisture stress and decreased crop yield. In order to avoid the underestimation or overestimation of crop water consumption, knowledge of the exact water loss through actual evapotranspiration is necessary for sustainable development and environmentally sound water management. The Penman-Monteith method is maintained as the single standard method for the computation of reference evapotranspiration (ET_0) from complete meteorological data but, it requires large number of climatic parameters that are not always easily available for many locations. Pan evaporation method is susceptible to the microclimatic conditions under which the pans are operating and the rigour of station maintenance. An attempt has been made to estimate actual evapotranspiration (ET_a) of drip irrigated Bt. cotton under silver black plastic mulch using soil moisture sensor. ET_a(ET_c) at different growth stage of Bt. cotton was estimated using soil moisture sensor and it was compared with ET_c estimated using Penman-Monteith and Pan evaporation method. Results revealed that Pan evaporation method and Penmen Monteith method over estimated ET_c by 19.26% and 13.78% than sensor based ET_c respectively. Sensor based method estimated lower cumulative ET_c at initial stage, development stage, mid stage, and end stage by 46.11%, 33.70%, 18.83% and 17.93%, and 22.89%, 17.80%, 16.09% and 14.89%over Pan evaporation and Penmen Monteith method respectively.

INTRODUCTION

Cotton is the most important global cash crop and controls economy of many nations. Like most major agricultural crops, cotton production and productivity is negatively influenced by moisture stress. Nearly, 60 % cotton growing area falls under rainfed conditions and is characterized by scarcity of soil moisture. So in rainfed condition, water resource management is crucial requirement for increasing agricultural production because food insecurity is becoming a main concern. Accurate estimation of evapotranspiration is more important for water users, for parameterization of important hydrologic and water resources planning and operation models, forecasting of drought and its monitoring, effective development and utilization of water resources, for operating weather and climate change forecasting models, water management and allocation in water-scarce regions, including the partitioning of water resources among states and nations. Many different methods for estimating reference evapotranspiration (ET_0) have been developed, most of which are complex and require a significant number of weather parameters such as solar radiation, temperature, wind speed and relative humidity (Pruitt, 1966; Doorenbos and Pruitt, 1977; Smith *et al*., 1996). Notably, the availability of data on these parameters is scarce in developing countries and at the same time, these methods require good computational skills. The Penman Monteith method (P-M Method) is maintained as the single standard method recommended by the FAO for the computation of ET_0 from complete meteorological data (Allen *et al.*, 2006; Smith *et al.*, 1990) but, the main shortcoming of the FAO 56 P-M method is, it requires large number of climatic parameters that are not always easily available for many locations. Pan Evapotranspiration methods clearly reflect the shortcomings of predicting crop evapotranspiration from open water evaporation. The method is susceptible to the microclimatic conditions under which the pans are operating and the rigour of station maintenance. Its performance proves erratic.

MATERIALS AND METHODS

An experiment was undertaken at Research cum demonstration farm of Centre of Excellence on Soil &

Water Management of Junagadh Agricultural University, Junagadhhas bearing of 21°30' N, 70°27' E and 77.5 above mean sea level. The climate of the area is categorized under subtropical and semi-arid with an average annual rainfall of 900 mm and average pan evaporation of 6.41 mm/day. May is the hottest month with mean weekly pan evaporation of 10.95 mm and mean monthly temperature varying between 35°C to 45°C. January is the coolest month with mean monthly minimum temperature varying between 7°C to 10°C. About 95% of the total rainfall is received during monsoon months only. The experiment conducted for consecutively two years during *Kharif* season of 2013-14 and 2014-15, to estimate actual evapotranspiration of drip irrigated Bt. cotton under silver black plastic mulch.Irrigation scheduling was done based on actual evapotranspiration measured with the help of soil moisture sensors installed at 10cm and 50cm from top of the soil near the root zone of cotton crop. The sensors were calibrated for local condition and moisture content calculated based on calibrated soil moisture characteristic curve. Crop evapotranspiration was also estimated using Penman Monteith and Pan Evaporation methods.

Estimation of actual evapotranspiration (ET_a)

Actual evapotranspiration ET_a (ET_c) was calculated using soil moisture sensors with data loggers installed at different depth for getting soil moisture periodically. After heavy rainfall or irrigation, the soil will drain until field capacity is reached. In the absence of water supply, the water content in the root zone decreases as a result of water uptake by the crop. It was calculated using following equation

$$ET_a = 1000 \times (M_1 - M_2) \times Z_r \times BD \quad (1)$$

Where, ET_a = Actual evapotranspiration (mm), M_1 = Moisture content after irrigation ($m^3\ m^{-3}$), M_2 = Moisture content before irrigation ($m^3\ m^{-3}$), Zr = Root depth (m)(calculated using model developed by Fereres *et al.*, 1981), BD = Bulk density (g/cc).

Estimation of ET_c using Penman-Monteith Equation

The FAO P-M method was developed by defining the reference crop as a hypothetical crop with an assumed height of 0.12 m having a surface resistance of 70 s m^{-1} and an albedo of 0.23, closely resembling the evaporation of an extensive surface of green grass of uniform height, actively growing and adequately watered. The FAO P-M method for calculating reference (potential) evapotranspiration ET can be expressed as Allen *et al*. (1998):

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \quad (2)$$

Where, ET_0= reference evapotranspiration (mm day^{-1}), Rn= net radiation at the crop surface (MJ $m^{-2}day^{-1}$), G = soil heat flux density (MJ $m^{-2}day^{-1}$), Ta = mean daily air temperature at 2 m height (°C), u_2= wind speed at 2 m height (m s^{-1}), e_s= saturation vapour pressure (kPa), e_a= actual vapour pressure (kPa), (e_s- e_a) = saturation vapour pressure deficit (kPa), A= slope vapour pressure curve (kPa °C^{-1}), and *a*=Psychrometric constant (kPa °C^{-1}).

ET_c was calculated by multiplying ET_0 with adjusted K_c for plastic mulch suggested by FAO 56.

Estimation of ET_c using Pan Evaporation method

One of the most common techniques for estimating ET_0 is using evaporation pan data, with adjustments made for the pan environment (Singh, 1989). However, reliable estimation of reference evapo-transpiration (ET_0) using pan evaporation (E_{pan}) data depends on the accurate determination of pan coefficients (K_{pan}), which is defined as the ratio of ET_0 to E_{pan} and is found to vary from 0.35 to 0.80. K_p is basically a correction factor which depends upon the prevailing upwind fetch distance, average daily wind speed, and relative humidity associated with the installation conditions of the evaporation pan (Doorenbos and Pruitt, 1977). Most of the K_{pan} estimation models have been developed based on the FAO-24 table using linear, nonlinear and indicator regression techniques or combinations thereof. In the present study, the Snyder model (1992) is adopted to estimate the pan coefficient. Snyder (1992) proposed a simpler equation to calculate daily K_{pan} values as a function of U_2, RH, and F. The final expression of the model can be expressed as:

$$K_{pan} = 0.482 + [0.24\ln(F)] - (0.000376\,U_2) + (0.0045\,RH) \quad (3)$$

The relationship between ET_0 and E_{pan} can be expressed as (Snyder, 1992):

$$ET_o = K_p \times E_{pan} \quad (4)$$

Where, ET_o = reference evapotranspiration (mm/day), K_p = pan coefficient, E_{pan} = pan evaporation (mm/day).

ET_c was calculated by multiplying ET_0 with adjusted $K_c$for plastic mulch suggested by FAO 56.

Crop coefficient for plastic mulched cotton as per FAO 56

K_c values decrease by an average of 10-30% due to the 50-80% reduction in soil evaporation. The value for K_{cini} under mulch is often as low as 0.10 suggested by FAO 56, Chapter 10- ET_c under various management practices. So the crop coefficient of cotton crop under mulching were reduced by 15% for $K_{c\ mid}$ and K_{cend}. Corrections for local conditions were made using following equations.

$$K_{C\,mid} = K_{C\,mid\,(Tab)} + [0.04(u_2 - 2) - 0.004\,(RH_{min} - 45]\left(\frac{h}{3}\right)^{0.3} \quad (5)$$

$$K_{C\,end} = K_{C\,end\,(Tab)} + [0.04(u_2 - 2) - 0.004\,(RH_{min} - 45]\left(\frac{h}{3}\right)^{0.3} \quad (6)$$

Adjusted FAO K_c was multiplied with evapotranspiration estimated by P-M equation and Pan Evaporation method to compute ET_c.

RESULTS AND DISCUSSION

Daily actual evapotranspiration was calculated using equation (1) considering depth of sowing, days to attain physiological maturity and maximum depth of root zone for Bt. cotton was 2.5 cm, 104 days and 75cm (Freddie *et al.*, 2001) respectively. $ET_0$was also estimated with P-M and Pan Evaporation method using equation no. (2) and (4). FAO 56 suggested K_{cini}, $K_{c\,mid}$ and K_{cend} values for cotton crop under plastic mulching were 0.1, 1.063 and 0.45 respectively. These values were corrected for local conditions as per the procedure suggested by FAO 56 using equation (5) and (6). The corrected values of K_{cini}, $K_{c\,mid}$ and K_{cend} were 0.1, 1.04 and 0.425 for 2013-14 and 0.1, 1.036 and 0.425 for 2014-15 respectively. ET_c was calculated by multiplying these adjusted K_c values with estimated ET_0 values calculated using P-M Method and Pan Evaporation method. Under silver black plastic mulch, cotton consumed less water due to low evaporative demand and weed free environment. Soil moisture conservation for mulching was quoted by Channabasavanna *et al.*, (1992) and Gupta and Acharya (1993).

Cumulative ET_c for silver black plastic mulch is depicted in Fig. 1. Lowest ET_c was observed in sensor based values. Pan ET_c overestimated than P-M ET_c and sensor based ET_c. Pan evaporation method and P-M method over estimated ET_c by 19.26% and 13.78% than sensor based ET_c respectively. Sensor based method estimated lower cumulative ET_c at initial stage, development stage, mid stage and end stage by 46.11%, 33.70%, 18.83% and 17.93%, and 22.89%, 17.80%, 16.09% and 14.89% over Pan evaporation and P-M method respectively. P-M method estimated lower ET_c by 30.12%, 19.34%, 3.27% and 3.56% over Pan ET_c at initial stage, development stage, mid stage, and end stage respectively.

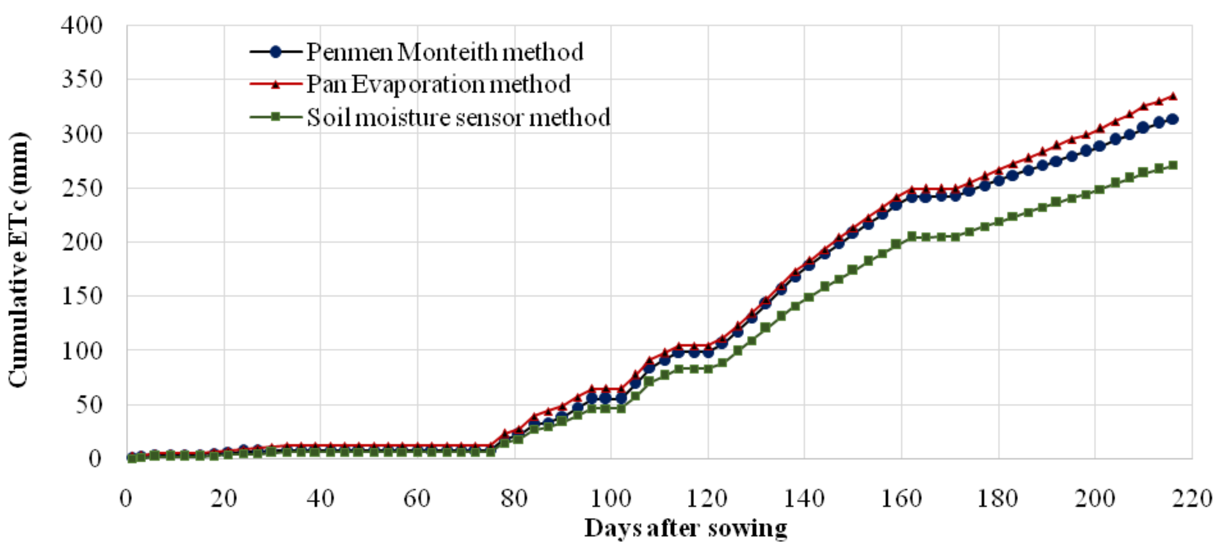

Fig. 1. Cumulative crop evapotranspiration of Bt. cotton under silver black plastic mulch

CONCLUSION

Study revealed that crop evapotranspiration estimated using Pan evaporation method yielded higher ET_c followed by Penmen Monteith ET_c and sensor based ET_c. Sensor based method estimated lower cumulative ET_c at initial stage, development stage, mid stage and end stage of Bt. cotton under silver black plastic mulch by 46.11%, 33.70%, 18.83% and 17.93%, and 22.89%, 17.80%, 16.09% and 14.89% over Pan evaporation and P-M method respectively.

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