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Research Article

Study on Water Requirement of Maize (*Zea mays L.*) using CROPWAT Model in Northern Transitional Zone of Karnataka

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Abstract: Appropriate strategies for planning and management of irrigated farmland. One of the major practices adopted by the researchers for estimating water requirement of crop is modelling. For determination of crop evapotranspiration and yield responses to water, CROPWAT model is used, which was developed by the Land and Water Development Division of Food Agricultural Organization (FAO). It includes a simple water balance model that allows the simulation of crop water stress conditions and estimation of yield reductions based on well established methodologies. An experiment to study water requirement of maize (*Zea mays* L.) for under rainfed condition at Dharwad was conducted during kharif season of 2011 in field deep black soil at Main Agricultural Research Station, Dharwad. The field experimental data with the two dates of sowing of maize *i.e* June 16, 2010 and July 30, 2010 were collected and analyzed. The total water requirement of maize sown at an early date was 116.0 mm and that of sown at late date was 183.8 mm. As a result, the water demand was more as compared to early sown maize. Therefore, water requirement of maize varied with planting dates.

Keywords: Reference evapotranspiration, CROPWAT model, maize, Crop water requirement

INTRODUCTION

Water is becoming increasingly scarce worldwide. Aridity and drought are natural causes of scarcity. More recently however man-made desertification and water shortages have aggravated natural scarcity while at the same time population is increasing and there is increased competition for water among water user sectors and regions. In addition, the quality of water is often degraded, so that water resources become less and less available. Thus, improved management and planning of the water resources are needed to ensure proper use and distribution of the water among competing users. For the accurate planning and delivery of the necessary amount of the water in the time and space can conserve water. A scarce water resources and growing competitions for water will reduce its availability for irrigation. Achieving greater efficiency of water use will be a primary challenge for the near future and will include the employment of techniques and practices that deliver a more accurate supply of water to crops. Prediction of the crop water requirement is of vital importance in water resources management. Crop water requirements are normally expressed by the rate of evapotranspitration (ET) in mm day^{-1} or mm $period^{-1}$.

One of the major practices adopted by the researchers for water requirement of crops is modeling. For determination of crop evapotranspiration and yield responses to water, CROPWAT model is used which was developed by the FAO Land and Water Development Division[1]. It also includes a simple water balance model that allows the simulation of crop water stress conditions and estimation of yield reductions based on well established methodologies. Several researchers have used the CROPWAT model for analyzing crop water and requirements in different parts of the world [2].

Among the cereals, maize (*Zea mays* L.) is one of the most important crop next only to wheat and rice in terms of total production in the world. Maize is grown throughout the world under a wide range of climatic conditions. The major producers of the maize in the world are USA followed by China, Brazil, Mexico, Argentina and India. In the world, maize is grown in area of 140 m ha with a production of 800 m t. In India, during 2010-11, maize is grown in an area of 8.0 m ha with a production of 18.5 m t with an average productivity of 2302 kg ha^{-1}. In Karnataka maize is grown on an area of 0.55 m ha with a production of 1.72 m t and productivity[3] of 3127 kg ha^{-1}.

STUDY AREA

The experiment was conducted at Main Agricultural Research Station (MARS), University of Agricultural Sciences, Dharwad, during *kharif/rabi* season of 2010 under rainfed condition in plot No 75 of Block ‘C’. The geographical co-ordinates of Dharwad are 15^0 26’ N latitude and 75^0 7’ E longitude with an altitude of 678 m above mean sea level. The Main Agricultural Research Station, Dharwad is situated in the Northern Transitional Zone of Karnataka (Zone-8) and has the climate of Semi-Arid Tropics. The meteorological data of experimental year and mean of 60 years indicated that the average total rainfall for the station is 713.8 mm of which 66 per cent (468.7 mm), 23 per cent (163.6 mm) and 11 per cent (81.6 mm) are received during monsoon (June-September), post monsoon (October-January) and summer (February-May) seasons, respectively. The rainfall is fairly well distributed from April to November with two peaks one in July (153.8 mm) and another in October (125.9 mm). The total annual rainfall received during 2010 was 133 per cent (952.5 mm) of the annual average.
The annual average maximum and minimum air temperature is 30.5 and 18.5 ^{0}C, respectively (1950-2009). April (36.6 ^{0}C) and May (35.2 ^{0}C) are the hottest months, whereas December (13.2 ^{0}C) and January (14.0) are coldest months. The monthly average relative humidity fluctuating between 54.5 to 89.3 per cent.

METHODOLOGY

Field study and data collection: The field experiment on “Study on water requirement of maize (*Zea mays* L.) using CROPWAT model for transitional track of Dharwad, Karnataka was conducted during *kharif* season of 2010. According to USDA soil textural classification chart, the experimental soil belongs to clayey. The pH of the soil was neutral with 7.5. The soil was low in available nitrogen content (223.8 kg N ha^{-1}) and medium in available phosphorous (31.6 kg P_2O_5 ha^{-1}) and high in available potassium (332.3 kg K_2O ha^{-1}). The field experimental data from the Main agricultural Research Station, University of Agricultural sciences, Dharwad, Karnataka with the two dates of sowing of maize *i.e* June 16 (2010) & July 30 (2010) were collected and analyzed. The daily meteorological data used for the study (*i.e.* minimum and maximum temperature, bright sunshine hours, relative humidity and rainfall) were taken from the Agrometeorological Observatory located at the Main Agricultural Research Station, Dharwad, Karnataka. The Penman Monteith explicit equation was used to calculate the reference evapotranspiration (ETo). In present study, the USDA Soil Conservation Service method was used for calculating the effective rainfall.

Method: CROPWAT for Windows is a decision support system developed by the Land and Water Development Division of FAO, Italy with the assistance of the Institute of Irrigation and Development Studies of Southampton, UK and National Water Research Centre, Egypt. The model carries out calculations for reference evapotranspiration, crop water requirements and irrigation requirements in order to develop irrigation schedules under various management conditions. It allows the development of recommendations for improved irrigation practices, the planning of irrigation schedules and the assessment of production under rainfed conditions or deficit irrigation[4]. CROPWAT uses the FAO Penman- Monteith method for calculation of reference crop evapotranspiration. The development of irrigation schedules and evaluation of rainfed and irrigation practices are based on a daily soil-moisture balance using various options for water supply and irrigation management conditions. The water requirement is calculated according to the cropping pattern provided in the program[5]. The reference evapotranspiration (ETo) was computed by Penman-Monteith Model[6]. In this model, most of the equation parameters are directly measured or can be readily calculated from weather data. The equation can be utilized for the direct calculation of any crop evapotranspiration (ETc). The FAO Penman-Monteith method to estimate ETo is:

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

Where,

ETo = 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}],

T = Air temperature at 2 m height [°C],

u_2 = Wind speed at 2 m height [m s^{-1}],

es = Saturation vapour pressure [kPa],

ea = Actual vapour pressure [kPa],

es - ea = Saturation vapour pressure deficit [kPa],

Δ = Slope vapour pressure curve [kPa $°C^{-1}$],

Y = Psychrometric constant [kPa $°C^{-1}$].

For crop water requirements and scheduling purposes, the monthly total rainfall has to be distributed into equivalent daily values. The model assumes that the monthly rain falls in six separate rainstorms which can be changed, one every five days. The model has available four Effective Rainfall methods. To calculate the effective rainfall the USDA Soil Conservation Service method was used[7].

$$P_{eff} = P_{tot} \times \frac{125 - 0.2\ P_{tot}}{125} \qquad \text{for } P_{tot} < 250^{mm}$$

$$P_{eff} = 125 + 0.1 \times P_{tot} \qquad \text{for } P_{tot} > 250^{mm}$$

Where,

Peff = Effective rainfall (mm)

Ptot = Total rainfall (mm)

Crop water requirements (ETcrop) over the Growing season are determined from ETo and estimates of crop evaporation rates, expressed as crop coefficients (Kc), based on well-established procedures (FAO, 1977), according to the following equation:

$$ETcrop = Kc \times ETo$$

Through estimates of effective rainfall, crop irrigation requirements are calculated assuming optimal water supply. With inputs on soil water retention and infiltration characteristics and estimates of rooting depth, a daily soil water balance is calculated, predicting water content in the rooted soil by means of a water conservation equation, which takes into account the incoming and outgoing flow of water. Stress conditions in the root zone are defined by the critical soil water content, expressed as the fraction of total available soil water between field capacity and wilting point that is readily available for crop transpiration, and characterizes a soil moisture condition in which crop transpiration is not limited by any flow restrictions in the root zone. The critical soil water content varies for different crops and different crop stages and is determined by the rooting density characteristics of the crop, evaporation rate and, to some extent, by the soil type. The soil data include information on total available soil water content and the maximum infiltration rate for runoff estimates. In addition, the initial soil water content at the start of the season is needed.

RESULTS AND DISCUSSION

Weather profile: The simulated values of reference evapotranspiration (ETo) through CROPWAT model using Penman-Monteith equation, for the Dharwad is shown in the Figure 1 along with the meteorological parameters for the crop season (2010-11). The reference crop evapotranspiration shows the highest (5.8 mm day^{-1}) and lowest value (3.6 mm day^{-1}) in the month of April and August, respectively. The increase in ETo during the October to May can be explained by the reduced rainfall along with rising temperature during summer period. Thus, the rainfall and air temperature has a direct effect on the reference crop evapotranspiration (ETo). Relative Humidity is a function of air temperature. Higher the temperature more is the amount of water vapour that can be hold by the atmosphere, however the relative humidity decreases with increasing temperature due to increasing saturation point. The extent of evaporation and transpiration depend on the amount of moisture present in the atmosphere. Figure 1 indicates that the humidity of the research site varies between 47 to 86 per cent during the crop growing season. The graphical presentation **(Fig.1**) reveals that there is strong relationship between solar radiation and reference evapotranspiration (ETo). Solar radiation remains high during January, February, march april and may and ETo follows the same pattern. Figure 2 shows that of the total seasonal rainfall, 246.7 mm and 197.6 mm were effective for early and late sown maize for Dharwad during 2011-12, respectively.

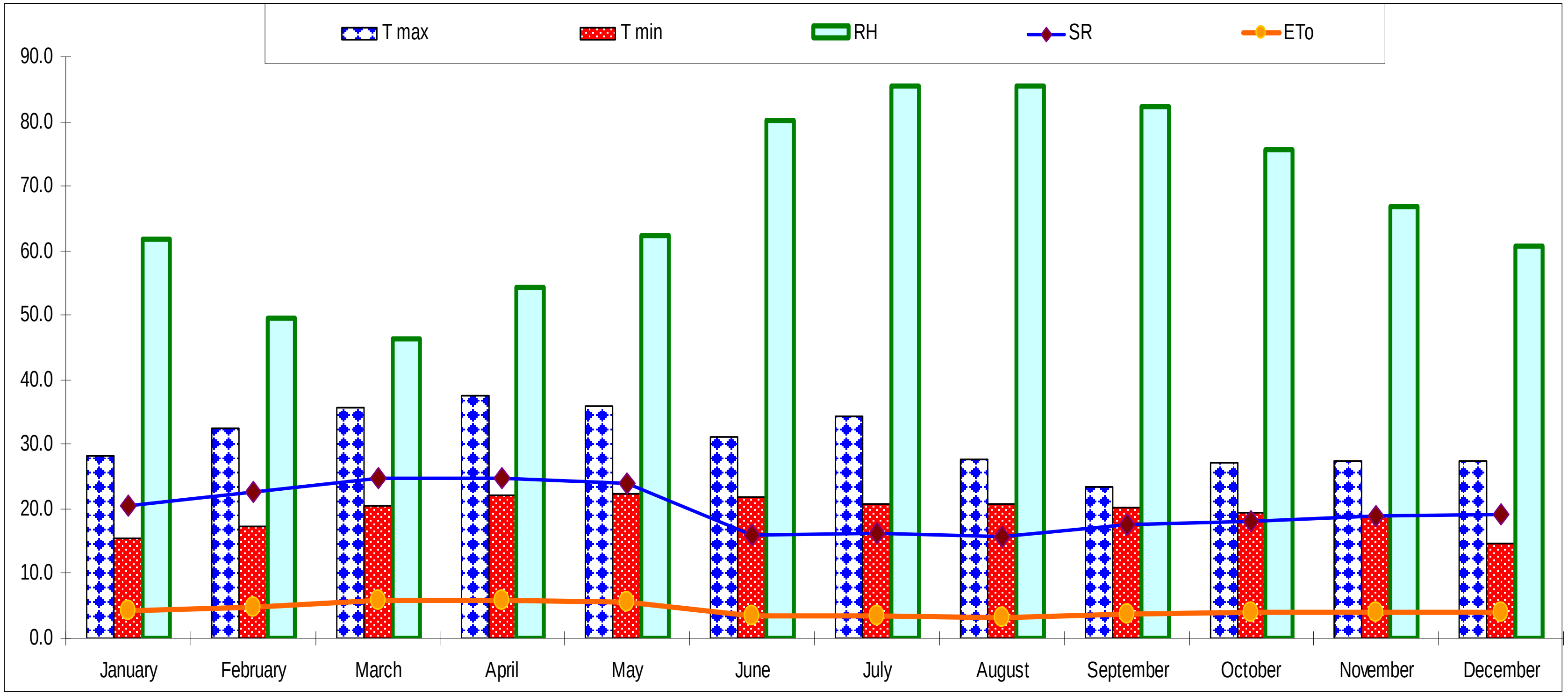

Fig. 1: Effect of weather parameters on reference evapotranspiration (ETo) at Dharwad during 2010

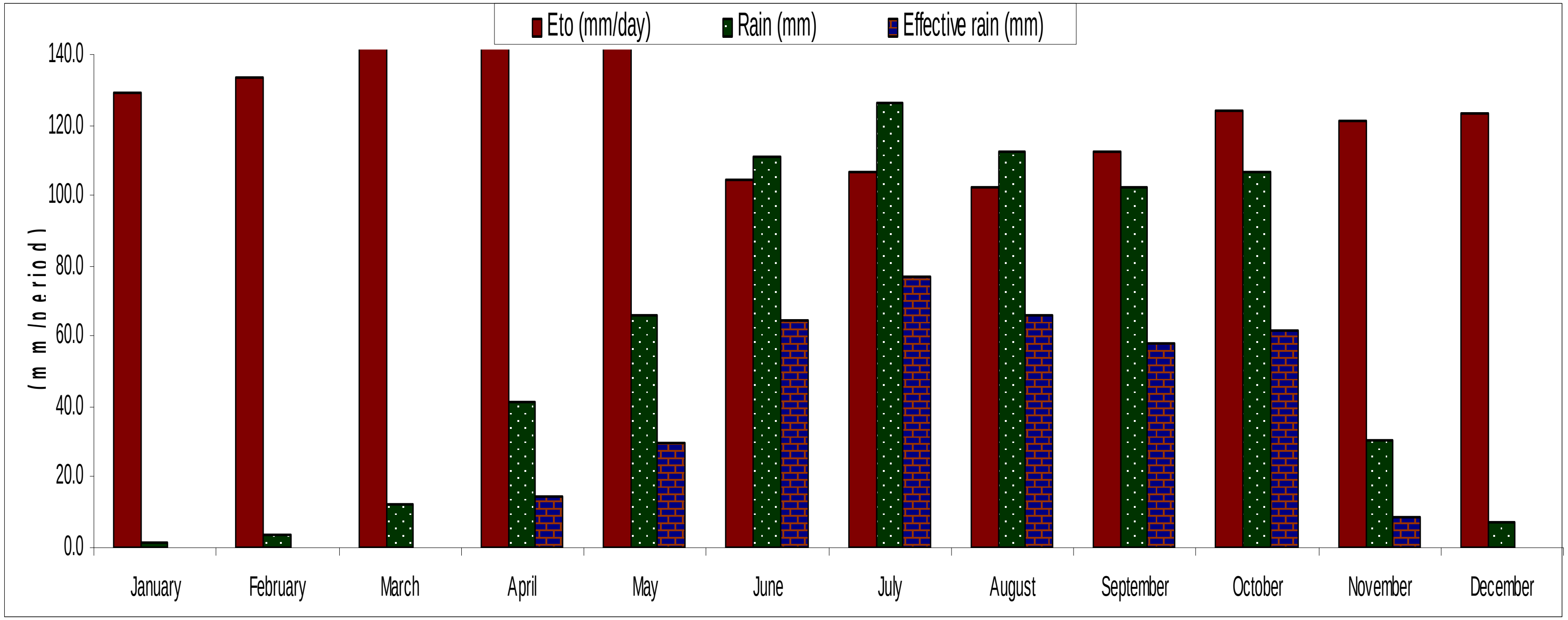

Fig. 2: Reference evapotranspiration (ETo), rainfall and effective rainfall at Dharwad

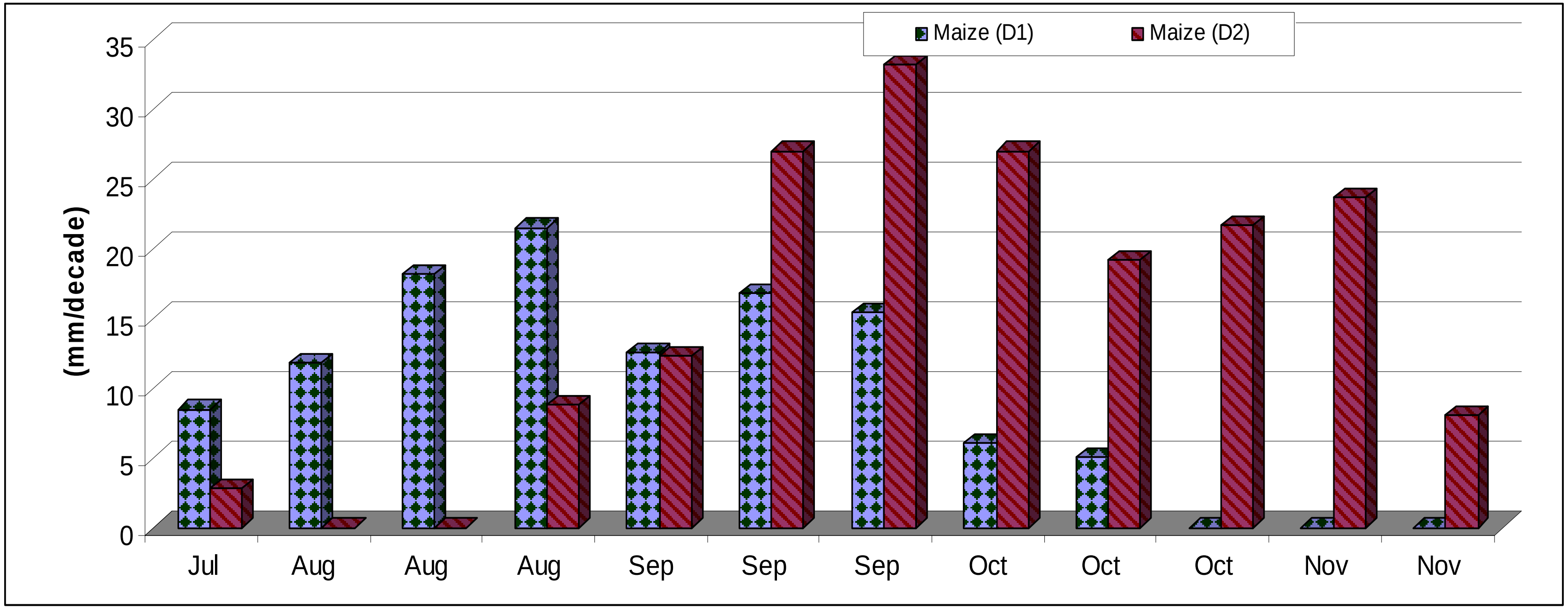

Fig. 3: Crop water requirement of early and late sown maize during crop season 2010 at Dharwad

Crop water requirement: In present study, evaporating demand is estimated using Penman-Monteith equation and it is related to the crop's water use for corresponding periods. Figure.3 shows the water requirement of maize with different sowing dates at the experimental site Dharwad. The water requirement of early sown maize (D_1) starts rising from mid-July during vegetative stage of the crop. The water requirement remains high throughout vegetative phase, varies from 11.8 to 25.1 mm decade^{-1}. It is interesting to note that, this period coincides with the tassel and cob initiation and grain filling period, which is critical stage for maize regarding water. The reduction of water demand at reproductive phase can be explained by storage of higher soil moisture in the profile in the deep black soil and also less water requirement of the crop during maturity phase due to less green leaves. In case of late sown, the water requirement during vegetative stage was less as compared to early sown maize due to even distribution of rainfall during August month. While from September II fortnight to up to harvest of crop (November) crop need higher demand of water (19.3 to 32 mm decade^{-1}). Interestingly these periods coincide with the flowering and grain filling period of maize and any shortage of water during these periods resulted in less grain yield due to reduction in number of grains per cob and also test weight. This finding could explain the reduction in maize grain yield under delayed sown condition in northern transition zone of Karnataka under rainfed condition. Being a late sown (maize-D_2) crop, late sown exposed to higher temperature during later part of its growing period. As a result, the water demand remains high as compared to early sown. The total water requirement of maize sown at an early date is 116.0 mm and that of sown at late date is 183.8. It can be inferred from the Figure 3 that the water requirement of the maize during the reproductive and grain filling stage is high due to the expected water loss through evapotranspiration and less rainfall during this stage. Therefore, it can be concluded that water requirement of maize varies with planting dates.

In present study the CROPWAT model was used to evaluate the reference evapotranspiration and crop water requirements of maize at Dharwad. From this investigation, it can conclude that, the crop water requirement varied with the planting date. This information can be effectively used for proper irrigation scheduling especially under delayed sown condition to get optimum yield. Use of models helps to achieve a more uniform recording of data and allows meaningful comparisons of findings in different studies and countries. An important attribute of the CROPWAT model is that it allows extension of the findings and conclusions from studies to conditions not tested in the field. Thus, it can provide practical recommendations to farmers and extension staff on deficit irrigation scheduling under various conditions of water supply, soil, and crop management conditions.

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