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RESEARCH

COMPARISON OF VARIOUS APPROACHES TO ESTIMATE CROP EVAPOTRANSPIRATION OF VEGETABLE CROPS

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Abstract: The estimation of crop evapotranspiration is very crucial to understand crop water requirement. There are many empirical methods are being adopted to calculate the crop evapotranspiration. A study was conducted at Indian Agricultural Research Institute, New Delhi to determine crop evapotranspiration of vegetable crops with two different approaches like percentage shaded area approach and crop co-efficient approach. In this study, the irrigation was scheduled according to real time soil moisture measurement based on tensiometer reading. The reference evapotranspiration (ETo) was calculated and compared with the crop evapotranspiration (ETc) of greenpea and okra. The estimated crop evapotranspiration (ETc) was less compared to reference evapotranspiration in both approaches. The estimated average ETo and ETc during green pea cultivation was 2.8 and 2.5 mm/day respectively. Similarly, the estimated average ETo and ETc during okra cultivation was 5.4 and 4.3 mm/day respectively. The crop evapotranspiration estimated by percentage area method was less compared to ETc calculated by crop coefficient approach.

Keywords: Crop evapotranspiration, Crop coefficient, Soil moisture, Tensiometer

INTRODUCTION

Evapotranspiration is the quantity of water transpired by plant during their growth plus moisture evaporated from the surface of the soil and the vegetation. Reference evapotranspiration is the evapotranspiration from a hypothetic reference crop. Crop evapotranspiration is the amount of water that is lost through evapotranspiration. To estimate crop evapotranspiration many methods are being followed. To understand crop water requirement crop evapotranspiration need to be estimated. To increase water use efficiency drip irrigation is followed. In many vegetable crops the yield and profit increased due to cultivation practice under drip irrigation. Water savings are also achieved in cultivation under drip irrigation (Mishra et al, 2009). Many empirical methods are being adopted to calculate the irrigation water amount to crops based on percentage shaded area approach and crop co-efficient approach. In this study, the irrigation was applied based on real time soil moisture measurement based on tensiometer reading. The water consumption rate under different methods was also determined.

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MATERIALS AND METHODS

A study was conducted at Water Technology Centre, Indian Agricultural Research Institute, New Delhi during 2021 to determine crop evapotranspiration of vegetable crops with two different approaches like percentage shaded area approach and crop co-efficient approach. In field greenpea seeds were sown in raised bed of 75 cm width under drip irrigation as well as in surface irrigation methods. Okra seeds were sown in raised bed of 45 cm width under drip irrigation and under micro sprinkler irrigation. In this study, the irrigation was scheduled according to real time soil moisture measurement based on tensiometer reading. The reference evapotranspiration (ETo) was calculated and compared with the crop evapotranspiration (ETc) of greenpea and okra. Various approacheslike percentage shaded area method, crop coefficient approach, real time soil moisture based irrigation, surface irrigation in green pea and micro sprinkler irrigation in okra were employed to estimate crop evapotranspiration.

Calculation of Reference Evapotranspiration, ET_o
Meteorological data was collected and the reference evapotranspiration was estimated by Penman Monteith method.

Penman-Monteith method

The Penman-Monteithmethod, is considered as a standard method for estimating evapotranspiration because of relatively accurate calculations for a range of climatic conditions. Kashyap and Panda (2021), assessed that penman monteith method is the most consistent method to calculate potential evapotranspiration and crop coefficient. The equation is given as,

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

Where,

ET_0 = reference evapotranspiration (mm day^{-1}),

R_n = net radiation at the cropsurface (MJ m^{-2} day^{-1}),

G = soil heat flux density (MJ m^{-2} day^{-1}),

T_{mean} = mean daily air temperature at 2m height (°C),

U_2 = wind speed at 2m height (m s^{-1}),

e_s = saturation vapor pressure (kPa),

e_a = actual vapor pressure (kPa),

e_s- e_a = saturation vapor pressure deficit (kPa),

Δ = slope vapor pressure curve (kPa °C^{-1}),

γ = psychrometric constant (kPa °C^{-1}).

Percentage shaded area approach

The depth of water application through drip irrigation system was calculated based on the equation given by Keller and Bliesner, 1990.

$$T_d = U_d \left[0.1(P_d)^{0.5}\right] \quad --- (2)$$

Where, T_d = average daily transpiration rate during the peak use month for the crop under trickle irrigation (mm/day); U_d = conventionally estimated average daily consumptive use rate during the peak use month for the mature crop with a full canopy, mm/day (i.e Ref ET); P_d = Percentage of soil surface area shaded by crop canopies at midday (solar noon), %

At noon the shaded portion by the canopy was measured. The daily shaded percentage of canopy with respect to crop spacing was calculated. The daily transpiration rate was calculated using the equation 2.

Crop coefficient approach

The actual evapotranspiration was calculated based on reference evapotranspiration rate and crop coefficient. The crop coefficient combined the effect of characteristics that distinguish a typical field crop from the grass reference, hence, different crops have different crop coefficients. The changing characteristics of the crop over the growing season also affect the K_c value. Evaporation is an integrated part of crop evapotranspiration, also has an effect on K_c.

$$ETc = ETo * \quad --- (3)$$

Where, ET_c = Crop evapotranspiration (mm); ET_o = Reference evapotranspiration (mm); K_c = Crop coefficient.

The crop coefficient values were taken from FAO 56 and multiplied with reference evapotranspiration to arrive crop evapotranspiration. The value of crop coefficient used for green pea (fresh) was 0.5 during initial stage, 0.83 during developmental stage, 1.15 during middle stage and 1.1 during end stage of crop growth. Whereas the value of crop coefficient used for okra crop was 0.5 during initial stage, 0.75 during developmental stage, 1.00 during middle stage and 0.8 during end stage of crop growth.

Real time soil moisture based irrigation

In this method, irrigation was scheduled based on soil moisture availability. Soil moisture was measured by tensiometer in terms of soil matric potential. Tensiometerswere installed at effective crop root zone depth. The pressure transducer in tensiometer automatically measures soil moisture tension and sent signal to the controller unit attached with it by cables. Soil moisture content for the respective soil matric potential was calibrated with gravimetric method. Throughout the season the moisture content availability was recorded for both greenpea and okra crop.

Estimation of Water consumption

The water consumption for greenpea and okra was estimated. In greenpeatrial the water consumption was observed through real time soil moisture based irrigation as well as surface irrigation method. In okra trial micro sprinkler irrigation was tried. The water consumption was estimated for real time soil moisture based irrigation and sprinkler irrigation method.

RESULTS AND DISCUSSION

The water consumption rate in percentage shaded area approach and crop coefficient approach was calculated and the comparison is depicted in Fig. 1 and 2 for green pea and okra.

Percentage shaded area approach

The depth of water application through drip irrigation system was calculated based on percentage shaded area approach. The depth of water application was estimated as maximum during middle stage of crop growth. In this the canopy coverage was maximum and during this stage the water requirement was also high. Very less water requirement was estimated during initial stage of crop growth. In greenpeaand okra the percentage shades varying during initial stage of crop growth varies from 1% to 20%, during developmental stage the percentage shade varying from 20% to 40%, during middle stage of crop growth the percentage shade area varied from 50% to 90%, whereas during end stage of crop growth the percentage shaded area ranged from 80% to 85%.

Crop coefficient approach

The actual evapotranspiration was calculated based on reference evapotranspiration rate and crop coefficient. The reference evapotranspiration values were found maximum compared to crop evapotranspiration values estimated by crop coefficient approach as well as by percentage shaded area based approach. The actual evapotranspiration for the chilli crop was estimated through soil water balance model and the crop coefficient was developed (Arunadevi*et al*., 2021). The crop coefficient of grapevine crop was developed from the shaded area method of estimating crop evapotranspiration (Williams *et al.*, 2022). The crop coefficient and water consumption (547 mm) of okra was estimated from the crop evapotranspiration values estimated through lysimeter method (Patil, 2010)

Comparison of cumulative water consumption

The cumulative water consumption in different method of irrigation approach was compared with real time moisture based water application method in green pea, okraa (Fig.3 and 4). The least amount of water consumption was recorded in real time moisture-based irrigation compared to drip irrigation based on crop coefficient approach and shaded area percentage. The water consumption was found nearly double in surface irrigation method with poor yield in green pea. The water consumption in Real time soil moisture (RTSM) based irrigation was 163 mm where as in crop coefficient approach it was 288.6 mm in green pea cultivation.

Similarly in okra RTSM based irrigation approach recoded less water consumption than other methods. The cumulative water consumption in okra was 350.7 mm. DeTar, 2009 calculated the total water consumption rate of 669 mm in cowpea through drip irrigation based on crop coefficient approach. Real time soil moisture based drip irrigation system produced higher yield, water use efficiency and higher fertilizer use efficiency compared to any other methods of irrigation in vegetable cultivation (Arunadevi*et al*., 2022). Daily consumptive use and crop coefficient were worked for okra crop under greenhouse condition in Nigeria (Oyedokun *et al*., 2023). The site specific crop coefficient values of okra were developed through lysimeter study by estimating crop evapotranspiration (Awari *et al*., 2024).

CONCLUSION

Crop evapotranspiration of greenpea and okra was determined with two different approaches like percentage shaded area approach and crop co-efficient approach. The estimated average ETo and ETc during green pea cultivation was 2.8 and 2.5 mm/day respectively. Similarly, the estimated average ETo and ETc during okra cultivation was 5.4 and 4.3 mm/day respectively. The crop evapotranspiration estimated by percentage area method was less compared to ETc calculated by crop coefficient approach. The water consumption rate was estimated in different methods. The least amount of water consumption was recorded in real time moisture-based irrigation scheduling compared to drip irrigation method based on crop coefficient approach and shaded area percentage in green pea and okra. The water consumption was found nearly double in surface irrigation method.

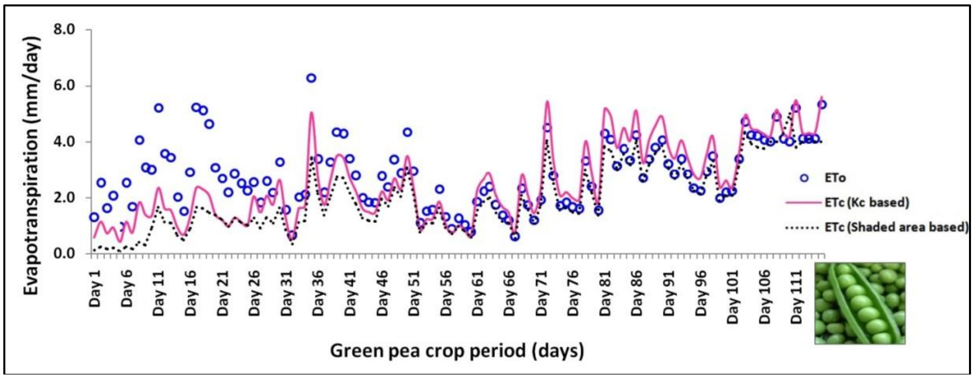

Fig. 1. Comparison of reference ET and crop evapotranspiration (Green pea)

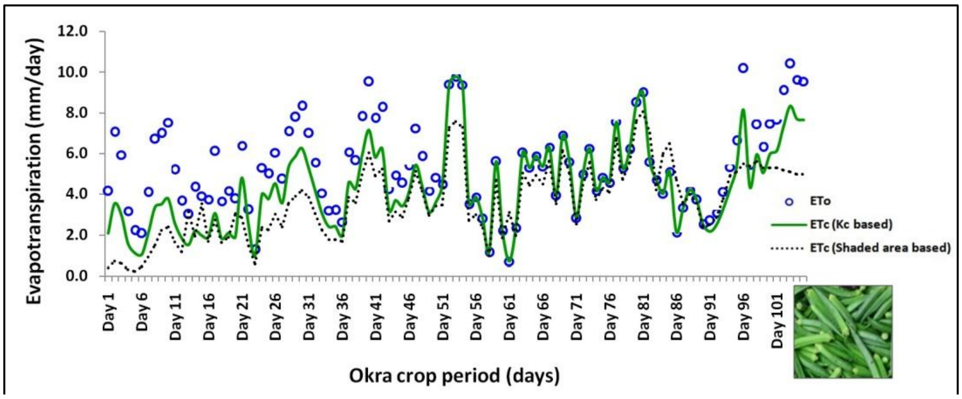

Fig.2. Comparison of reference ET crop evapotranspiration (Okra)

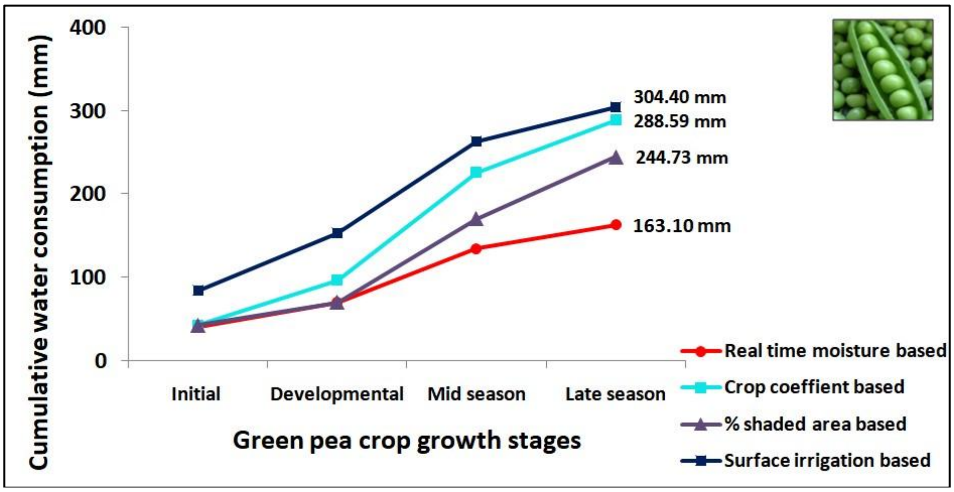

Fig. 3. Comparison of various approaches to estimate crop water consumption (Greenpea)

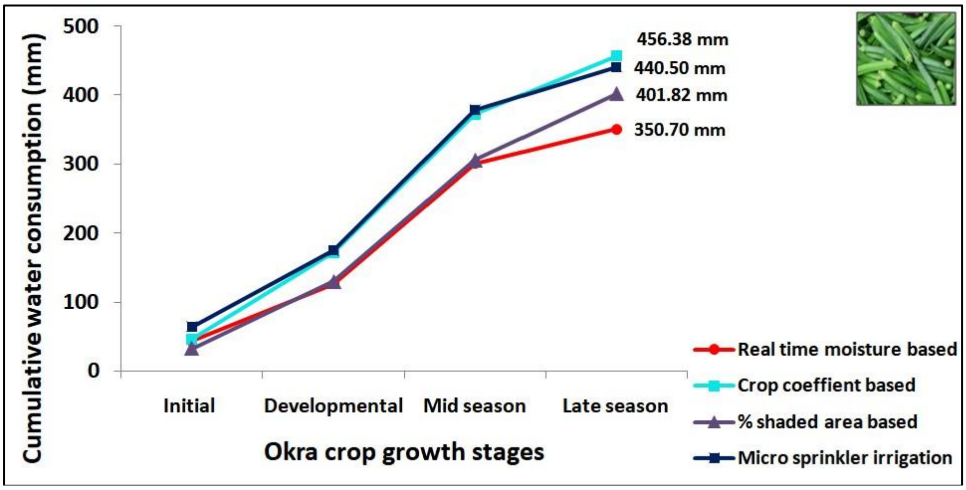

Fig. 4. Comparison of various approaches to estimate crop water consumption (okra)

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