E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2024; 7(3): 390-393
Received: 05-12-2023
Accepted: 14-01-2024

Vikas Mishra
PG Student, Department of Agronomy Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya, Uttar Pradesh, India

Er Bhavna Singh
Guest Faculty, Department of Agronomy Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya, Uttar Pradesh, India

Dr. Rakesh Kumar Mishra
Department of Agricultural Economics, SHUATS, Prayagraj, Uttar Pradesh, India

Corresponding Author:
Vikas Mishra
PG Student, Department of Agronomy Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya, Uttar Pradesh, India

Water requirement Assessment under drip micro-sprinkler & surface irrigation for broccoli yield

Vikas Mishra, ER Bhavna Singh and Dr. Rakesh Kumar Mishra

DOI: https://doi.org/10.33545/2618060X.2024.v7.i3f.454

Abstract
India is the second largest producer after China, while the US ranks third. Broccoli is a cool-season crop that can be grown in the spring or fall. In India, Broccoli is boom for rural economy. It is shallow rooted crop. Therefore, irrigation should be applied frequently to prevent the plant from injures in dry soil. Reference ET was found to be between 9.1 and 5.3 mm/day during the growing season showing a high variability due to significant changes in temperature & incoming solar radiation. Potential ET for broccoli was highest in February (116.2 mm) during the mid season showing the high crop water demand during this period. Irrigation water requirement for broccoli using Drip was found to be 33% less than Surface irrigation. Water Use Efficiency was found to higher in case of Drip (2.27 Kg/m^3) than in the case of Surface (1.36kg/m^3).

Keywords: Drip irrigation, water use efficiency, Broccoli yield

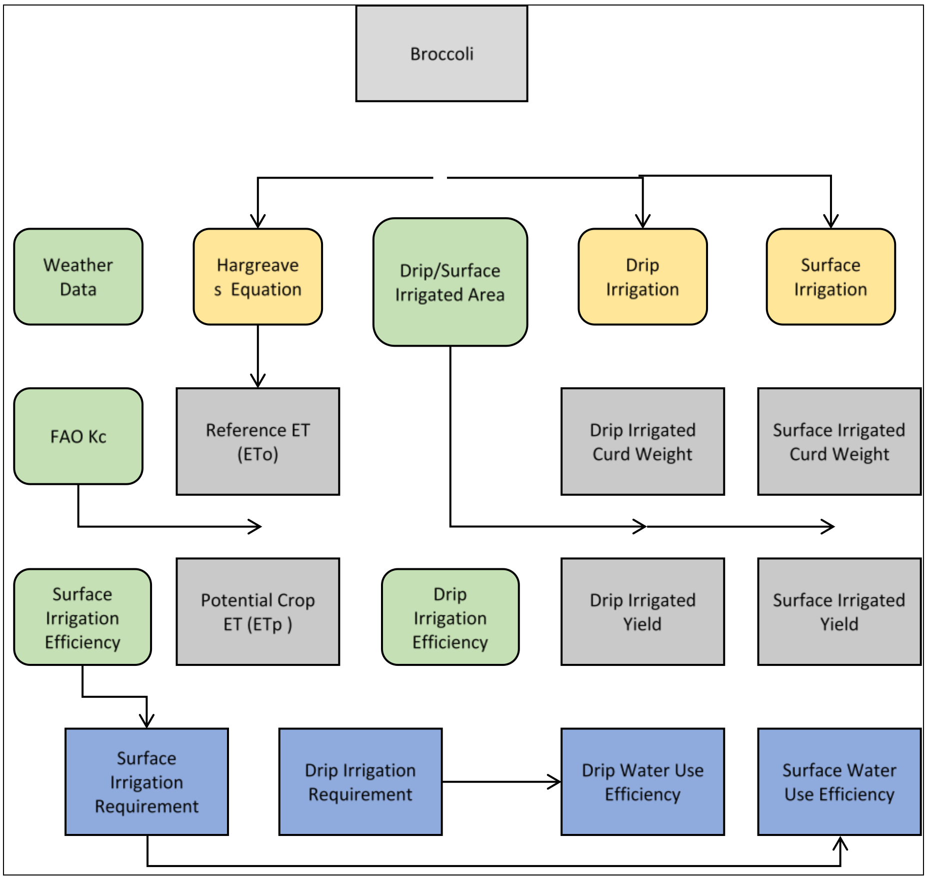
Introduction
India is the second largest producer after China, while the US ranks third. Broccoli is a cool-season crop that can be grown in the spring or fall. In India, Broccoli is boom for rural economy. It is shallow rooted crop. Therefore, irrigation should be applied frequently to prevent the plant from injures in dry soil. The crop is sensitive to water stress and needs better drainage facilities during early period of growth. Both the climatic and soil matric potential status may be used for monitoring the irrigation frequency. Indian farmers adopt various methods of irrigation like, free flooding, check-basin, furrow etc., for irrigating Broccoli.

All these aforementioned irrigation techniques comes under surface irrigation which is defined as the group of application techniques where water is applied and distributed over the soil surface by gravity. It is by far the most common form of irrigation throughout the world and has been practiced in many areas virtually unchanged for thousands of years. However, surface irrigation can result in increase water losses and decrease in overall production as the water distribution under this method is uncontrolled and therefore, inherently inefficient. In reality, some of the irrigation practices grouped under surface irrigation involves a significant degree of management.

An improper irrigation practice reduces marketable yield, quality, water use efficiency and economic return as well as leads to water logging and salinity. When water supply and irrigation equipment are adequate, irrigators tend to over irrigate, believing that applying more water will increase crop yields. Instead, over irrigation can reduce yields because the excess soil moisture often results in plant disease, nutrient leaching, and reduced pesticide effectiveness. In addition, water and energy are wasted.

Efficient irrigation and management practices are necessary to increase production and minimize water losses. Water applied directly to the root zone minimizes loss through run off and deep percolation. Precise and control water applications are necessary to achieve the desired yield and water use efficiency. Drip irrigation, also known as trickle irrigation or micro irrigation or localized irrigation is an alternative method for irrigation where water can be applied in a controlled manner compared to surface irrigation.

Drip irrigation saves water as well as fertilizer by allowing water to drip slowly to the roots of plants, either onto the soil surface or directly onto the root zone, through a network of valves, pipes, tubing, and emitters. It is done through narrow tubes that deliver water directly to the base of the plant. In micro sprinkler method, water is sprayed into the air through a sprinkler nozzle and allows falling on the land surface in a uniform pattern at a rate less than the infiltration rate of the soil. The spray is developed by the flow of water under pressure through small orifices or nozzles. The pressure is usually obtained by pumping. With careful selection of nozzles sizes, operating pressures and sprinkler spacing's, irrigation water required to refill the crop root zone can be applied uniformly at a rate to suit the infiltration rate of the soils, thereby obtaining efficient irrigation. Proper irrigation scheduling which covers the three most important aspects of irrigation - when (timing), how (method of irrigation) and how much (quantity) to irrigate, minimizes runoff and percolation losses, which in turn maximizes irrigation efficiency and increases crop production.



Materials and Methods

Irrigation water requirement is a function of total seasonal potential evapotranspiration rate and efficiency of the irrigation method utilized. In the present study the irrigation water requirements for Broccoli were estimated using the following relations.

Irrigation Water Requirement = ET_P*100/ Irrigation Method Efficiency ------------- (3.1)

Where, ET_P is the seasonal potential ET for Broccoli, mm

The seasonal potential ET for Broccoli was estimated by summaring daily ET_P values during the growing season (Oct 1st - Mar 14th). The daily ET_P for cabbage was estimated using the following equation:

$ET_p = ET_o \times K_c$ --- (3.2)

Where,

ET_p is daily potential ET for Broccoli, mm

ET_O is daily reference ET, mm

K_c is crop coefficient for Broccoli, dimensionless

In equation 3.2, crop coefficients (K_c) represent the phonological stages of the crop. It consider the impacts of crop type, variety and development stages. The crop coefficients for Broccoli were obtained from FAO 56.

Reference ET (ET_o) in equation 3.2 is evapotranspiration rate from a reference surface (e.g. grass) not short of water. It primarily describes the atmospheric demand for evaporation. In the present study ET_O was estimated using the following relation (Hargreaves al., 1985 and Hargreaves, 1994).

$ET_O = 0.0023 – 0.408R_a (T_{avg} + 17.8)TD^{0.5}$ --------------------(3.3)

Where,

ET_o = Daily Reference, mm

R_a = Extra terrestrial radiation, $MJm^{-2}d^{-1}$

T_{avg} = Daily average air temperature, ^0C

TD = Daily air temperature range, ^0C

T_{avg} in equation 3.3 is estimated as the average of daily maximum and minimum air temperatures. TD is estimated as the difference between daily maximum and daily minimum air temperature. The daily minimum and maximum temperatures were obtained using long period (2013-2023) data from the agro-meteorological station located within ANDUAT. The constant 0.408 is used to convert the radiation to evaporation equal as in mm. the other two parameter 0.0023 and 17.8 were obtained by HARGREAVES et. al.(1985) by fitting measured ET_o value in equation 3.3.

In equation 3.3, R_a is estimated using the following relationships provided in FAO 56:

$$R_a = \frac{24x60}{\pi} G_{sc} d_r [\omega_s Sin\varphi Sin\delta + Cos\varphi Cos\delta Sin\omega_s] \text{-------- (3.4)}$$

Where:

Ra is extraterrestrial radiation, $MJm^{-2}d^{-1}$

G_{sc} solar constant = 0.0820 $MJm^{-2}d^{-1}$

d_r inverse relative distance Earth-Sun (Equation 3.5),

$\omega_s$sunset hour angle (Equation 3.7) [rad],

ϕ latitude [rad] of study area,

δ solar declination (Equation 3.6) [rad].

The inverse relative distance Earth-Sun, dr, and the solar declination, δ, are given by:

$$d_r = 1 + 0.033cos\left(\frac{2\pi}{365}J\right) \text{---------------------------- (3.5)}$$

$$\delta = 0.409sin\left(\frac{2\pi}{365}J - 1.39\right) \text{-------------------------- (3.6)}$$

Where J is the number of the day in the year between 1 (1 January) and 365 or 366 (31 December).

The sunset hour angle, ω_s, is given by:

$$\omega_s = arccos[-tan\varphi tan\delta] \text{-------------------------- (3.7)}$$

Yield

The total weight of the Broccoli curds produced under drip and surface irrigation were measured post harvesting. Total yield for Broccoli under the respective irrigation method was estimated using the following equation:

Yield = Curd Weight/Area------------------------------------ (3.8)

Where,

Curd weight is the total weight of Broccoli post harvesting under drip and surface irrigation respectively, Kg.

Area refers to total area on which Broccoli was grown under drip and surface irrigation respectively, hectare.

Water use efficiency/crop water productivity

An irrigation management practice is evaluated to access better utilization of irrigation water. The evaluation is expressed in terms of crop yield per unit volume of water applied and is known as Water Use Efficiency (WUE) or Crop Water Productivity. WUE can be defined as the unit volume of water required to produce an amount of marketable crop e.g. kilograms of Broccoli produced by applying 1 m^3 of water. WUE for Broccoli grown under drip and surface irrigation was estimated as:

WUE = [crop yield (kg/ha)] / [seasonal water applied (m^3/ha)] --------------- (3.9)

Results and Discussion

Reference ET_0

Reference ET in the present study was estimated using long term (2013-2023) weather data from ANDUAT's agro meteorological station. The daily ET_0 during growing season of broccoli (Nov 11th to March 20^{th}) varied between 1.8mm – 5.6 with an average daily value of 3.7 mm and 0.8mm of standard deviation.

The monthly total ET_0 during the growing period is provided in table 4.1. Despite the month of March having least number of days during the entire growing season, considered in March ET_0 was found to be highest (180.1 mm) as compared to the other months. This can be attributed to increase in incoming solar radiation and hence the air temperature as the summer approached.

Broccoli crop coefficient

The daily crop coefficients for broccoli were estimated using the FAO guidelines and are presented. The daily crop coefficients for broccoli varied between 0.7 - 1.05 during the growing (Nov 11th - Mar 20th) and an average of 0.89 and standard deviation of 0.15.

Monthly averages of crop coefficients for cabbage during the growing period is provided. The mean crop coefficient for broccoli was found to maximum (1.05) in the month of February while minimum (0.7) being in November.

Potential crop ET (ET_P)

The daily potential ET of broccoli during the growing season (Nov 11th - Mar 20th) is presented. The daily potential ET for broccoli varied from 1.9 mm - 5.3 mm with average being 3.2 mm and 0.8 mm of standard deviation.

The monthly total potential ET of broccoli was found to be maximum (108.8 mm) in the month of March which can be attributed to increase in air temperature which in turn had increased the overall evaporative demand. The total potential ET for broccoli for entire growing season from Nov 11th - March 14th (165 days) was found to be 534.0mm.

Irrigation water requirements

The total irrigation water requirements for the entire growing season (Nov 11th - Mar 20th) was found to be 890 mm, 593mm and 712 mm for surface and drip irrigation methods respectively.

Yield

The total curd weight post harvesting for broccoli was found to be 145.5kg, 131.1 Kg and 115.5 kg under drip and surface irrigation respectively. Yield of cabbage was estimated by taking the total weight of broccoli curds under drip and surface and micro sprinkler irrigation and dividing by the respective areas in hectares. The total yield of broccoli under drip and surface irrigation methods were 13,472 Kg/ha, 12,139 kg/ha and 10,694 Kg/ha respectively.

Water use efficiency/crop water productivity

The WUE of broccoli was estimated as the ratio between the total wt. of the curds and the total volume of water applied using drip and surface irrigation respectively for the entire growing season. The WUE for broccoli under drip and surface irrigation was found to be 2.27 Kg/m^2, 1.36Kg/m^2 and1.50 Kg/m^2 respectively.

Conclusions

Broccoli crop was grown at the Irrigation Research Centre of ANDUAT using drip and surface irrigation methods. Seasonal crop water requirement, irrigation requirements, yield and water use efficiencies for broccoli grown using drip and surface irrigation methods were estimated following the FAO guidelines. The following conclusions were drawn from this study:

- Reference ET was found to be between 9.1 and 5.3 mm/day during the growing season showing a high variability due to significant changes in temperature & incoming solar radiation.
- Potential ET for broccoli was highest in February (116.2 mm) during the mid-season showing the high crop water demand during this period.
- Irrigation water requirement for broccoli using Drip was found to be 33% less than Surface irrigation.
- Water Use Efficiency was found to higher in case of Drip (2.27 Kg/m^3) than in the case of Surface (1.36kg/m^3)
- Overall, in context to the present study, Drip irrigation was found to be a better option for irrigating/growing cabbage than Surface as:
- Irrigation water requirement was less in Drip irrigation and
- Water Use Efficiency was more for Drip Irrigation.

The aforementioned conclusions further verifies the fact that evaporative losses and wastage of water is considerable less in Drip irrigation than in the Surface irrigation. Drip irrigation enables more control and precise application of water as compared to Surface irrigation.

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