Evapotranspiration includes both evaporation from land surface and transpiration of water from plants, and constitutes a major component of hydrologic cycle. Therefore, its accurate estimation is of vital importance for hydrologic studies. Six empirical methods for calculating ET, namely, Hargreaves (Temperature based), FAO-24 Radiation, Priestley-Taylor and Turc (Radiation Based) and FAO-24 Penman and Kimberly-Penman (Combination) were evaluated using meteorological data from four climatological stations (Jagdalpur, Bombay, Bellary and Kharagpur) to determine the best and worst method for each location. The reference evapotranspiration (ETo) values estimated by all methods were compared with the FAO-56 Penman-Monteith ETo estimates, which were taken as the standard. Based on the Standard Error Estimates, the FAO-24 radiation method ranked first for the Jagdalpur and Bombay stations. The 1982 Kimberly-Penman ranked first for Kharagpur and Bellary.

**Keywords:** Reference ETo, Crop ET, Climatological Data, SSE, Crop Coefficient.

**INTRODUCTION**

The reference evapotranspiration is one of the most important things to consider for irrigation management to crops. Evapotranspiration (ET) is important to irrigation management because crop yield relates directly to ET. Irrigators who are working to achieve maximum yields need to apply water to meet the crop's ET demand. Applying extra water beyond ET demand will not translate into extra yield and deficit irrigation may reduce the yield significantly. Therefore accurate estimation of ET is of utmost importance.

Evapotranspiration can be estimated directly using water balance approach or lysimeter. However, these techniques are not only time consuming, costly and laborious but also may not be feasible to adopt for long term evapotranspiration estimation from different vegetative surfaces. Therefore, in the past fifty years much research has been done to estimate ET indirectly by mathematical statistical methods based on variable climatic parameters.

Crop ET for a given crop can be estimated using grass reference crop evapotranspiration (ETo) and crop coefficient, whereas ETo can be estimated using different methods depending on the availability of climatic data. These different methods of ETo estimation can be grouped into combination theory (Penman VPD#1, Penman VPD#3, Penman-Monteith, FAO-24 Penman (c=1), 1982 Kimberly-Penman, 1972 Kimberly-Penman, FAO-24 Corrected Penman) and empirical formulations based on radiation (Turc, Jensen-Haise, Priestley-Taylor and FAO-24 Radiation), temperature Thornthwaite, SCS Blaney-Criddle, FAO-24 Blaney-Criddle, Hargreaves) and pan evaporation (Christiansen Pan, FAO-24 Pan) (George et al. 2002).

Due to the availability of numerous ET estimation methods, irrigation managers are confused about the reliability of each method. Therefore there is a need to identify the best and worst methods in each category for each location. Jensen et al. (1990) compared 20 different ET estimation methods against lysimeter measured ET for 11 stations around the world under different climatic conditions and concluded that the Penman-Monteith method estimates were close to lysimeter ET in both arid and humid climatic conditions. This research compares the ETo estimated by different methods with FAO-56 Penman-Monteith due the non-availability of lysimeter ET to identify which method fits well to the Penman-Monteith estimates.

**DESCRIPTION OF METHODS**

The ET estimation methods are generally grouped into temperature, radiation and combination theory. The methods are described in detail hereunder.

**Temperature Methods**

One of the earliest methods of estimating ET involved the use of air temperature and the studies for relating ET to air temperature initiated in the 1920's. Many scientists have established relationships between air temperature and ET (Lowry and Johnson, 1942; Thornthwaite, 1948). Blaney and Criddle (1950) observed that the consumptive use of crops during the growing season was closely correlated with mean monthly temperature and daylight hours. They developed a simplified formula for estimating consumptive use for the arid western regions of the United States. Doorenbos and Pruitt (1977) presented the most fundamental revision of the Blaney-Criddle method. Hargreaves and Samani (1985) proposed a method for estimating reference ET that requires only maximum and minimum air temperatures. Since Blaney-Criddle method is not suitable for monthly estimates, only Hargreaves method is selected in this study.

**Hargreaves**

Hargreaves and Samani (1985) proposed an equation for estimating grass-related reference ET. Since solar radiation data are not frequently available, this method estimates ETo from extraterrestrial radiation and mean monthly maximum and minimum temperatures as follows:
\[ E_{To} = 0.0023 \, R_A \sqrt{TD} \left( T_{\text{mean}} + 17.8 \right) \]  
\[ \text{where } \quad TD \text{ is the difference between mean daily maximum and minimum temperatures [°C], and } R_A \text{ is extraterrestrial solar radiation [MJ m}^{-2}\text{ d}^{-1}.] \]

Radiation Methods

A number of ET estimation methods (Makkink, 1957; Priestley and Taylor, 1972; Turc, 1961; Doorenbos and Pruitt, 1977) have been developed based on energy balance because solar radiation provides the required energy for the phase change of water and often limits the ET process where water is readily available. Most often, direct solar radiation is used because national weather networks, frequently measuring the radiation and air temperature, have been found, through correlation, to be a useful second variable. Three radiation methods, namely, Turc, Priestley-Taylor and FAO-24 Radiation are included in this analysis.

Turc

Turc (1961) simplified the earlier version of an equation for potential ET for 10 day periods under general climatic conditions of Western Europe. He proposed the following equations for two humidity conditions:

\[ E_{To} = 0.013 \frac{T_{\text{mean}}}{(T_{\text{mean}}+15)}(R_s + 50) \frac{1}{\lambda} \]  
\[ \{\text{For } RH_{\text{mean}} > 50\% \} \quad (2) \]

\[ E_{To} = 0.013 \frac{T_{\text{mean}}}{(T_{\text{mean}}+15)}(R_s + 50) \frac{1}{\lambda} \left( 1 + \frac{50 - RH_{\text{mean}}}{70} \right) \]  
\[ \{\text{For } RH_{\text{mean}} \leq 50\% \} \quad (3) \]

where, \( R_s \) is the solar radiation [cal cm\(^{-2}\) d\(^{-1}\)] and can be calculated as \( R_s / 0.041869 \), \( R_s \) is solar radiation [MJ m\(^{-2}\) d\(^{-1}\)], \( RH_{\text{mean}} \) is the average relative humidity [%] and \( \lambda \) is the latent heat of vaporization [MJkg\(^{-1}\)].

Priestley-Taylor

Priestley and Taylor (1972) proposed an equation for a generally wet surface area which is a condition required for potential evaporation. The aerodynamic component was deleted and the energy component was multiplied by a short wave reflectance coefficient (albedo), \( \alpha = 1.26 \). The final equation can be expressed as:

\[ E_p = a \frac{\Delta}{\Delta + \gamma} (R_n - G) \]  
\[ \text{where, } E_p \text{ is the potential evaporation; } \Delta \text{ is the slope of saturation vapor pressure curve at mean air temperature [kPa °C}^{-1}], \gamma \text{ is the psychrometric constant [kPa °C}^{-1}], R_n \text{ is the net radiation [MJ m}^{-2}\text{ d}^{-1}], G \text{ is the soil heat flux density [MJ m}^{-2}\text{ d}^{-1}], \alpha \text{ is the adjustment factor and can be estimated using the following expression:} \]

\[ E_{To} = a + b \left[ \frac{\Delta - R_s}{\Delta + \gamma} \frac{1}{\lambda} + b \right] \]  
\[ \{\text{For } RH_{\text{mean}} > 50\% \} \quad (5) \]

\[ \text{where, } a \text{ is a coefficient and is equal to -0.3 and } b \text{ is the day time wind speed.} \]

Combination Methods

Earlier ET estimation methods were based on either energy balance or mass transfer approaches. However, the combination methods were developed by combining the energy balance, heat and mass transfer approaches. These methods combine fundamental physical principles and empirical concepts based on standard meteorological observations and have been widely used for estimation of ET from climate data.

Penman (1948) first derived the combination equation. He combined the components to account for energy required to sustain evaporation and a mechanism required to remove the vapor. The energy source involved an estimate of net radiation from extraterrestrial radiation, percentage of sunshine and relative humidity. Later many scientists modified the Penman equation by incorporating the stomatal resistance, modifying the wind function and vapor pressure deficits (Penman, 1963; Wright and Jensen, 1972; Wright, 1982; Doorenbos and Pruitt, 1977; Monteith, 1965). The FAO-24 Penman (c=1), 1982 Kimberly-Penman and Penman-Monteith methods are selected for this study.

FAO-24 Corrected Penman (c = 1)

Doorenbos and Pruitt (1977) presented a modified Penman equation for estimating reference ET for grass. The major modification involved a more sensitive wind function than that used by Penman and an adjustment factor c that is based on local climatic conditions. The resulted equation is given below:

\[ E_{To} = c \left[ \frac{\Delta}{\Delta + \gamma} (R_n - G) + \frac{\gamma}{\Delta + \gamma} 2.7 W_f (e_a - e_d) \right] \]  
\[ \text{where, } c \text{ is the adjustment factor, } e_a \text{ is the saturation vapor pressure [kPa], } e_d \text{ is the actual vapor pressure [kPa] and } W_f \text{ is wind function for the FAO-24 Corrected Penman method and it can be calculated by:} \]

\[ W_f = 1 + 0.864 u_2 \]  
\[ \text{where, } u_2 \text{ is the wind speed measured at 2 m height, [m s}^{-1}]. \]
1982 Kimberly-Penman

Wright (1982) presented variable wind function coefficients for an alfalfa reference crop (ETr) at Kimberly, Idaho, expressed as fifth order polynomials with calendar day (D) as the independent variable. The 1982 Kimberly Penman equation is:

$$ETr = \frac{1}{\lambda} \left( \frac{\Delta}{\lambda + \gamma} \right) \left( R_n - G \right) + \frac{1}{\lambda} \left( \frac{\gamma}{\lambda + \gamma} \right) 6.43 \ W_f \ (e_a - e_d)$$

(9)

where $W_f$ is the wind function for the 1982 Kimberly Penman method,

$$W_f = a_w + b_w \ u_2$$

(10)

$a_w$ and $b_w$ are wind function coefficients given as:

$$a_w = 0.4 + 1.4 \ \text{exp} \left\{ -\left(\frac{(D-173)}{58}\right)^2 \right\}$$

(11)

$$b_w = 0.605 + 0.345 \ \text{exp} \left\{ -\left(\frac{(D-243)}{80}\right)^2 \right\}$$

(12)

For southern latitude use $D'$ instead of $D$ is estimated as:

$$D' = (D - 182) \quad \text{for} \quad D \geq 182$$

(13)

$$D' = (D + 182) \quad \text{for} \quad D < 182$$

(14)

Where, D is the day of the year.

FAO-56 Penman-Monteith

The FAO-56 Penman-Monteith equation is a modification of the Penman (1963) equation. The main difference is that the Penman-Monteith equation includes the effect of canopy resistance on evapotranspiration. Allen et al. (1996, 1998) presented the following form of the Penman-Monteith model for estimation of ETo in mm/day:

$$ETo = \frac{0.408 \Delta (R_n - G) + \gamma \ \frac{900}{(T_{mean} + 273)} u_2 (e_a - e_d)}{\Delta + \gamma^*}$$

(15)

in which, $T_{mean}$ is average air temperature, [°C]; $u_2$ is wind speed measured at 2 m height, [m s$^{-1}$] and $\gamma^*$ is a modified psychrometric constant, [kPa °C$^{-1}$]. In the above equation the modified psychrometric constant ($\gamma^*$) and slope of saturation vapor pressure curve ($\Delta$) at mean air temperature ($T_m$) can be calculated as:

$$\gamma^* = \gamma \left(1 + 0.34 \ u_2\right)$$

(16)

$$\Delta = (4099 \ e_a^2) / (T_{mean} + 237.3)^2$$

(17)

DESCRIPTION OF STUDY AREA AND INPUT DATA

The data were collected from 4 different climatologic stations in India. The stations were Jagdalpur, Bombay, Bellary and Kharagpur. Of these, Bellary is located in arid region and all other three in humid region.

The Jagdalpur station is located in the humid region of Central India at a latitude of 19.07° N and longitude of 82.02° E with an elevation of 557.3 m above MSL. Daily data on temperature, relative humidity, wind speed, pan evaporation and sunshine hours from January 1, 1995 to December 31, 1995 were collected from the Zonal Agricultural Research Station of Indira Gandhi Krishi Viswa Vidyalaya, Raipur. The observatory is situated in the research farm of the University and is fully covered with grass. The study area falls under tropical climate with hot summer and cold winter. The mean monthly minimum and maximum temperatures range from 20 to 26°C and 30 to 41°C respectively, from April 1 to July 31 and 3 to 20°C, and 23 to 30°C, respectively from August 1 to February 28. The mean monthly minimum relative humidity ranges from 11% in March to 79% in August and maximum value ranges from 61% in May to 94% in October. Relatively strong wind velocity is experienced in the month of June and July.

For Bellary and Bombay, the data were taken from India Meteorological Department publication. The Bellary station is located in the arid region of Southern India. The meteorological station at Bellary is located in the compound of the Government Hospital Head Quarters. The station is situated at 15.09° N latitude and 76.51° E longitude with an altitude of 449 m above MSL. The average monthly data on temperature, relative humidity, wind velocity and sunshine hours were available. The mean monthly maximum temperature of the station varies from 38.1°C in April to 29.3°C in December, whereas the mean monthly minimum temperature ranges from 17°C in January to 25.8°C in May. The mean relative humidity ranges from 39% in February to 65% in August and September. Maximum relative humidity occurs during the months of August and September. Wind velocity prominent during the months of June, July and August.

The Bombay station is situated in Colaba, almost at the extreme south end, about 5 km southwest of Fort of Bombay and separating the harbor from the Back Bay and having an altitude of 11 m from MSL. The eastern wall of observatory compound faces the sea. The average monthly data on temperature, relative humidity, wind velocity and sunshine hours from January 1, 1995 to December 31, 1995 were collected from the Zonal Agricultural Research Station of Indira Gandhi Krishi Viswa Vidyalaya, Raipur. The station is maintained throughout the year except between April and June, when the wind speed is relatively stronger.

Kharagpur is located in the coastal humid region of Eastern India. Monthly climatic data on temperature, relative humidity, wind velocity and sunshine hours for the year 1996 were used for ETo estimation. The observatory is maintained throughout the year with adequate water supply and full cover conditions. The mean monthly relative humidity varies from 55% in March to 88% in September. The mean monthly minimum temperature ranges from 12°C in January to 27°C in May, whereas mean monthly maximum temperature varies from 29°C to 43.5°C in the corresponding months. The wind speeds are gentle throughout the year except between April and June, when the wind speed is relatively stronger.
RESULTS & DISCUSSION

ETo values were estimated by all the above methods and were used for inter comparison of different methods. The ETo values obtained by different methods were compared with the FAO-56 Penman-Monteith ETo estimate due to the non-availability of reliable lysimeter data in those locations. SEE values were calculated as follows:

\[
SEE = \left( \frac{\sum_{i=1}^{n} (Y_i - \hat{Y}_i)^2}{n-1} \right)^{0.5}
\]  

(18)

Where SEE = standard error of estimate; \( Y \) = ETo estimated by the chosen standard method (FAO-56 Penman-Monteith method); \( \hat{Y} \) = corresponding ETo estimated by the comparison method; and \( n \) = total number of observations. The SEE gives equal weight to the absolute difference between the standard method and the comparison method. It is a measure of the goodness of fit between ET values estimated by the different methods and standard method. The SEE has units of mm/day and (n-1) degrees of freedom.

Linear regression analysis was performed between the ETo estimates by the standard and comparison methods as follows:

\[
ET_{\text{Penman-Monteith}} = b \cdot ET_{\text{Method}}
\]  

(19)

where, \( b \) is the regression coefficient. The use of regression through the origin was selected to evaluate the goodness of fit between ETo method estimates and the FAO-56 Penman-Monteith estimates because both values should theoretically approach the origin when actual ETo is zero. The results are discussed below:

Jagdalpur

The mean monthly ETo was estimated using all the methods and compared with the Penman-Monteith estimates. Out of all the six methods, the FAO-24 Penman(c=1) method yielded the highest mean ETo (7.7 mm/day). The Priestley-Taylor methods estimated the lowest mean ETo of 3.9 mm/day (Table 1). The FAO-24 radiation and Turc methods resulted in the minimum and maximum SEE values.

Of the two combination methods, the 1982 Kimberly-Penman method performed better than the FAO-24 Penman method.

### Table 1. Statistical summary of monthly ETo estimates for Jagdalpur

<table>
<thead>
<tr>
<th>Statistical Parameters (1)</th>
<th>ETo Method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>KP-82 (2)</td>
</tr>
<tr>
<td>Mean (mm/day)</td>
<td>6.85</td>
</tr>
<tr>
<td>SEE (mm/day)</td>
<td>1.63</td>
</tr>
<tr>
<td>( r^2 )</td>
<td>0.86</td>
</tr>
<tr>
<td>( b )</td>
<td>1.18</td>
</tr>
<tr>
<td>% of PM</td>
<td>122</td>
</tr>
</tbody>
</table>

**Fig. 1 - Comparison of ETo estimates for Jagdalpur**
The Kimberly-Penman and FAO-24 Penman overestimated ETo by about 22% and 38%, respectively, for both cases. This overestimation may be partly due to high wind speed and humidity at the site. All three radiation methods under-estimated ETo for both cases because solar radiation data were not available and were indirectly estimated from sunshine hours. The FAO-24 Radiation method performed better than all the other methods even though it under-estimated ETo by 5%. However, the Priestley-Taylor and Turc methods significantly under-estimated ETo estimates.

The Hargreaves method consistently under-estimated ETo values. Based on the SEE, the FAO-24 Radiation method ranked first and the other methods ranked in decreasing order were 1982 Kimberly-Penman, Hargreaves, Priestley-Taylor, FAO-24 Penman and Turc Radiation.

**Bombay**

For the Bombay station the mean monthly ETo ranged from 3.9 mm/day for the Hargreaves method to 8.0 mm/day for the FAO Penman. The standard error varied from 0.32 mm/day for the FAO-24 Radiation method to 2.77 mm/day for the FAO-24 Penman method (Table 2).

The 1982 Kimberly-Penman and FAO-24 Penman (c=1) method over-predicted ETo by about 14 and 49%, respectively. The FAO-24 radiation ETo estimates were in close agreement with the Penman-Monteith ETo estimates for all months except the peak month (Fig. 2). This method yielded the lowest SEE (0.32 mm/day), the highest coefficient of determination (0.94) and showed the most consistency in the values of regression coefficient. The Priestley-Taylor and Turc radiation methods under-predicted ETo by about 16 and 22%, respectively. The Hargreaves method under-predicted ETo by 28%. Among the methods the FAO-24 radiation method ranked the first based on the SEE and other methods are ranked in decreasing order are Turc, Priestley-Taylor, Hargreaves, 1982 Kimberly-Penman and FAO-24 Penman (c=1).

**Bellary**

For Bellary, which is located in the arid region, ETo were estimated using all combination, radiation and Hargreaves methods and compared with the Penman-Monteith (Fig. 3). The mean monthly ETo estimated ranged from 4.6 mm/day for the Priestley-Taylor method to 10.6 mm/day for the FAO-24 Penman (c=1) method (Table 3). The SEE of different methods ranged from 1.09 for the Kimberly-Penman to 3.6 mm/day for the FAO-24 Penman. All the methods except the combination methods under-predicted ETo.

### Table 2. Statistical summary of monthly ETo estimates for Bombay

<table>
<thead>
<tr>
<th>Statistical Parameters</th>
<th>KP-82</th>
<th>FAOP</th>
<th>FAOR</th>
<th>PT</th>
<th>TR</th>
<th>HG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (mm/day)</td>
<td>6.15</td>
<td>8.00</td>
<td>5.43</td>
<td>4.20</td>
<td>4.52</td>
<td>3.86</td>
</tr>
<tr>
<td>SEE (mm/day)</td>
<td>1.94</td>
<td>2.77</td>
<td>0.32</td>
<td>1.29</td>
<td>1.11</td>
<td>1.66</td>
</tr>
<tr>
<td>r²</td>
<td>0.55</td>
<td>0.93</td>
<td>0.94</td>
<td>0.55</td>
<td>0.93</td>
<td>0.58</td>
</tr>
<tr>
<td>b</td>
<td>0.87</td>
<td>0.70</td>
<td>0.98</td>
<td>1.20</td>
<td>1.28</td>
<td>1.39</td>
</tr>
<tr>
<td>% of PM</td>
<td>114</td>
<td>149</td>
<td>102</td>
<td>84</td>
<td>78</td>
<td>72</td>
</tr>
</tbody>
</table>

![Fig. 2 - Comparison of ETo estimates for Bombay](image-url)
The two combination methods over-predicted ETo from April to August because of high wind velocity during these months. The FAO-24 Radiation method performed better than the other two radiation methods. Furthermore, the Hargreaves method also performed poorly. Of all the methods evaluated, the Kimberly-Penman ranked first with the lowest SEE. The other methods ranked in the decreasing order are FAO-24 Radiation, Hargreaves, Turc Radiation, Priestley-Taylor and FAO-24 Penman (c=1).

**Kharagpur**

Fig. 4 shows the comparison of mean monthly ETo estimates between the Penman-Monteith and all the combination, radiation and Hargreaves methods. The Hargreaves and Turc methods yielded the maximum and minimum mean monthly ETo of 5.3 and 3.7 mm/day, respectively. The SEE of different methods ranged from 0.69 mm/day for the Kimberly-Penman to 1.39 mm/day for the Hargreaves method. The coefficient of determination was found to be greater than 0.8 for all the methods (Table 4).

Among the two combination methods, the Kimberly-Penman performed better than the FAO-24 Penman method. The Kimberly-Penman over-predicted mean monthly ETo by 14%, but gave the lowest SEE (0.69 mm/day) and a high $R^2$ (0.97). These two methods over estimated ETo during the period from March to June due to the high wind velocity during these periods. Among the three radiation methods, the FAO-24 radiation method over-estimated (4%) and the other two methods under-estimated mean monthly ETo. The FAO-24 radiation method over estimated ETo especially during first three months and the last where the mean actual sunshine hours used for estimating solar radiation are more than 8 hours. The Hargreaves method over-predicted ETo by about 31%, and yielded the maximum SEE. This may be due to the reason that maximum and minimum temperature difference is very high at this station. These deviations are expected, because the Hargreaves method is the only method that requires measurement of only one daily parameter, air temperature. Overall, the FAO-24 Radiation and 1982 Kimberly-Penman methods predicted the Penman-Monteith ETo best. The 1982 Kimberly-Penman method has the lowest SEE and ranked as

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**Table 3. Statistical summary of monthly ETo estimates for Bellary**

<table>
<thead>
<tr>
<th>ETo Estimation Method</th>
<th>KP-82 (2)</th>
<th>FAOP (3)</th>
<th>FAOR (4)</th>
<th>PT (5)</th>
<th>TR (6)</th>
<th>HG (7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (mm/day)</td>
<td>8.16</td>
<td>10.60</td>
<td>6.75</td>
<td>4.56</td>
<td>4.76</td>
<td>4.86</td>
</tr>
<tr>
<td>SEE (mm/day)</td>
<td>1.09</td>
<td>3.60</td>
<td>1.24</td>
<td>3.22</td>
<td>3.10</td>
<td>2.87</td>
</tr>
<tr>
<td>$r^2$</td>
<td>0.58</td>
<td>0.86</td>
<td>0.71</td>
<td>0.78</td>
<td>0.47</td>
<td>0.86</td>
</tr>
<tr>
<td>$b$</td>
<td>0.87</td>
<td>0.69</td>
<td>1.10</td>
<td>1.64</td>
<td>1.54</td>
<td>1.54</td>
</tr>
<tr>
<td>% of PM</td>
<td>110</td>
<td>143</td>
<td>91</td>
<td>62</td>
<td>64</td>
<td>66</td>
</tr>
</tbody>
</table>
first and other methods ranked in the decreasing order were FAO-24 radiation, Turc, Priestley-Taylor, FAO-24 Penman (c=1) and Hargreaves.

**SUMMARY & CONCLUSION**

Six empirical methods for calculating ET namely Hargreaves (Temperature based), FAO-24 Radiation, Priestley-Taylor and Turc (Radiation Based) and FAO-24 Penman and Kimberly-Penman (Combination) were evaluated using meteorological data from four climatological stations (Jagdalpur, Bombay, Bellary and Kharagpur). Due to the non-availability of measured lysimeter data, the FAO-56 Penman-Monteith method as recommended by FAO was taken as the standard for evaluating the six methods for each location.

For Jagdalpur station (humid region), the performance of the FAO-24 Radiation method was in close agreement with the FAO-56 Penman-Monteith method. FAO-24 Radiation method ranked first and the other methods ranked in decreasing order were 1982 Kimberly-Penman, Hargreaves, Turc Radiation, Priestley-Taylor and FAO-24 Penman. Of all the methods evaluated, the Kimberly-Penman predicted Penman-Monteith ET\(_o\) more closely for Bellary station. The other methods ranked in the decreasing order are FAO-24 Radiation, Hargreaves, Turc Radiation, Priestley-Taylor and FAO-24 Penman (c=1).

For Bombay the FAO-24 radiation method ranked the first based on the SEE and other methods are ranked in decreasing order were Turc, Priestley-Taylor, Hargreaves, 1982 Kimberly-Penman and FAO-24 Penman (c=1). The 1982 Kimberly-Penman method has the lowest SEE and ranked as first for the Kharagpur station and other methods ranked in the decreasing order were FAO-24 radiation, Turc, Priestley-Taylor, FAO-24 Penman (c=1) and Hargreaves.

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