# Stagewise water requirement of vegetable crops under protected and unprotected cultivation

ATISH SAGAR1\* and P K SINGH1

G B Pant University of Agriculture and Technology, Pantnagar, Uttarakhand 263 145, India

Received: 15 July 2020; Accepted: 06 September 2021

#### ABSTRACT

The study was undertaken with the objective to estimate the crop water requirement of capsicum (Capsicum annuum L.), cucumber (Cucumis sativus L.) and tomato (Solanum lycopersicum L.) grown under naturally ventilated polyhouse and open environment during 2015-17 at Irrigation & Drainage Engineering, GBPUAT, Pantnagar. The water requirement was estimated using reference evapotranspiration and crop coefficient by incorporating the wetting percentage, crop coefficient and crop spacing. The water requirement was estimated for crops of two seasons grown under polyhouse and open environment and was found to be 203.77 mm and 101.68 mm for capsicum 1, 126.65 mm and 285.11 mm for capsicum 2, whereas 106.53 mm and 253.22 mm for cucumber 1, 130 mm and 605.8 mm for cucumber 2 respectively. During six months of growing period, the average water requirement for crops under polyhouse and open environment were found to be 30% higher than that of polyhouse.

**Keywords**: End-season, Mid-season, Open Environment, Polyhouse

Efficient use of water is the prime objective of precision irrigation management. With future climate change and water scarcity, management of water will become an important issue in intensive vegetable cultivation. Vegetables play important role in daily food of human beings since, they are important source of vitamins, minerals and nutrients required for the maintenance of body health. The per capita vegetable consumption in India is around 180-200 g/day against a minimum requirement of about 300 g/day, recommended by Indian Council of Medical Research (ICMR) and National Institute of Nutrition (NIN), Hyderabad (Sachdeva et al. 2013).

Protected cultivation provides favourable environment conditions for the crop growth for getting high yield and produce (Singh 2004). During extreme cold in winter season (November-February) vegetables can be grown under greenhouse structure. Evapotranspiration (ET) plays an important role in maintaining water balance of ecosystem (Singh B and Sirohi N P S 2004). Accurate measurement of evapotranspiration is necessary for proper irrigation management, crop production, water resources management, environmental assessment, ecosystem modelers and solar energy system. The knowledge of reference evapotranspiration (ET<sub>o</sub>) is very essential to evaluate the actual crop evapotranspiration (ET<sub>o</sub>). It is

also useful to estimate the atmospheric water demand of the region and hence can be used for various applications including drought monitoring, irrigation scheduling, and understanding climate change impacts (Rohitashw K and Mukesh K 2017)

Meanwhile, Oudin et al. (2005) investigated optimal, method to calculate PET (Potential Evapotranspiration) for use in rainfall-runoff model. Tegos et al. (2015) summarized historical developments of ET<sub>o</sub> methods using standard meteorological data and Mcmahon et al. (2016) considered the simplification of the Penman Monteith model having high efficiency in the estimating of ET<sub>0</sub>. In polyhouse analysis, estimation of ET has predominantly been conducted by using the Penman-Monteith model (Takakura et al. 2009). Pollet (2000) also used the application of the Penman-Monteith model to calculate the ET of head lettuce in glasshouse conditions.

The optimal use of irrigation in the polyhouse can be characterized as the supply of sufficient water according to plant needs in the root zone and avoiding the leaching of nutrients in deeper soil layers (Krugger et al. 1999). Keeping above points under consideration and to develop sustainable agriculture, it is important to explore the accurate water requirement of vegetables crops under protected and unprotected cultivation at different growth stages.

## MATERIALS AND METHODS

The study was undertaken with the objective to estimate the crop water requirement of different vegetables crop under naturally ventilated polyhouse and open environment. Water

<sup>1</sup>College of Technology, G B Pant University of Agriculture & Technology, Pantnagar, Uttarakhand. \*Corresponding author email: atishmicky.sagar@gmail.com

requirement of capsicum (*Capsicum annuum* L.), cucumber (*Cucumis sativus* L.) and tomato (*Solanum lycopersicum* L.) under polyhouse were estimated using reference evapotranspiration and crop coefficient data. These data were further used to determine the water requirement under micro-irrigation by incorporating the wetting percentage and crop spacing. The water requirement was estimated for capsicum crop grown in two seasons under polyhouse and open environment for the duration starting from 10<sup>th</sup> February, 2015 to 7<sup>th</sup> July, 2015 (1<sup>st</sup> season) and 16<sup>th</sup> September, 2016 to 10<sup>th</sup> February 2017 (2<sup>nd</sup> season).

The estimated water requirement of cucumber crop also grown in two seasons under polyhouse and open environment for the durations starting from 1<sup>st</sup> September, 2015 to 14<sup>th</sup> December, 2015 (1<sup>st</sup> season) and 1<sup>st</sup> February, 2016 to 13<sup>th</sup> June 2016 (2<sup>nd</sup> season). Similarly, the water requirement of Tomato grown under polyhouse and open environment for the durations starting from 2<sup>nd</sup> November, 2017 to 29<sup>th</sup> April, 2018 for only one season.

Study area: The study area comes under climatic zone of western Himalayan region and is located in the Shivalik foothills of the Himalayas representing the Tarai regions of Uttarakhand. The experiment was conducted in a single-span polyhouse E-W oriented, located at Irrigation and Drainage Engineering Department, College of Technology, G.B. Pant University of Agriculture & Technology, Pantnagar, Uttarakhand. The experimental site is located at 29.0210°N latitude, 79.4897°E longitude and at an altitude of 243.83 m above mean sea level.

Variation of mean monthly micro environmental parameters under polyhouse: The observations were carried out in the single span, naturally ventilated polyhouse to study the variation in the micro environmental parameters such as mean monthly maximum temperature (T<sub>max</sub>), minimum temperature (T<sub>min</sub>), maximum relative humidity (RH<sub>max</sub>), and minimum relative humidity (RH<sub>min</sub>). The mean monthly maximum temperature values ranged from 34.12°C in January to 60.23°C in June with coefficient of variation of 2.27%. Similarly, the mean monthly minimum temperature values ranged from 6.07°C in December to 24.80°C in August with coefficient of variation of 2.33%. Thus, December recorded annual coldest month while June recorded the highest value of mean monthly temperature. The mean monthly maximum relative humidity values ranged from 87.87% in July to 98.65% in August whereas minimum relative humidity prevailed in the month of October (31.66%).

Variation of mean monthly micro environmental parameters in open environment: The mean monthly maximum temperature values ranged from 16.86°C in February to 43.66°C in June with coefficient of variation of 2.46%. Similarly, the mean monthly minimum temperature values ranged from 2.96°C in December to 23.56°C in August with coefficient of variation of 2.71%. Thus, December recorded annual coldest month while June recorded the highest value of mean monthly temperature indicating the annual hottest month. The mean monthly

maximum Relative Humidity values ranged from 93.00% in September to 98% in April and June where, least value was obtained in April i.e. 18%. The maximum wind velocity was in June which was 8 km/h and minimum was 2.41 km/h in December.

Estimation of reference evapotranspiration for water requirement: The reference evapotranspiration (ET<sub>0</sub>) was estimated using the FAO Penman Monteith (1998) model. Estimation of ET<sub>0</sub> using equation 2.1 on daily basis required meteorological data consisting of maximum and minimum daily air temperatures ( $T_{max}$  and  $T_{min}$ ), mean daily actual vapour pressure (e<sub>a</sub>) derived from dew point temperature or relative humidity (Rh<sub>1</sub> and Rh<sub>2</sub>) data, daily average of 24 h wind speed measured at 2 m height  $(u_2)$ , net radiation (R<sub>n</sub>) measured or computed from solar and long wave-radiation or the actual duration of sunshine hours (n). The extra- terrestrial radiation (R<sub>n</sub>) and day light hours (n) for specific day of the month was also computed. As the magnitude of soil heat flux (G) beneath the reference grass surface was relatively small, it was ignored for daily time stake. The wind velocity inside polyhouse was zero. Reference evapotranspiration (ET<sub>0</sub>) was further used for estimation of water requirement of capsicum, cucumber and tomato crop under naturally ventilated polyhouse and open environment. The FAO P-M equation is considered to be the best method (Allen et al. 1998) across a wide range of climatic conditions and is recommended by the FAO as the standard method for estimation of ET<sub>0</sub> (Kumar R et al. 2012). The Penman- Monteith equation for the calculation of daily  $ET_0$  (mm/day) is given below.

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

Where, ET<sub>o</sub> is reference evapotranspiration (mm/day), R<sub>n</sub> is net radiation at the crop surface (MJ/m/day), G is soil heat flux density (MJ/m²/day), T is mean daily air temperature at 2 m height (°C), U<sub>2</sub> is wind speed at 2 m height (m/s), e<sub>s</sub> is saturation vapour pressure (kPa), e<sub>a</sub> is actual vapour pressure (kPa), e<sub>s</sub> - e<sub>a</sub> is saturation vapour pressure deficit, VPD (kPa),  $\Delta$  is slope vapour pressure curve (kPa/°C),  $\gamma$  is psychrometric constant (kPa/°C).

The effects of characteristics that distinguish field crops from grass are integrated into the crop coefficient ( $K_c$ ). In the crop coefficient approach, crop evapotranspiration is calculated by multiplying  $ET_0$  by  $K_c$  (FAO 56).

Estimation of crop evapotranspiration ( $ET_o$ ): Crop evapotranspiration under standard conditions is defined as the evapotranspiration from disease free, well fertilized crops, grown in large fields, under optimum field conditions and achieving full production under the given climatic conditions. The daily irrigation water requirement for the vegetable crops was estimated by using the following relationship:

$$WR = ET_o \times K_c \times W_p \times A$$

where, WR is crop water requirement (L/d), ET<sub>o</sub> is reference

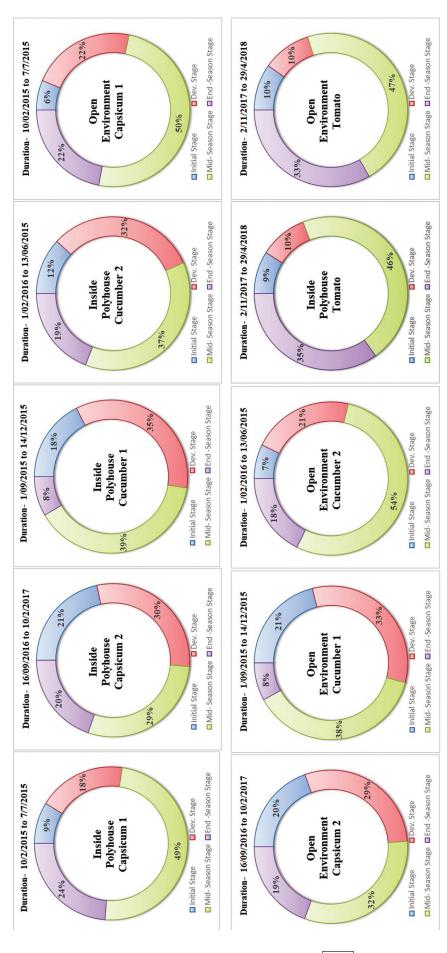


Fig 1 Relative water requirement of total ET<sub>c</sub> during different growth stages in percentage under polyhouse and open environment

Table 1 Crop coefficient values of various vegetable crops

Crop	K <sub>c ini</sub>	K <sub>c mid</sub>	K <sub>c end</sub>
Capsicum	0.33	0.67	0.30
Cucumber	0.50	1.01	0.75
Tomato	0.55	1.04	0.78

the end of the crop period under both conditions. The water requirement in open environment was estimated as 55.85% higher than that of polyhouse.

Water requirement of cucumber: The pattern of crop water requirement for 1<sup>st</sup> season crop under open environment and polyhouse showed similar trend and was found to be continuously decreasing in trend up to the

Table 2 Crop water requirement of different crops in mm

Stage/ Crop	Inside Polyhouse				Open Environment			
	Capsicum 1	Capsicum 2	Cucumber 1	Cucumber 2	Capsicum 1	Capsicum 2	Cucumber 1	Cucumber 2
Initial Stage	17.81	27.36	18.70	15.46	6.40	55.63	53.42	43.80
Dev. Stage	37.97	37.65	37.11	40.99	22.45	83.71	83.67	129.83
Mid- Season Stage	99.60	36.67	41.78	48.56	50.48	90.36	96.00	324.99
End -Season Stage	48.40	24.98	8.94	24.88	22.35	55.42	20.13	107.16
Total	203.78	126.66	106.53	129.89	101.68	285.12	253.22	605.78

The water requirement were estimated for crops of two seasons grown under polyhouse and open environment was found to be 203.77 mm and 101.68 mm for capsicum 1, 126.65 mm and 285.11 mm for capsicum 2, whereas 106.53 mm and 253.22 mm for cucumber 1, 130 mm and 605.8 mm for cucumber 2 respectively.

evapotranspiration (mm/d),  $K_c$  is crop coefficient,  $W_p$  is wetting fraction (taken as 0.90 for close growing crops), A is plant area [i.e. spacing between rows (m) × spacing between plants, (m)].

The crop coefficients,  $K_c$ , were used based on the FAO-56 curve methods. The crop coefficient, values vary with the type of crop, its growing stage, growing season and the prevailing weather conditions. The value of  $K_c$  for capsicum was taken from Tahashildar *et al.* 2015, for tomato Tahashildar *et al.* (2017), whereas for Cucumber from FAO Irrigation and Drainage Paper No. 56 (Table 1).

### RESULTS AND DISCUSSION

Water requirement of capsicum, cucumber and tomato under polyhouse were estimated using reference evapotranspiration and crop coefficient data. These data were further used to determine the water requirement under micro irrigation by incorporating the wetting percentage and crop spacing.

Water requirement of capsicum: The estimated water requirement of capsicum crop grown in two seasons under polyhouse and open environment for the durations starting from 10<sup>th</sup> February, 2015 to 7<sup>th</sup> July, 2015 (Capsicum 1) and 16<sup>th</sup> September, 2016 to 10<sup>th</sup> February 2017 (Capsicum 2) are presented Fig 1. The duration of the crop was 148 days for both the season. The pattern of crop water requirement for 1st season crop under open environment was continuously increasing up to mid-June and then started decreasing till the end of the crop period. However, the pattern of water requirement under polyhouse uniformly increased up to mid-June then gradually decreased till final harvesting of the crop. The results of the 2<sup>nd</sup> season crop showed that the pattern of crop water requirement under polyhouse and open environment followed similar pattern throughout cropping period. The water requirement was found to be in decreasing trend up to mid-January 2016 and then in increasing trend till

end of the crop period. The water requirement in open environment was estimated as 59.54% higher than that of polyhouse. The pattern of crop water requirement of the 2<sup>nd</sup> season under polyhouse and open environment followed the similar pattern but in different manner, initially both line increased uniformly with constant difference but after the end of February 2016, the difference started increasing till end of crop period.

Growth stage wise water requirement of different vegetable crops under polyhouse (PH) and open environment (OE): In this context the investigation was carried out to distinguish the water requirement of vegetables crop at various plant growth stages. The highest water requirement was 50.43 l/plant during mid-season stage for capsicum 1 among all crops grown in open environment and under polyhouse. The maximum water requirement for tomato crop was 17.79 1/ plant during mid-season stage. The water requirement was low during initial stages of growth in all the crops. This is due to low canopy cover of the crop during this stage. With the advancement of vegetative stage and development of crop, the percent ground cover, leaf area and crop height increased resulting in increase in water requirement. The water requirement was maximum during the mid-season stage i.e., vegetative growth, flowering and fruiting period. The water requirement again depleted with the decrease in canopy cover during the late season stage.

Water requirement of capsicum and cucumber under polyhouse were estimated using reference evapotranspiration and crop coefficient data. The summary of the results drawn on the basis of the investigations are summarised in Table 2.

#### REFERENCES

Allen R G, Smith M, Perrier A and Pereira L S. 1994. An update for the definition of reference evapotranspiration. ICID bulletin **43**(2): 1–34.

Buttaro D, Santamaria P, Signore A, Cantore V, Boari F, Montesano

- F F and Parente A. 2015. Irrigation management of greenhouse tomato and cucumber using tensiometer: effects on yield, quality and water use. *Agriculture and agricultural science procedia* **4**: 440–44.
- Krugger E, Schmidt G and Rasim G. 1999. Effect of irrigation on yield, fruit size and firmness of strawberry cv. Elsanta. IV International Strawberry Symposium 567: 471–74.
- Kumar R, Jat M K and Shankar V. 2012. Methods to estimate irrigated reference crop evapotranspiration—a review. *Water Science and Technology* **66**(3): 525–35.
- McMahon T A, Finlayson B L and Peel M C. 2016. Historical developments of models for estimating evaporation using standard meteorological data. *Wiley Interdisciplinary Reviews: Water* **3**(6): 788–818.
- Oudin L, Hervieu F, Michel C, Perrin C, Andréassian V, Anctil F and Loumagne C. 2005. Which potential evapotranspiration input for a lumped rainfall–runoff model. Part2- Towards a simple and efficient potential evapotranspiration model for rainfall–runoff modelling. *Journal of Hydrology* 303(1-4): 290–306.
- Papadopopouls I. 1992. Fertigation of vegetables in plastic-house: present situation and future aspects. *Acta Horticulturae* (ISHS) 323: 1–174.
- Pollet I V and Pieters J G. 2000. Condensation and radiation transmittance of greenhouse cladding materials, part 2: results for a complete condensation cycle. *Journal of Agricultural Engineering Research* **75**(1): 65–72.
- Rohitashw K and Mukesh K. 2017. Evaluation of reference evapotranspiration models using single crop coefficient method and lysimeter data. *Indian Journal of Agricultural Sciences* **87**(3): 350–54.

- Sachdeva S, Sachdev T R and Sachdeva R. 2013. Increasing fruit and vegetable consumption: challenges and opportunities. *Indian journal of community medicine: official publication of Indian Association of Preventive & Social Medicine* **38**(4): 192.
- Sagar A and Singh P K. (2019). Evapotranspiration Based Micro Irrigation Scheduling of Tomato Crop under Naturally Ventilated Polyhouse. Current Journal of Applied Science and Technology 1-7.
- Singh B and Sirohi N P S. 2004, June. Protected cultivation of vegetables in India: problems and future prospects. (In) International Symposium on Greenhouses, Environmental Controls and In-house Mechanization for Crop Production in the Tropics 710: 339–42.
- Tahashildar M, Bora P K, Ray L I and Thakuria D. 2015.
  Determination of Crop Coefficient for Capsicum (Capsicum annumm L.) in Eastern Himalayan Region through Field Lysimeter. Indian Journal of Dryland Agricultural Research and Development 30(1): 15–23.
- Tahashildar M, Bora P K, Ray L I and Ram V. 2017. Cropcoefficients of tomato as derived using monolithic weighing type lysimeter in mid hill region of Meghalaya. MAUSAM **68**(4): 723–32.
- Takakura T, Kubota C, Sase S, Hayashi M, Ishii M, Takayama K and Giacomelli G A. 2009. Measurement of evapotranspiration rate in a single-span greenhouse using the energy-balance equation. *Biosystems engineering* **102**(3): 298–304.
- Tegos A, Malamos N and Koutsoyiannis D. 2015. A parsimonious regional parametric evapotranspiration model based on a simplification of the Penman–Monteith formula. *Journal of Hydrology* 524: 708–17.