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Water Requirement of Solanaceous Vegetable Crops in Kashmir Valley

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Authors' contributions

This work was carried out in collaboration among all authors. Author LA designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Author SQ and Author BA managed the analyses of the study. Authors OAB and NM managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Studies on water balance and irrigation at agricultural areas require accurate values of reference evapotranspiration. The values obtained can help farmers to determine the water requirement of these vegetable crops so that proper irrigation can be applied according to its growth stage and weather condition. The objective of this study was to calculate water requirements for four Solanaceous vegetable crops: Tomato, Potato, Chilli and Brinjal grown in temperate conditions of Kashmir Valley. Water requirements were calculated using the FAO-56 Penman-Monteith Method. The total water requirement for tomato, potato, chilli and brinjal was found 458 mm, 286 mm, 343 mm and 410 mm respectively. The maximum water was required by all crops during the mid-season stage comprising nearly 45-60% of the total water requirement of the crop.

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1. INTRODUCTION

The family Solanaceae includes potato, tomato, eggplant, capsicum and chillies. These comprise of some of the most popular vegetables grown and consumed in Kashmir Valley. A large quantity of water is used by these crops for their growth and development. Nearly 90% of the water absorbed by roots is transpired back to the atmosphere. This increases the water requirement of these crops [1]. Hence adequate water management is essential for proper growth and yield of these crops. Water stress affects the crop yields especially if it occurs at the key stages of growth [2]. Insufficient water supply inhibits plant growth in terms of leaf area and plant height [3,4].

Crop water use is a function of evaporation (E) and transpiration (T) that fluctuates daily. Evapotranspiration (ET) is one of the most difficult components to be determined in the water balance as compared to the other components like precipitation or irrigation [5, 6].The crop evapotranspiration (ETc) is defined as "the ET rate of crop under standard conditions where there is no stress by water quality constraints, pests, or inadequate soil fertility" [7]. Correct estimation of Etc and thus the crop water requirement is essential for determination of water availability, crop water balance and crop water requirements [8].

Crop water requirement is defined as the "depth of water required by plants to compensate the water loss via ET so that plants are able to grow optimally while soil water balances the shows amount of soil water added, removed or stored in volume of soil during a time period" [7]. ETc can help farmers in order to decide irrigation period and irrigation frequency to increase crop yields and profits while minimizing input costs, energy and environmental impacts.

A number of models for the estimation of ET_0 are available but the results are inconsistent with the values of ET_0. This is due to the differences in modeling assumptions and input data requirements. Another reason for inconsistency is that the models are developed for specific regions [9]. FAO-56 Penman-Monteith due to close approximation to lysimeter observations is consideredto be the best approach for estimating ET_0 [10,11].

2. STUDY AREA AND DATA USED

The state of Jammu and Kashmir falls politically within the Indian union and is located in the north western extremity of the Himalayas between 32º10' and 37º10' N latitudes and 72º30' and 80°30' E longitudes. Covering a total area of about 2, 22,236 km^2, the state is divided into three provinces (Fig. 1) viz. Jammu (26293 km^2), Ladakh (59146 km^2) and Kashmir Valley (15948 km^2), with each province differing markedly from one another in its climate, vegetation and culture. The altitude of the irrigated temperate region of Kashmir Valley rangesfrom 1524–2100 m AMSL .Theweather data for the present study was obtained from Regional Meteorological Centre, Srinagar. The data set consisted of daily values of maximum temperature, minimum temperature, morning relative humidity, afternoon relative humidity, sunshine hours and wind speed for the period 1992-2017.

3. METHODOLOGY

The reference evapotranspiration and the crop water requirement of the solanaceous crops were estimated by means of FAO-56 Penman-Monteith Method [7]. The FAO-56 Penman-Monteith Method has been established as a standard method for calculation of reference evapotranspiration [12,13,14]. The method has also been verified to be more suitable for Indian conditions than FAO-24 Penman method [15]. The irrigation water use efficiency can be enhanced by the application of FAO-56 PM Method and thus the distribution of water at different levels can be improved [16]. The method has been applied to determine the water requirement of number of crops grown in Kashmir valley like cereal crops, pulses apple and saffron [17,18,19].

3.1 FAO-56 Penman-Monteith Methods

The penman method was developed to calculate the evaporation from open water surfaces [20]. The model was then modified by Monteith for its application to cropped surfaces as well [21]. The equation of

Fig. 1. Study area

modified Penman-Monteith method also known as FAO-56 Penman-Monteith method is given as:

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

Where,

ET_0 = reference evapotranspiration [mm day^{-1}],

R_n = net radiation at the crop surface [MJ m-2 day

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

T_{mean} = mean daily air temperature at 2 m height [°C]

U_2 = wind speed at 2 m 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}].

4. CROP COEFFICIENT (K_c)

Crop coefficients (Kc) are used with reference evapotranspiration (ET_0) toestimate specific crop evapotranspiration rates (ETc) and are defined as the ratio of ETc to ET_0. Crop coefficients vary with crop type, the growth stage of the crop, weather and irrigation method, and with some cultural practices.

Crop coefficient is an important parameter for indirect estimation of crop evapotranspiration. It gives information on water requirement of crop and the impact of other parameters on it, for instance, biological characteristics of crops, level of crop yield, conditions of soil tillage etc. [9,22]. The values of crop coefficients for the crops under study at different stages of growth were obtained from FAO.

4.1 Crop Water Requirement

The canopy properties and aerodynamic resistance of the crop results in difference between the reference evapotranspiration and crop water requirement. The water requirement of the crops is also different for different stages of growth. Crop Water Requirement is thus computed from reference evapotranspiration and crop coefficient as [10]:

$$ET_c = K_c \times ET_o$$

Where,

ET_c = crop evapotranspiration/Crop water requirement (mm day^{-1}),

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

K_c = crop coefficient.

5. SOLANACEOUS VEGETABLES

5.1 Tomato (*Solanum lycopersicum* L.)

Tomato is the most important fruit vegetable grown throughout the world and ranking second in importance to potato in many countries. It is

widely accepted as 'Protective Food' and is grown extensively in the state of Jammu and Kashmir. Tomato is a warm season crop and cannot withstand severe frosts. A warm sunny weather is most suited for its proper ripening, color development, quality and high yields. The optimum temperature for germination ranges from 18°C to 26°C. The irrigation should be so arranged that the soil remains moderately moist. Excessive irrigation induces the plant to vine and dropping off the blossoms. During summer season, irrigation at every 3 to 4 days interval is necessary, whereas for spring season crop 10 to 15 days interval is sufficient. Subsequent irrigations are given according to need of the crop. Irrigation at flowering and fruiting stage is imperative for higher quality yields.

5.2 Brinjal / Eggplant (*Solanum melongena* L.)

Brinjal is the most common vegetable crop grown widely in India for its varied shape, size and colour of fruits. It is a popular vegetable due to its high productivity and wide adaptation. It is a warm season crop and requires a relatively long growing season with plenty of sunshine and moderate day temperature of 21°-27°C. Brinjal being moderately deep rooted crop needs irrigation at frequent intervals. During summer, irrigation is applied at 4-5 days interval and during cold weather irrigation is applied at 10-15 days interval. Furrow method of irrigation is the most common method.

5.3 Chilli (*Capsicum annuum* L.)

Chilli or hot pepper is a tropical vegetable crop commonly used throughout the world as a spice for its pungency and red ripe color of dried fruits. It is also cultivated for its green immature fruits. It performs well in warm humid tropical and subtropical regions. Optimum temperature for its successful cultivation is 20-33°C. Extreme temperature (below 15°C and above 35°C) significantly reduces the reproductive growth and pollen viability. Humidity favors vegetative growth but frost is injurious. Low temperature at fruit ripening stage is likely to delay the color development in fruits. It performs well in areas with annual rainfall ranging from 600 - 1200 mm spread over a period of 4 - 5 months.

Chilli needs judicious irrigation for proper growth and yield. Frequent and heavy irrigations induce lanky growth and cause flower shedding. Critical stages of irrigation are flowering, fruit setting and fruit development and after periodical harvests. During summer, irrigation is applied at 4 - 5 days interval and during cold weather irrigation is applied at 10 - 12 days interval. Furrow method is the most common method of irrigation.

5.4 Potato (*Solanum tuberosum* L.)

Potato is the fourth major food crops of the world after rice, wheat and maize. Being a major source of carbohydrates, it is often used as a substitute for cereals and is grown in almost every country. Potato is a cool season crop; however at low temperature vegetative growth is restricted and at freezing point irrecoverable frost injury occurs to the plant. Long days coupled with high temperature conditions promote vegetative growth without formation of tubers and short day with low temperature induce tuberization. Optimum temperature for good plant growth is 15-20°C. Most of the cultivars do not tuberize when the prevailing night temperature is above 21°C.

Adequate irrigation is essential for proper growth and yield of potato. Stolon formation, tuber initiation and tuber development stages are the critical stages for irrigation. Irrigating the crop at an interval of 7-10 days after earthing up is essential. The level of irrigation water must not exceed 3/4th part of ridges. Total water requirement for the crop varies between 350-550 mm.

6. RESULTS AND DISCUSSION

The total water requirement for the different crops of Solanaceous family under Kashmir valley conditions was determined using FAO-56 Penman-Monteith Method. 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. This comprised nearly 40-60% of the total water requirement of the crops. The water requirement again depleted with the decrease in canopy cover during the late season stage. In this stage, the leaves and roots begin to dry and finally the crops die. The relative water requirement during different stages is shown in Fig. 2.

The water requirement of the four crops namely tomato, potato, chilli and brinjal during different stages of growth is given in Table 1.

The water requirement is represented graphically in Fig. 3. The water requirement was lowest for the potato crop being 286 mm. while the highest water requirement was obtained for the tomato crop being 457 mm. the water requirement for brinjal and chilly was found to be 410 and 340 mm respectively.

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Table 1. Crop water requirement of different crops of solanaceae family in Kashmir Valley

	Tomato	Brinjal	Potato	Chilli
Initial	49	38	22	20
Development	112	112	37	58
Mid-Season	195	191	131	198
Late-season	102	68	97	68
Total	457	410	286	343

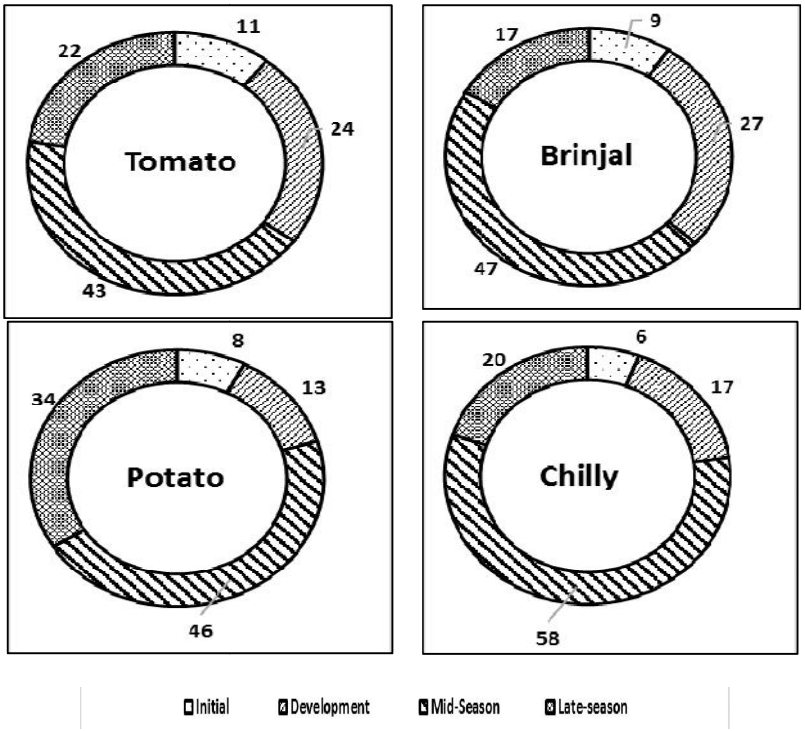

Fig. 2. Relative water requirement during different growth stages

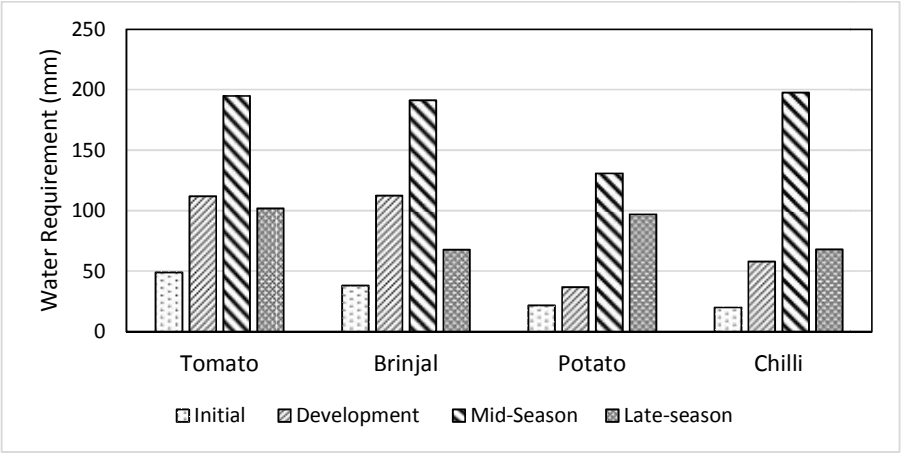

Fig. 3. Water requirement (mm) of different solanaceous crops for different stages of growth

7. CONCLUSION

In the present study, the crop water requirement of four Solanaceous vegetable crops: Tomato, Potato, Chilli and Brinjal grown in temperate conditions of Kashmir Valley was determined based on crop coefficient (Kc) and reference evapotranspiration (ET_0). Results showed that these crops required moderate amount of water throughout their period of growth (286-457 mm). The maximum water requirement was during the vegetative growth stage for all the crops. Efficient irrigation practices, especially at critical stages of crop growth, are necessary to ensure good yield particularly in absence or failure of rainfall during the growing season. The data on potential evapotranspiration and the Crop Water Requirement is essential for determination of irrigation water requirements. This in turn is helpful for efficient scheduling of irrigation for harvesting maximum benefits.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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