Short Communication

Water and nutrient requirement in soilless cultivation of tomato (*Solanum lycopersicum L)* under protected conditions in temperate region of India

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Tomato crop *(Solanum lycopersicum L)* is one of the world's ten most significant vegetables, with around 100 MT of fresh tomato fruits production each year. Several mathematical models are available to compute the reference evapotranspiration (ET_0) using different meteorological parameters (Mehta and Pandey, 2015; Bhavsar and Patel, 2016). The crop coefficient (K_c) value indicates crop-specific water usage and is essential for accurate water requirement demand for various crops cultivated in various climatic regions (Doorenbos and Pruitt, 1977).

Reference evapotranspiration (ETo) has relation between the energy and water cycles, and it is the primary source of water vapor in the atmosphere (Salam and Islam, 2020). It regulates the quantity of water needed for vegetation development, runoff, loss of water for water bodies, and water requirements for ecological sustainability. As a result, it's one of the most significant hydro meteorological factors for irrigation and water resource management, as well as ecological monitoring (Pour *et al*., 2020; Farooq *et al.,* 2021). Climate variability has an influence on the hydrological cycle, particularly evapotranspiration (ET) and soil moisture, which are important factors in determining water movement in soil (Srivastava *et al*., 2017). These changes have major implications for management of irrigation and crop production (Bhat *et al.,* 2017).

Soilless cultivation is one of the most important aspects of long-term protected cultivation of vegetables. Nutrient reuse after nutrient replenishment, can minimize water and fertilizer use as well as environmental contamination, which are commonly linked with over-irrigation (Stanghellini *et al*., 2005).In future, cultivation in open field is not possible to feed the growing population without increasing agricultural production and hence the soil-less culture is becoming more relevant in the present scenario, to cope-up with challenges of food security and sustainability.

The field experiment in soilless cultivation on tomato (Golden-600 hybrid variety) crop was conducted under poly house condition at experimental farm of Sher-e- Kashmir University of Agricultural Sciences and Technology of Kashmir, Srinagar, India. The study area located between 32°17' and of 37°5 North latitudes and 73°26' and 80°30' and 81° East longitudes with elevation of 1500 m amsl The gothic type naturally ventilated poly house of 15x8x3 m size was used for crop production. The coco-peat one meter length slab was used to grow tomato crop. The average monthly weather data (T_{max}, T_{min}, RH, sunshine hours (S) and rainfall (R)) for the year 2019 was collected from the Agro Meteorological Field Unit of University situated around 350 m away from the field experiment.

FAO-56 Penman-Monteith method (P-M)

The FAO56 Penman-Monteith method (P-M) is widely used for reference evapotranspiration (ET_0) estimation (Allen *et al.,*1998).

$$ET_0 = \frac{0.408\,\Delta(R_n-G)+ \gamma\frac{900}{T_{mean}+273}U_2\,(e_s-e_a)}{\Delta+\gamma\,(1+0.34\,U_2)}$$

Where,

R_n =the net radiation at the crop surface (MJ m^{-2} day $^{-1}$), G= the soil

Table 1: Composition of nutrient solution used for soilless grown tomatoes in coco-peat medium

Nutrient	Nutrient in grams in 1000 liters
NPK (19%, 19% 19%)	1300
Calcium	700
Iron	300
Boron	40
Copper	60
Molybdenum	150
Zinc	30
Manganese	50
Magnesium	200

heat flux (MJ m^{-2} day^{-1}); T= the mean daily air temperature (°C), u_2 is wind speed (ms^{-1}) at 2 m height; e_s and e_a are saturation and actual vapor pressure respectively (kPa); e_s - e_a is saturation vapor pressure deficit (kPa), Δ =the slope vapour pressure curve (kPa °C^{-1}) γ =the psychrometric constant (kPa °C), LAI = leaf area index (m^2 m^{-2}), VPD = vapor pressure deficit (kPa), K = hydraulic conductivity of the soil (LT^{-1}); Cp = air specific heat at constant pressure (MJkg^{-1}C^{-1}), r_a = aerodynamic resistance (sm^{-1}), r_c = canopy resistance (sm^{-1})

Stanghellini equation

The Stanghellini equation (Stanghellini,2005) was used to evaluate the reference evapotranspiration inside the polyhouse.

Table 2: Reference evapotranspiration (ETo), crop evapotranspiration (ETc) and irrigation requirement (IR) of soilless grown tomato crop inside and outside of polyhouse in different month during crop growth stages

Month (s)	ET$_0$ (mm/day)		ET$_c$ (mm/day)		Irrigation requirement (IR) (mm/day)	
	polyhouse	Outside)	polyhouse	Outside	polyhouse	Outside
April	2.65	2.59	0.42	0.76	0.31	0.76
May	3.75	3.29	0.99	1.11	0.59	1.11
June	4.59	3.68	1.57	1.87	1.42	1.87
July	4.79	4.09	1.83	2.65	1.73	2.65
August	3.41	3.30	1.24	1.85	0.77	1.85

$$ET_o = \frac{2LAI\left\{\Delta(R_n - G) + Ki\ VPD.\rho.Cp\right\}}{\overline{ra}}{\lambda\Delta\ (1+rc/ra)} \qquad (2)$$

Crop evapotranspiration was estimated inside the polyhouseusing the simplified Penman-Monteith equation

$$ET = \alpha[1 - EXP(-K\ LAI)]R_{i,g} + \beta(LAI)VPD \qquad (3)$$

Where Kt = time unit (conversion factor) that is equal to 86,400 s day^{-1}

$$\alpha = \frac{1}{\lambda}\left(\frac{\Delta+\gamma}{\Delta}\right) \qquad (4)$$

$$\beta = \frac{1}{\lambda}\left(\frac{Kt\ \rho.Cp}{ra}/\Delta + \lambda\right) \qquad (5)$$

The crop coefficient is the ratio of reference crop evapotranspiration to the crop evapotranspiration. The crop water requirement was determined using the values of K_c throughout various growth phases, such as the initial stage, development stage, mid stage, and late-season stage.

$$ET_c = ET_o \text{ x Kc} \qquad (6)$$

The difference between crop evapotranspiration and effective rainfall is the irrigation demand.

Irrigation requirement = crop water requirement- Effective Rain   *(7)*

The evapotranspiration was calculated on daily basis and then summed for different stages of growth and total water requirement of the tomato crop. The effective rain was calculated from Cropwat software. The composition of nutrient solution used for soilless grown tomatoes in coco -peat medium is given in Table 1.

Water and nutrient use effieciency

The water and nutrient use effieciency of tomato crop in soilless medium was determined. The water use efficiency (WUE) is the ratio of yield of crop ((kg ha^{-1}) and total water applied in mm**.** The nutrient use efficiency (NUE) is the ratio of Yield (Kg) and total fertilizer applied (Kg).

Computation of ETand nutrient and water use efficiency of was determined in the study. The comparison of monthly reference evapotranspiration (ET$_0$), Crop evapotranspiration (ETc) and Irrigation requirement (IR) for soilless tomato crop inside polyhouse and open field condition is presented in Table 2. The reference evapotranspiration for polyhouse and open field was maximum in the month of July having values of 4.79 mm/day and 4.09 mm/day, respectively. The lowest value reference evapotranspiration was recorded in the month of April having values 2.65mm/day and 2.59 mm/day. The growth stage wise crop water requirement (CWR) and irrigation requirement (IR) of soilless grown tomato crop in polyhouse was also determined. Inside polyhouse CWR is equal to IR because effective rainfall is considered zero. In the greenhouse, it can be seen that during initial stage crop water requirement was 22.8mm, during development stage was 51.4 mm, mid stage it was 102.7 mm and during late-season stage, it was 57.1mm. In the greenhouse, the total CWR throughout the growing season was 234.0 mm and The CWR was maximum 102.7 mm during mid stage.

The CWR outside the greenhouse was maximum (72.95 mm) during mid stage. The stage wise IR also showed that during initial stage it was 9.3 mm, during development stage it was 27.8 mm, mid stage it was 69.6 mm and during late-season stage was 51.6 mm. The difference between CWR and IR is due to effective rain and the difference was maximum during late-season stage due

to maximum effective precipitation in outside poly house. The total effective rain over the entire cycle was 13.9 mm/Dec. The total irrigation requirement and total crop water requirement for the tomato crop outside was found to be 158.3 mm/dec. and 172.4 mm/dec, respectively. The maximum IR (19.3 mm/dec) and maximum CWR (20.05) were found during mid stage.

Drip irrigation levels had a favorable and significant effect on WUE and NUE in tomato. The WUE of tomatoes grown in soilless media is about 250 kg/ha-mm. Whereas NUE is 110 kg yield/kg nutrient. The data on fruit yield per plant in soilless culture shows that in greenhouse conditions. The fruit yield of each plant inside the polyhouse was about 13.1 kg/plant where as outside polyhouse it was 4.6 kg/plant.

In this study soilless media was evaluated inside polyhouse and in open field conditions and compared them in terms of evapotranspiration, water requirement, irrigation scheduling, water use efficiency, nutrient use efficiency and yield of tomatoes for the decision-making processes. The total crop water requirement (ETc) of soilless grown tomatoes in the greenhouse was found to be 234.0 mm. The total irrigation requirement and total crop water requirement (ETc) of the tomato crop gown outside was found to be 158.3 mm and 172.4 mm, respectively. The fruit yield of each plant inside the polyhouse was about13.1 kg/plant where as outside greenhouse it was 4.6kg/plant. So, growing of crops in the soilless media in the polyhouse gives the better yield both in terms of quality and quantity and can be used in the future to overcome the food demand.

Conflict of Interest Statement: The author (s) declares (s) that there is no conflict of interest.

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