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Water requirement and irrigation management of mustard cultivation in Imphal West areas of Manipur, North East India

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Abstract
In order to represent valley areas of Manipur, the current study set out to determine the crop water and irrigation water requirements for mustard crop at different sites throughout the Imphal West district of Manipur. Total net irrigation requirement (NIR) of mustard crop was highest in the year 2019-2020 at 211 mm/season and the average net irrigation requirement of mustard using the FAO-56 equation is evaluated at 193 (±16) mm/season. Therefore, this method can be suitably used to predict the water demand of mustard. Thus, this study contributed to the information and effective management on the net irrigation water requirements for mustard crop would aid in the intelligent use of available water and strategies for sustainable crop production in Imphal west area of Manipur, North East India.

Keywords: Crop evapotranspiration, effective rainfall, net irrigation requirement, mustard

1. Introduction

Water is a crucial natural resource for growing crops. It is essential for agricultural production, and making the greatest use of the water resources available is necessary for effective crop production and high yield. There are numerous biological, physiological, physical, and chemical processes at play in the relationships between crops and soil. Due to a variety of factors, water is becoming increasingly scarce in India, raising concerns about the country's rapidly growing population and ability to produce enough food. Due to its growing population and the intense mounting strain from many industries, including both agriculture and industry, the nation is currently under severe water stress. The global climate change is another significant element that is becoming a significant factor for India's water security. India's water security could be seriously threatened by climate change. In the course of the twenty-first century, it is anticipated that India's hydro-climatic regime would change dramatically. Based on an irrigation model, McCabe and Wolock's (1992) [4] analysis found a substantial correlation between the rise in mean annual water use and the rise in temperature. The sustainability of life on earth depends on the availability of water as a natural resource. For any developing area, efficient water resource management is essential (Jha *et al*., 2020) [3]. Despite the region's high rainfall, there is severe water shortage, particularly in the post-monsoon season, due to inadequate soil and water conservation practises, inadequate rainwater management conditions, and inadequate soil management practises. Therefore, effective crop production is necessary for agricultural development as well as for enhancing the economics and quality of life in rural areas (Singh *et al*., 2021) [5]. In order to improve agricultural water management methods in the irrigated area, it is urgent to estimate water supply and crop water demand under various environmental, climatic, and soil conditions. This is especially important in developing countries where water scarcity is on the rise (Singh *et al*., 2020) [6].
On the other side, the ecosystem's ability to produce food is being negatively impacted by the depletion and degradation of the natural resource base that supports agriculture. However, as the population, per capita income, and industry sector demand expand, so does the demand for agriculture. Crop production during the rabi season in Manipur is mostly dependent on soil moisture, post monsoon rainfalls and surface water that has been saved or conserved. In order to use irrigation water judiciously for irrigation scheduling, irrigation scheme planning, and effective water management system design, it is important to have accurate estimations of the water needed by various crops in a particular set of climatological circumstances of a region. In order to represent the valley areas of Manipur, an effort has been made to determine the

crop water and irrigation water requirements for mustard crop has been analysed in this study. Imphal West district is located in the central valley areas of Manipur surrounded by hilly terrains.

2. Material and Methods
2.1 Study area
The north eastern Indian state of Manipur is where the study was conducted. The observation unit is located at the Experimental Farm, ICAR Research Complex for NEH Region, Manipur Centre, Imphal, Lamphelpat, Manipur, at 24°49′36″N latitude and 93°55′28″E longitude. The study site is located at an elevation of 777 m. (MSL). The wet monsoon season lasts from the beginning of May to the end of October, with an average annual rainfall of 1449 mm in the study region. Almost the entire state of Manipur engages in widespread rainfed agriculture for the production of crops.

2.2 Data Collection
In order to estimate the mustard water demand and crop irrigation needs for this study crop data from 2017 to 2021 were used. The ICAR Research Complex for NEH Region, Manipur Centre, Imphal, Lamphelpat, Manipur provided the meteorological information, including the highest and lowest temperatures, maximum and lowest relative humidity, sunshine hours, wind speed, and crop calendar.

2.3 Crop Evapotranspiration
A device called a lysimeter is used to measure evapotranspiration (ETc) for a specific vegetation type on-site. Different techniques for estimating ETc from meteorological data are available in the absence of reliable field data. The most reliable technique used by many researchers over globe has been the FAO-56 Method also known as Penman-Monteith Evapotranspiration method. The equation of reference evapotranspiration (ET_o) for the FAO-56 method (Allen *et al*., 1998) [1] was calculated as:

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

where, ET_o = reference evapotranspiration (mm/day), R_n = net radiation at the crop surface (MJ/m^2 day), G = soil heat flux density (MJ/m^2 day), T = mean daily temperature at 2 m height in ºC, e_s = saturation vapour pressure (kPa), e_a = actual vapor pressure (kPa), e_s - e_a = saturation vapour pressure deficit (kPa), Δ = slope vapour pressure curve (kPa/ ºC), γ = psychrometric constant (kPa/ ºC), and u_2 = wind speed at 2 m height in m/s.

2.4 Crop Coefficient
The FAO-56 Table 12 (Allen *et al*., 1998) [1] provides representative crop coefficients (Kc) values for the early, middle, and late stages of crop growth for a variety of crops. The standard equation, which is shown below, was used to correct the tabulated values of the FAO-56 crop coefficients for local weather conditions:

$$K_{c\,mid} = K_{c\,mid(tab)} + [0.04(u_2 - 2) - 0.004(RH_{min} - 45)](\frac{h}{3})^{0.3} \qquad (3)$$

$$K_{cend} = K_{cend(tab)} + [0.04(u_2 - 2) - 0.004(RH_{min} - 45)](\frac{h}{3})^{0.3} \qquad (4)$$

where, $K_{c\ ini}$ = K_c value for the initial stage of the crop, $K_{c\ mid\ (tab)}$ = tabulated value of $K_{c\ mid}$ in Table 12 of FAO-56, u_2 = average daily wind speed at 2 m height during mid-crop growth stage over grass in m/s, RH_{min} = mean value for daily minimum relative humidity during the late-season stage [%], for 20% ≤ RH_{min} ≤ 80%, h = mean plant height during the late-season stage [m], for 0.1 m ≤ h ≤ 10 m, and $K_{c\text{-}end}$ (tab) = value for $K_{c\text{-}end}$ in Table 12 of FAO-56.

2.5 Effective Rainfall
The amount of water in the soil that would be received by the crop's root zone from rainfall must be calculated in order to calculate the crop's water requirements. As a result, it is necessary to measure the rainfall so that the effective rainfall can be calculated from the recorded rainfall. The part of total precipitation known as effective precipitation has the ability to lower the net amount of irrigation water required by plants. The USDA Soil Conservation Service's approach was used to calculate effective rainfall (Dastane, 1974) [2]. The used equations are shown below.

$$P_{eff} = P(125 - 0.2P)/125 \quad \text{For } p \le 250 \text{ mm}$$

$$P_{eff} = 125 + 0.1P \quad \text{For } p > 250 \text{ mm} \qquad (3)$$

Where P_{eff} = effective rainfall (mm/month); P = total precipitation (mm/month). This technique is extensively used for evaluating effective rainfall.

3. Results and Discussion
3.1 Variation of crop coefficient (Kc)
The period 2019-2020, the mid-season stage of field mustard minimum K_c obtained at 1.09 and followed by 1.11 1.12, and during 2017-2018 and 2018-2019 period respectively. On the other hand, during the mid-season stage of mustard maximum K_c is estimated at 1.22 during 2019-2020 periods, followed by 1.20 and 1.20 during the period 2017-2018 and 2018-2019, respectively. Likewise, during late season stage of mustard minimum K_c is evaluated at 0.33 during 2018-2019 periods and followed by 0.38 and 0.39 during 2017-2018 and 2019-2020 periods respectively. In contrast, during the mid-season stage of mustard maximum K_c is calculated at 1.22 during 2019-2020 period, followed by 1.20 and 1.20 respectively during 2017-2018 and 2018-2019 period respectively. The variation of crop coefficient (K_c) of mustard for crop growth period of different years during 2017-2018, 2018-2019 and 2019-2020 are given in Fig. 1(a-c).

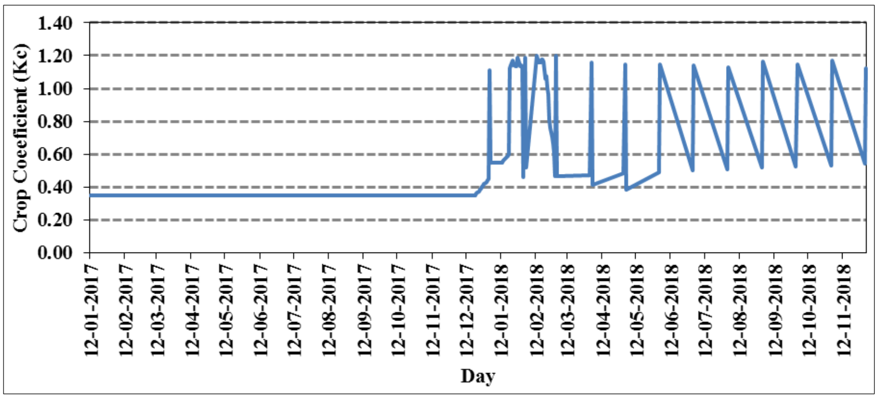

Fig 1(a): Variation of crop coefficient (K_c)of mustard for crop growth period of different years during 2017-2018 period

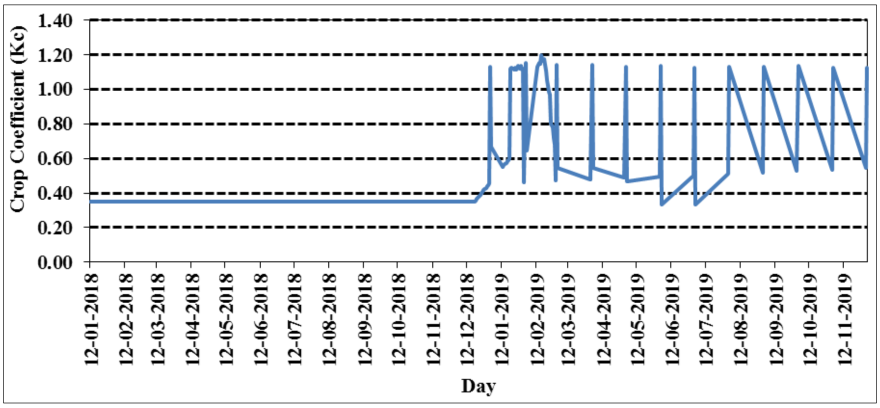

Fig 1(b): Variation of crop coefficient (K_c)of mustard for crop growth period of different years during 2018-2019 period

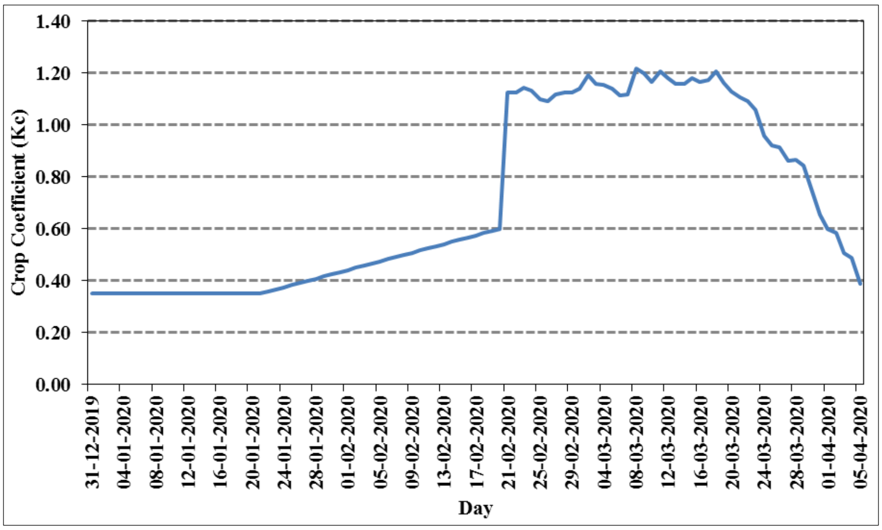

Fig1(c): Variation of crop coefficient (K_c) of mustard for crop growth period of different years during 2019-2020 period

3.2 Crop Evapotranspiration, Effective Rainfall and Net Irrigation Requirement

Crop evapotranspiration (ETc) of mustard crop is maximum in the year 2019-2020 at 7.98 mm/day and followed by the year 2017-2018 and 2018-2019 at 7.62 mm/day and 6.84 mm/day respectively. While, the crop evapotranspiration (ETc) of mustard is minimum in the year 2018-2019 at 0.37 mm/day and followed by the year 2019-2020 and 2017-2018 at 0.41 mm/day and 0.43 mm/day respectively. Further, effective rainfall (ER) is maximum in the year 2017-2018 at 3.05 mm/day and followed by 2.85 mm/day and 1.29 mm/day for the year 2019-2020 and 2018-2019. The average net irrigation requirement (NIR) of mustard crop was highest in the year 2019-2020 at 2.18 (±2.29) mm/day and followed by 1.93(±2.01) mm/day and 1.77(±1.56) mm/day during the year 2017-2018 and 2018-2019 respectively. The comparison between crop evapotranspiration, effective rainfall and net irrigation requirement are given in Fig 2(a-c).

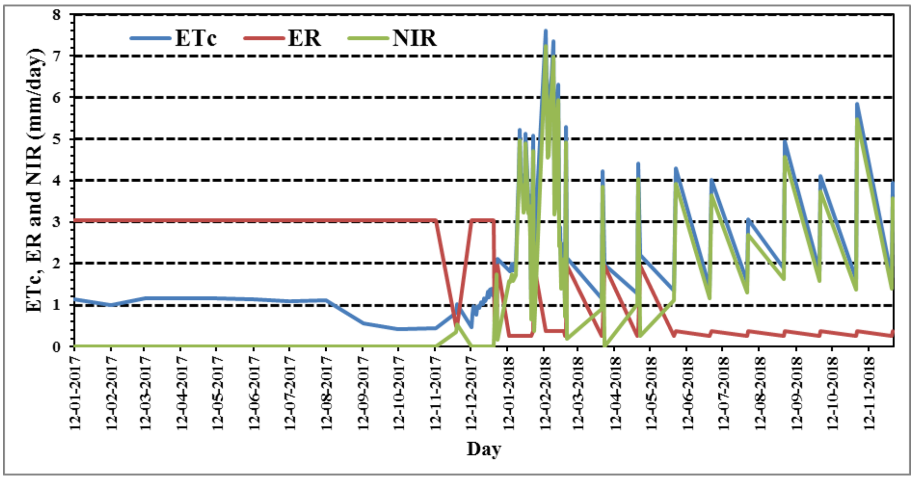

Fig 2(a): The crop evapotranspiration (ETc), effective rainfall (ER) and net irrigation requirement (NIR) for the year 2017-2018

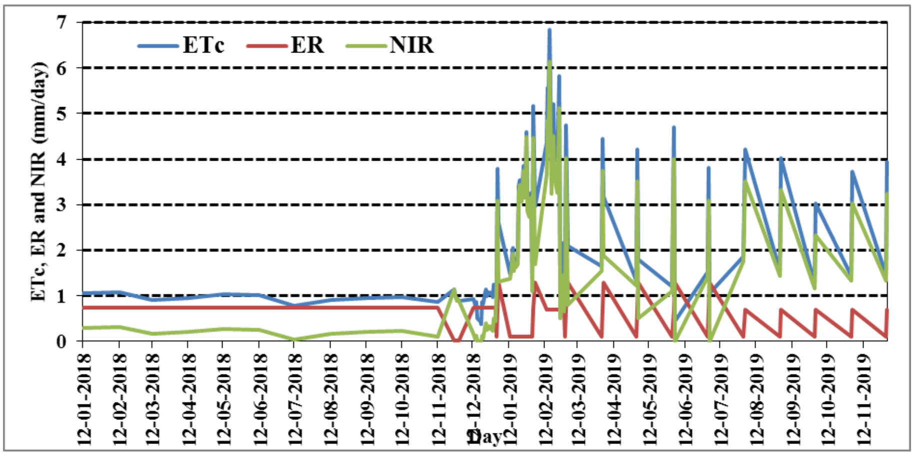

Fig 2(b): The crop evapotranspiration (ETc), effective rainfall (ER) and net irrigation requirement (NIR) for the year 2018-2019

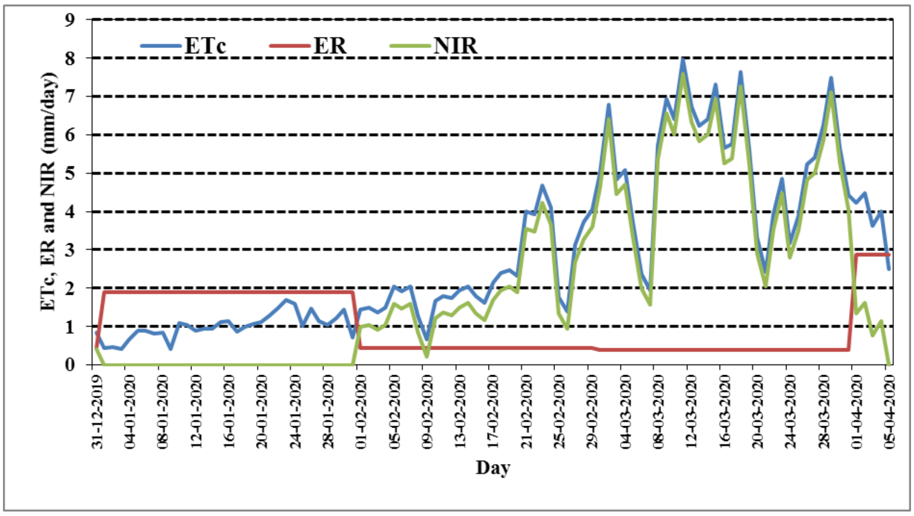

Fig 2(c): The Crop evapotranspiration (ETc), effective rainfall (ER) and net irrigation requirement (NIR) for the year 2019-2020

Total net irrigation requirement (NIR) of mustard crop was highest in the year 2019-2020 at 211 mm/season and lowest NIR was estimated in the year 2018-2019 at 180 mm/season. While moderate NIR was estimated at 187 mm/season in the year 2017-2018. The average of three years from 2017-2018 to 2019-2020 was evaluated at 193 mm/season at the standard deviation (SD) of ±16 mm/season. The NIR of mustard can be managing from the post monsoon rainfall, as well as from other sources such as river, farm pond and lakes, etc. There can also scope for utilising of groundwater as still yet to be exploited in state of Manipur. If such water management is done effectively the yield of mustard crop can be increased at a higher rate which will also help in economic development of Manipur in the agricultural sector. There should be policy from the state government for supply of irrigation scheme and management of water resources in the state of Manipur.

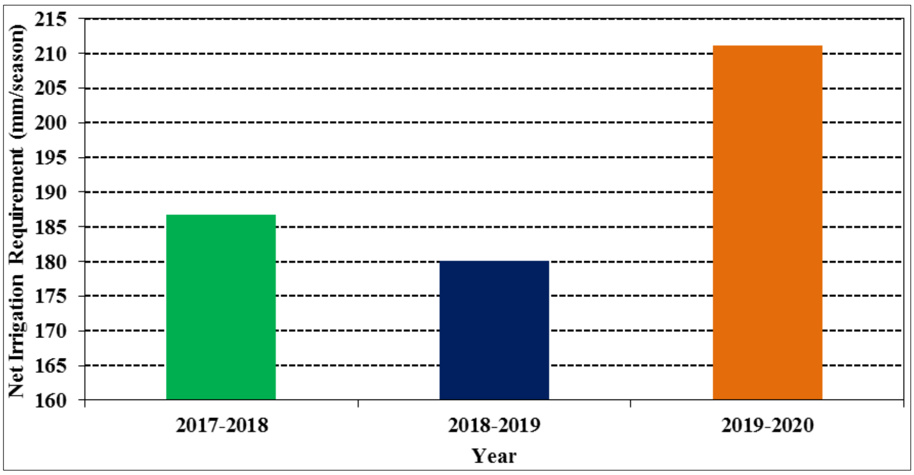

Fig. 3. The year-wise net irrigation requirement of mustard Imphal West area of Manipur

4. Conclusions

The study has been carried out to assess crop evapotranspiration (ET_c), effective rainfall, and net irrigation requirement through a case study in Imphal West district, Manipur. It is concluded that the average net irrigation requirement of mustard using the FAO-56 equation/method is estimated at 193 (±16) mm/season. Therefore, this method can be suitably used to predict the water demand of mustard. Thus, this study contributed to the effective management of net irrigation requirements and strategies for sustainable crop production in the Imphal west area of Manipur, North East India.

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