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# Estimation of Crop Water Requirement of Micro Irrigated Orchard Crops for different Agro-Climatic Conditions of Madhya Pradesh

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**ABSTRACT**
*Accurate quantification of crop water requirements of any crop is essentially required for irrigation scheduling and water management. The present study was undertaken to estimate the crop water requirement of major orchard crops of twenty districts of Madhya Pradesh. These crops included mango, guava, lemon, orange, aonla, papaya and banana. The daily crop water requirement for major fruit crops of each selected district were determined using estimated average reference evapotranspiration and crop coefficient values of orchard crops at different phonological stages. The maximum daily mean crop water requirement per day for mango, guava, lemon, aonla, orange, papaya, and banana was estimated as 78.02, 74.61, 55.65, 63.19, 116.18, 18.38 and 25.99 litres respectively. The study indicated that the crop water requirement of guava (85.44 lpd), lemon (62.99 lpd) and aonla (68.71 lpd) is highest in Datia whereas for mango it is higher at Panna (84.30 lpd) during its critical stage. Among the fruit crops the water requirement of orange is found to be highest (124.11 lpd) in Sehore. These peak water requirement values for different orchard crops can be utilized for optimum use of water as well as for planning and design of drip irrigation system for different agro-climatic conditions of the state.*
***Keywords:*** *Reference evapotranspiration ($ET_o$), Aquacrop model, crop water requirement, crop coefficient ($K_c$), orchard crops.*

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## INTRODUCTION

Water is a precious and most commonly used natural resource with limited availability. Agriculture continues to draw a major share (90%) of available water resources and the demand is likely to increase further [1]. The increasing worldwide shortages of water and costs of irrigation are leading to an emphasis on accurate assessment of crop water requirement for precise irrigation water application to various crops. Adequate data on irrigation water requirements of most crops is not available in developing nations of the world. This is one of the reasons why for the failure of large scale irrigation projects in most developing countries of the world. Madhya Pradesh (MP) remains a state of developmental paradoxes of a gross cropped area of 20.76 Mha, only 6.51 Mha is net irrigated area during 2011-12. In spite of technological advances and annual rainfall (800 to 1600 mm) productivity and success of agriculture in rainfed areas continues to be governed by vagaries of rains. However, this rainfall is distributed unevenly both temporally and spatially, and the distribution is not optimal for the growing seasons of various crops. Therefore, to effectively and efficiently use the available water sources to meet the possible variation of cropping pattern, studies of crop water requirements for different crops based on reference evapotranspiration and crop coefficient are crucial. For proper irrigation management the challenge is to estimate crops water requirement in the context of growth

stages and climate [2]. Every change in the climate could affect parameters such as precipitation temperature, relative humidity and this leads to the change in crop water requirement. Hence estimation of crop water requirement according to climatic is necessary for design of efficient irrigation system. Irrigation scheduling for different crops require planning and knowledge of water requirement. The basic principle of micro irrigation is to supply water according to crop water requirement. Due to variation in phonological stages (bloom, fruit set, fruit development, fruit maturation) of perennial crops with time, water requirement of crops varies during growing period. The crop water requirement is depends on the crop characteristics and evapotranspiration of crops. Water requirement as the amount of water that is lost through evapotranspiration [3]. Reference evapotranspiration is the combined process of evaporation from the soil and transpiration from the plants [4]. A lot of research has been undertaken to estimate a kind of reference ($ET_o$) using meteorological data from which crop water requirement can be calculated [5]. The FAO recommended the Penman Monteith as sole standard approach and provide consistent reference evapotranspiration ($ET_o$) values in all region and climates. Therefore, the present study was undertaken to estimate the crop water requirement of major fruit or orchard crops based on computed reference crop evapotranspiration using long period weather data of different agro climatic conditions of Madhya Pradesh.

## MATERIALS AND METHODS

### Study area

The study was carried out for different agro-climatic conditions of Madhya Pradesh which are situated between 21°6'N to 26°30'N latitude and 74°9'E to 82°48'E longitude with an area of 1,38,923 km$^2$. The region comprises of five agro-climatic zones of Madhya Pradesh namely Kymore Plateau and Satpura Hills, Central Narmada Valley, Bundelkhand Region, Satpura Plateau and Vindhya Plateau, which covers twenty districts of the state. Madhya Pradesh state has great variability in the rainfall of 800 mm in the western part to more than 1600 mm in eastern area. The climate ranges from sub-humid area of central part to semi-arid in the northern Madhya Pradesh. Hot dry summer extends from April to June followed by monsoon

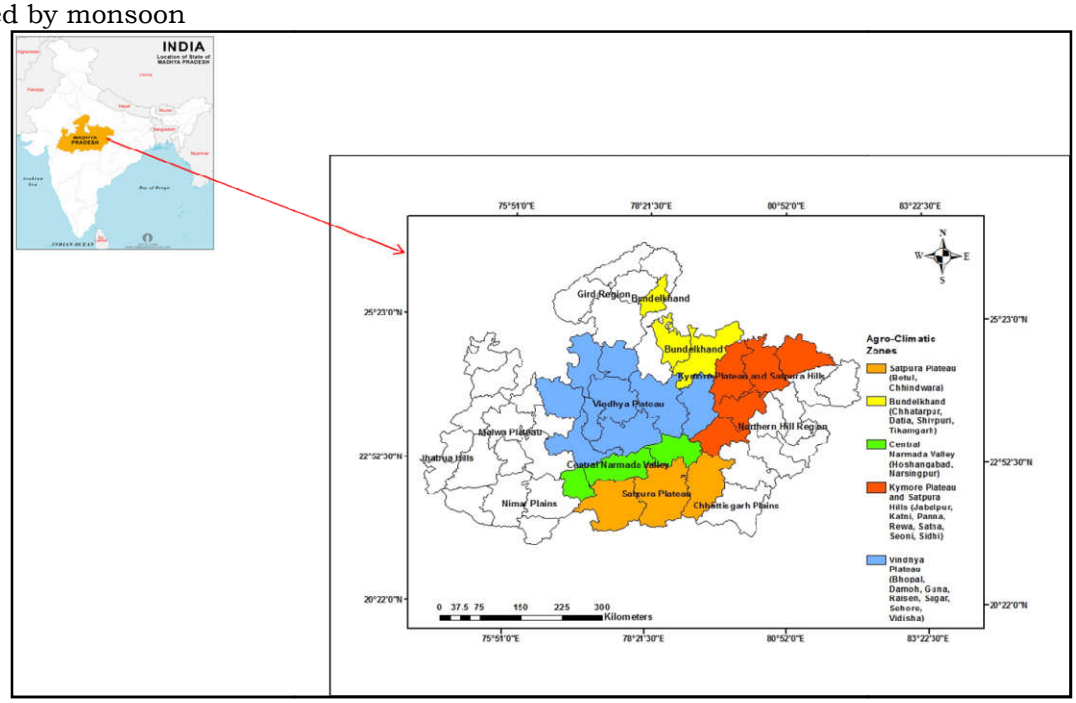


**Fig. 1: Location map of study area**

from July to September and winter months (November to February) are cool and relatively dry. Summer temperature ranging from 33°C to 44°C and winter temperature ranging from 10°C to 27°C. Various crops have also been identified for different agro-climatic zones. The daily weather data (maximum temperature, minimum temperature, mean relative humidity, wind speed and solar radiation) for 35 years period (1979 to 2013) of different districts were obtained from global weather data site and was used to estimate reference

evapotranspiration ($ET_o$). The major orchard or fruit crops of different districts were taken for the study.

**Crop water requirement**

The crop water requirement is the function of plants, source area covered by plants and evapotranspiration rate. In order to work out on crop water requirement the reference evapotranspiration ($ET_o$) for all twenty districts of different agro-climatic zones were derived from daily weather data set using Aquacrop model. Aquacrop developed by Food and Agriculture Organization, Italy which uses the FAO Penman-Monteith method to calculate reference evapotranspiration. Crop water requirement has been calculated for each plant based on crop coefficient for different phonological stages of crop and estimated reference evapotranspiration. The water requirement or volume of water to be applied for different orchard crops was calculated by the following relationship.

$$CWR = \frac{A \times ET_o \times K_c \times W_p}{E_u}$$

Where,

CWR = Water requirement of crop, litre/day/plant

A = Area of the crop ($m^2$) = row to row (m) × plant to plant spacing (m);

$ET_o$ = Reference evapotranspiration, mm/day

$K_c$ = Crop coefficient;

$W_p$ = Percentage wetted area, decimal

$E_u$ = Emission uniformity of drip system, decimal

Most perennial crops growth continuous year around and the crop coefficient ($K_c$) varies by month based on phonological stages of plant and percentage of the growth shaded by the tree canopy. The phonological stage wise values of crop coefficient for perennial fruit crops were taken from previous study done by Kisekka et al. [7] are depicted in Table 1 and the water requirement of crop is determined based on crop area covered and percentage wetted area of different orchard crops which is presented in Table 2.

**Table 1: Typical crop coefficient ($K_c$) for perennial fruit crops**

| Month | Mango | Citrus | Papaya | Guava | Banana | Aonla |
|---|---|---|---|---|---|---|
| January | 0.60 | 0.79 | 0.54 | 0.80 | 1.00 | 0.50 |
| February | 0.50 | 0.86 | 0.54 | 0.80 | 1.00 | 0.60 |
| March | 0.45 | 0.93 | 0.54 | 0.80 | 1.10 | 0.65 |
| April | 0.45 | 0.97 | 0.71 | 0.85 | 1.20 | 0.65 |
| May | 0.50 | 1.03 | 0.87 | 0.90 | 1.20 | 0.75 |
| June | 0.50 | 1.05 | 0.87 | 1.00 | 1.25 | 0.75 |
| July | 0.60 | 1.05 | 0.91 | 1.00 | 1.25 | 0.75 |
| August | 0.80 | 1.03 | 0.91 | 1.00 | 1.25 | 0.75 |
| September | 0.80 | 1.00 | 0.87 | 1.00 | 1.10 | 0.75 |
| October | 0.70 | 0.90 | 0.78 | 0.85 | 1.10 | 0.71 |
| November | 0.70 | 0.87 | 0.54 | 0.80 | 1.00 | 0.71 |
| December | 0.60 | 0.79 | 0.54 | 0.80 | 1.00 | 0.71 |

**Table 2: Spacing and percent wetted area for selected fruit crops**

| Crop | Crop spacing (m) | % wetted area |
|---|---|---|
| Mango | 6 × 6 | 40 |
| Lemon | 5 × 5 | 20 |
| Papaya | 2 × 2 | 50 |
| Guava | 5 × 5 | 30 |
| Aonla | 6 × 6 | 30 |
| Banana | 2 × 2 | 50 |
| Custard apple | 5 × 5 | 20 |
| Pomegranate | 5 × 5 | 20 |
| Grapes | 3 × 1.6 | 50 |
| Orange | 6 × 6 | 30 |

## RESULTS AND DISCUSSION

The average daily crop water requirement of major fruit crops of each districts were determined using reference evapotranspiration ($ET_o$) and crop coefficient in different phonological stages of crops. The standard meteorological week wise variation in crop water requirement of selected crops under different districts presented in Fig. 2. The daily water requirement of mango determined for all selected districts. The major variation in CWR was found in nine districts of Madhya Pradesh along with mean variation presented graphically in Fig. 2 (a). It is revealed that the water requirement of mango increases continuously from January to May then decreases afterwards. The least amount of mean CWR of mango was found to be 32.67 lpd in 1st SMW and highest 78.02 lpd in month of May (21st SMW). Among the districts it observed that the total CWR of mango is highest in Panna and it is lowest in Chhindwara. In case of lemon mean CWR varies from 14.74 lpd to 55.65 lpd and it was maximum during fruit setting stage. The highest CWR of lemon was found in Datia whereas lowest in Seoni. For guava water requirement increases continuously from 1st SMW and reaches to its peak 74.61 lpd in 23rd SMW during its fruit growth stage and total amount of CWR of guava is lowest in Narsinghpur district. In case of aonla mean CWR was found to be 13.94 lpd in month of January (1st SMW). The water requirement goes on increasing during the successive meteorological weeks, reaching a maximum of 63.19 lpd at 21st SMW and reduces to 23.54 lpd in the 32nd SMW. The CWR of aonla was higher in Datia and lower in Sagar. For orange week wise daily water requirement was determined for six districts presented in Fig. 2 (e). It was seen that small variation in water requirement from 1st SMW to 9th SMW between all districts. It has highest mean CWR 116.18 lpd at 21st SMW whereas across the location it varies between 106.57 lpd to 124.11 lpd. The papaya crop had mean crop water requirement of 7.64 lpd in the 10th SMW at the time of planting. The peak water requirement to be observed in the 21st SMW i.e. 18.38 lpd during developmental stage. The requirement than declines gradually to minimum of 4.03 lpd. The daily water requirement of banana determined only for Sidhi district and it observed that water requirement increases continuously after planting stage (10th SMW) and reaches to its peak value 25.99 lpd in 21st SMW. The least amount of CWR of banana was found to be 7.09 lpd at 1st SMW.

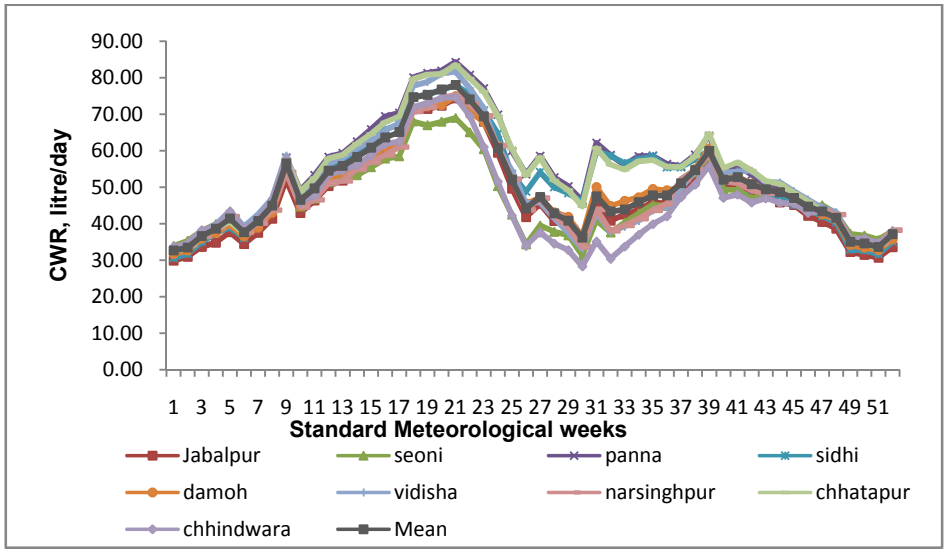


**Fig. 2(a): Stage wise variation in CWR of Mango in different district of Madhya Pradesh**

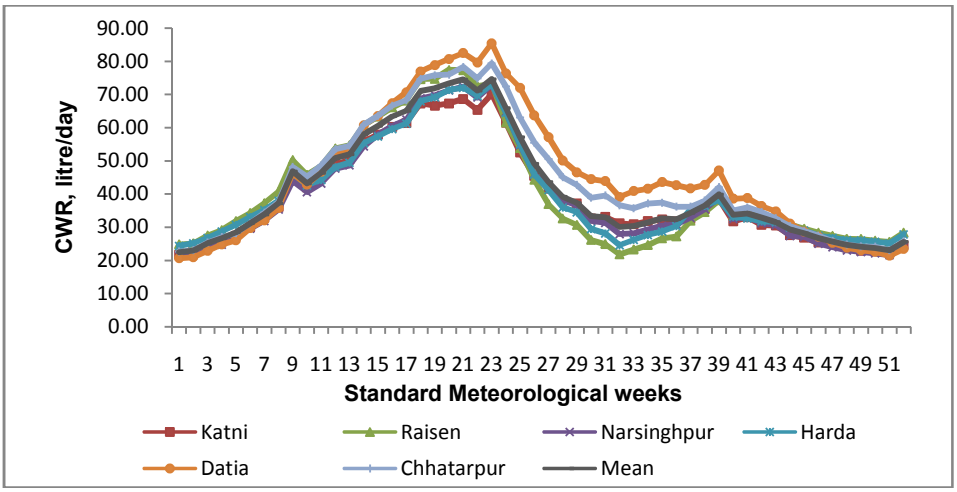


**Fig. 2(b): Stage wise variation in CWR of Guava in different district of Madhya Pradesh**

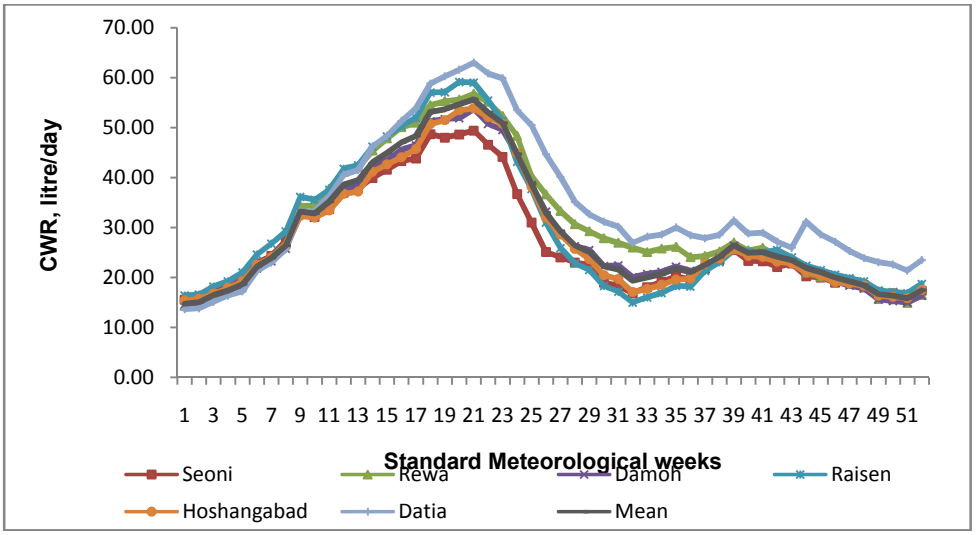


**Fig. 2(c): Stage wise variation in CWR of Lemon in different district of Madhya Pradesh**

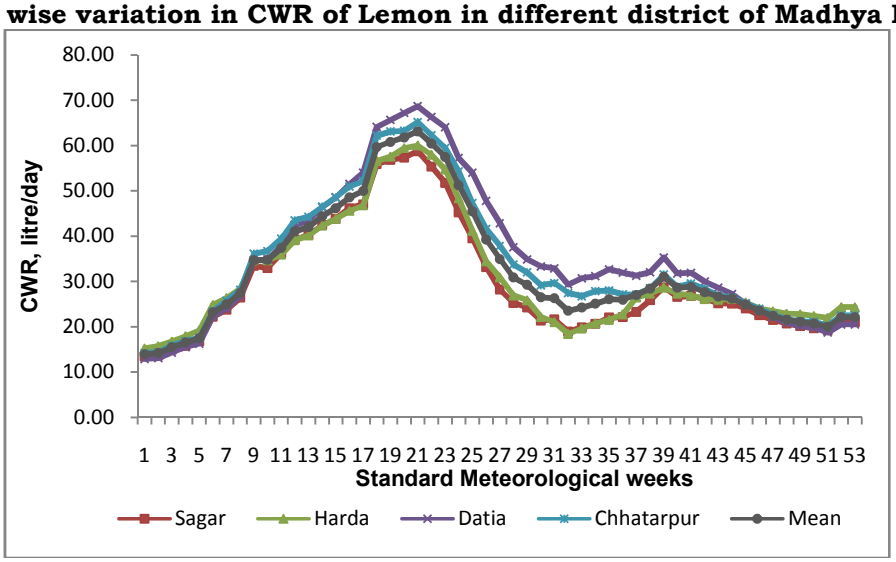


**Fig. 2(d): Stage wise variation in CWR of Aonla in different district of Madhya Pradesh**

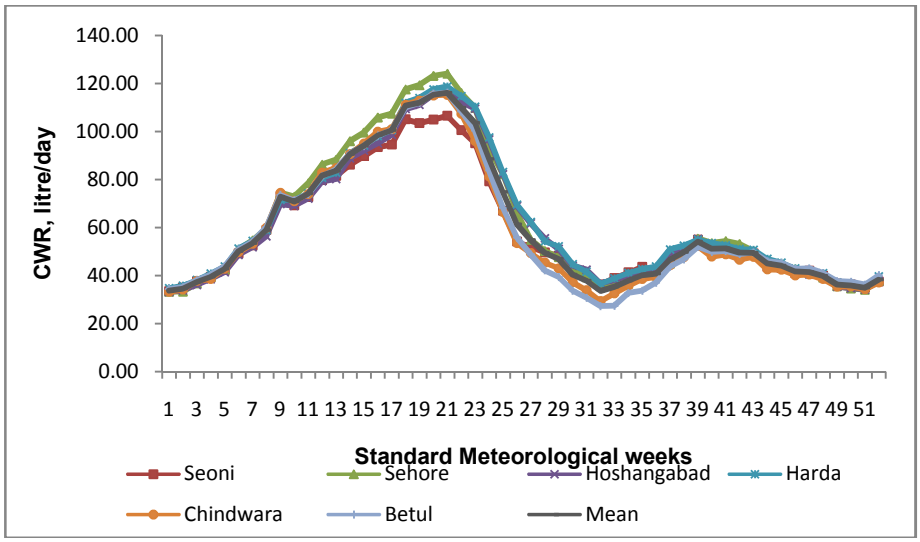


**Fig. 2(e): Stage wise variation in CWR of Orange in different district of Madhya Pradesh**

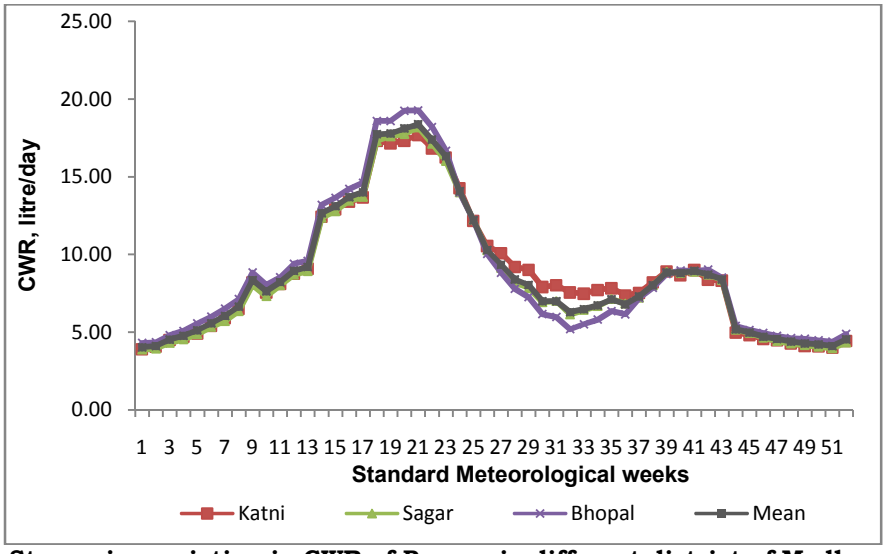


**Fig. 2(f): Stage wise variation in CWR of Papaya in different district of Madhya Pradesh**

**Fig. 2: Stage wise variation in CWR of different orchard crops in under different districts of Madhya Pradesh**

## CONCLUSIONS

It may be concluded from the study that the amounts of water required for different orchard crops are found to be increasing from initial stage to the mid season and reduces at the end of late season. The maximum amount of water required at the flowering and fruit setting stage and comparatively less water required in initial and maturity stage. Evapotranspiration being the dominant governing factor in crop water requirement estimation. The maximum daily mean crop water requirement per day for mango, guava, lemon, aonla, orange, papaya, and banana was estimated as 78.02, 74.61, 55.65, 63.19, 116.18, 18.38 and 25.99 litres respectively. Among the fruit crops the water requirement of orange is found to be highest in Sehore (124.11 lpd) and lowest in Seoni (106.57 lpd). From the analysis it has been observed that the crop water requirement for most of the fruit crops is higher in Datia followed by Chhatarpur and Panna districts whereas lower in Seoni and Chhindwara districts. The information generated can be used for planning and designing of drip irrigation system for different crops of selected districts of Madhya Pradesh.

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