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Short communication

Climate-smart irrigation strategies for drip-irrigated exotic vegetables: An analysis of Bok choy, Chinese cabbage, Zucchini, and Broccoli in Jalandhar Punjab

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Exotic vegetables like Bok choy, Chinese cabbage, Zucchini, and Broccoli are nutrient-rich, promoting immunity, digestion, and reducing inflammation. Their sensitivity to water stress necessitates efficient irrigation for optimal yield. Climate change exacerbates water demand by disrupting precipitation patterns and increasing extreme weather events, emphasizing the need for precise water management. Rising temperatures and shifts in rainfall patterns increase evapotranspiration rates, intensifying water stress during critical growth stages of exotic crops. In Punjab, declining groundwater levels have emerged as a critical challenge, significantly constraining irrigation water availability and affecting sustainable crop productivity. To address these challenges, precise irrigation scheduling methods are essential, as traditional practices, such as the water balance method, are often insufficient for achieving optimal water use efficiency (Sharma *et al.,* 2024). These conventional methods fail to account for the growth-stage-specific water requirements of crops, which vary significantly throughout their development cycle. There is a notable scarcity of literature on the growth-stage-specific irrigation water requirements for drip-irrigated exotic crops in the selected study area, particularly for crops like Bok choy, Chinese cabbage, Zucchini, and Broccoli. This gap in research makes it difficult to develop efficient and region-specific irrigation practices for these crops, especially considering their unique water demands and the challenges posed by climate change. The lack of such data underscores the need for targeted studies to fill this knowledge void and provide actionable guidelines for farmers in water-scarce regions.

Advancements in irrigation technologies, including drip and sprinkler systems, have been adopted in water-scarce regions to improve resource utilization and enhance crop performance (Sharma *et al.,* 2023). A modern approach to irrigation management incorporates climatological data and crop-specific parameters, such as crop coefficient (Kc) and canopy area, to estimate daily irrigation requirements based on reference evapotranspiration (ETo) (Saxena *et al.,* 2020; Mehta and Pandey, 2016; Satpute *et al.,* 2021). ETo, influenced by temperature, humidity, solar radiation, and wind speed, is critical for effective irrigation scheduling under changing climatic conditions. In the absence of comprehensive weather data, pan evaporation measurements from Class-A pan evaporimeters, combined with pan coefficients, provide an alternative method for scheduling irrigation (Sharma *et al.,* 2023). Calculating crop evapotranspiration (ETc) by integrating ETo with Kc enables precise water allocation and enhances crop resilience to environmental stress. This study, conducted under Jalandhar's agro-climatic conditions, aimed to develop growth-stage-specific irrigation schedules for exotic vegetables, including Bok choy, Chinese cabbage, Zucchini, and Broccoli, during the rabi season. By employing a climatological approach, the study assessed irrigation water requirements for drip-irrigated crops, providing critical insights to optimize irrigation practices, improve water use efficiency, and adapt to climate change.

The study was carried out for Jalandhar, located at 31.25°N latitude, 75.70°E longitude, and an elevation of 280 m above mean sea level. The region experiences a humid subtropical climate, with an average annual temperature of 23.1°C and a total precipitation of 957 mm. Irrigation schedules for the selected Exotic vegetables crops were developed based on daily pan evaporation data collected during the rabi seasons from November 25 to March 24 over the past three growing years: GY_1 (2021-22), GY_2 (2022-23), and GY_3 (2023-24). These data were obtained from the meteorological observatory at Lovely Professional University (LPU), Punjab.

Estimation of reference evapotranspiration

The reference evapotranspiration (ET_0) was calculated

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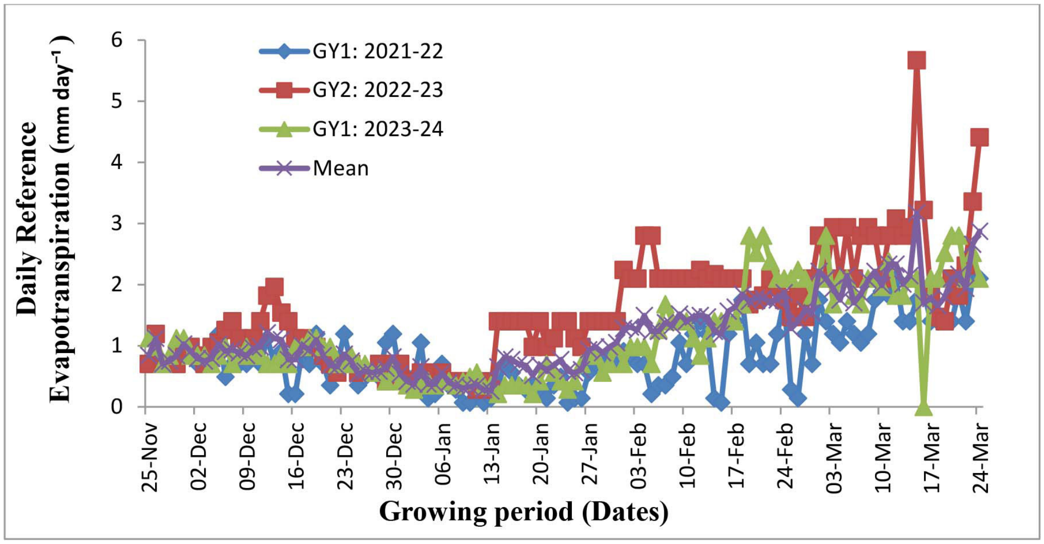

Fig 1: Estimated daily reference evapotranspiration in selected study area during selected growing years

Table 1: Yearly variation in growth stage wise daily average crop evapotranspiration (ETc) and irrigation water requirement (IWR) of selected exotic vegetables crops in Jalandhar, Punjab

Name of Crops	Year	Average daily ETc (mm day^{-1})				Average daily IWR (liter plant^{-1} day^{-1})			
		Initial	Development	Mid	Late	Initial	Development	Mid	Late
Bok Choy	GY_1	0.31	0.40	0.57	0.17	0.01	0.01	0.02	0.01
	GY_2	0.34	0.57	0.62	0.59	0.01	0.02	0.02	0.01
	GY_3	0.36	0.43	0.57	0.19	0.01	0.02	0.02	0.01
Chinese cabbage	GY_1	0.32	0.41	0.64	0.60	0.06	0.08	0.12	0.11
	GY_2	0.44	0.49	1.63	1.11	0.08	0.09	0.30	0.20
	GY_3	0.35	0.51	0.85	0.83	0.06	0.09	0.16	0.18
Zucchini	GY_1	0.31	0.32	0.74	0.57	0.01	0.01	0.03	0.02
	GY_2	0.44	0.62	2.11	1.10	0.02	0.02	0.08	0.04
	GY_3	0.36	0.34	1.12	1.22	0.01	0.01	0.04	0.04
Broccoli	GY_1	0.53	0.55	0.58	0.56	0.10	0.10	0.10	0.10
	GY_2	0.66	0.75	1.49	1.03	0.12	0.14	0.27	0.19
	GY_3	0.63	0.62	0.78	0.77	0.11	0.11	0.14	0.14

using following equation. Irrigation was scheduled based on daily pan evaporation data. Sharma *et al.,* (2023) previously recommended the pan evaporation approach for estimating the irrigation water requirement in the study area:

$$ETo = Epan \times Kp$$

Where, ETo: Reference evapotranspiration (mm day^{-1}); Epan: Pan evaporation (mm day^{-1}); Kp: Pan coefficient taken as 0.7 (Sharma *et al.,* 2023).

Estimation irrigation water requirement under drip irrigation

The stage-specific irrigation water requirement (IWR) is primarily a function of the evapotranspiration rate, crop coefficient, and the area occupied by the plants. The water demand or the volume of water required for the selected Exotic vegetable crops at various growth stages was determined using the following equation:

$$IWR = ETo \times A \times Kc \times Wp$$

Where, IWR = Irrigation water requirement of crop, liter day^{-1} plant^{-1}, ETo = Reference evapotranspiration, mm day^{-1}. A = Area of the crop (m^2) = row to row (m) × plant to plant spacing (m), Kc = Crop coefficient; Wp = Percentage wetted area, decimal.

The crop coefficient (Kc) values as per following Table 2 were used to calculate the IWR at different growth stages of all selected Exotic vegetables crops (Ding *et al.,* 2021; Oliveira *et al.,* 2020). Developing stage-specific irrigation scheduling guidelines enables efficient utilization of water resources in exotic vegetable crop production. By aligning irrigation with the critical water requirements of crops at different growth stages, this approach minimizes water stress and supports adaptation to water scarcity.

Table 2: Growth stage wise daily average crop evapotranspiration (ETc) and irrigation water requirement (IWR) of selected exotic vegetables crops (Pooled data)

Growth stages	Initial	Development	Mid	Late
Bok choy (Growing period: 25 Nov to 23 Jan, Spacing: 20 × 20 cm)				
Duration of growth stage	10	20	20	10
Crop Coefficient (Kc)	0.4	0.4 to 1.1	1.2	0.5
Average daily ETc (mm day^{-1})	0.341	0.468	0.585	0.317
Average daily IWR (ml day^{-1})	0.0123	0.0169	0.0211	0.0093
Chinese cabbage (Growing period: 25 Nov to 19 March, Spacing: 45 × 45 cm)				
Duration of growth stage	20	15	50	30
Crop Coefficient (Kc)	0.4	0.4 to 1	1.2	0.5
Average daily ETc (mm day^{-1})	0.370	0.473	1.039	0.847
Average daily IWR (ml day^{-1})	0.0674	0.0886	0.1894	0.1654
Zucchini (Growing period: 25 Nov to 19 March, Spacing: 45 × 45 cm)				
Duration of growth stage	15	20	50	30
Crop Coefficient (Kc)	0.6	0.6 to 1	1.1	0.4
Average daily ETc (mm day^{-1})	0.369	0.429	1.323	0.963
Average daily IWR (ml day^{-1})	0.0133	0.0154	0.0476	0.0347
Broccoli (Growing period: 25 Nov. to 15 March, Spacing: 50 × 15 cm)				
Duration of growth stage	20	35	40	25
Crop Coefficient (Kc)	0.5	0.7 to 1.2	1.2	0.3
Average daily ETc (mm day^{-1})	0.604	0.638	0.953	0.788
Average daily IWR (ml day^{-1})	0.1101	0.1162	0.1727	0.1421

Temporal variation in ET_O, ET_C and IWR

The estimated daily reference evapotranspiration (ETo) exhibited significant variability across the growing years, ranging from 0.14 to 2.1 mm day^{-1} in GY1, 0.28 to 5.67 mm day^{-1} in GY2, and 0.21 to 2.8 mm day^{-1} in GY3. The total ETo during these growing years varied between 99.9 mm and 139.2 mm in the selected study area (Fig. 1). This variation is likely attributable to the temporal fluctuations in daily weather parameters, which influence the water loss measured by the Class-A pan evaporimeter. These fluctuations, in turn, impact the crop water demand, underscoring the need to adapt irrigation scheduling practices to account for climatic variability. Changes in temperature, humidity, and wind speed impact pan evaporation and evapotranspiration, affecting crop water availability. Failure to adapt irrigation practices can lead to over-irrigation, nutrient leaching, or under-irrigation, stressing plants and reducing yields. Precision irrigation with real-time, region-specific ETc data is essential. According to the data presented in Table 1, the estimated growth stage-wise daily crop evapotranspiration (ETc) for Bok choy exhibited variability across the growing years, ranging from 0.17 to 0.57 mm day^{-1} in GY1, 0.34 to 0.62 mm day^{-1} in GY2, and 0.36 to 0.57 mm day^{-1} in GY3. Similarly, the estimated growth stage-wise daily ETc for Chinese cabbage showed considerable variability across the growing years, with values ranging from 0.32 to 0.64 mm day^{-1} in GY1, 0.44 to 1.63 mm day^{-1} in GY2, and 0.35 to 0.85 mm day^{-1} in GY3. While for zucchini crop, the estimated growth stage-wise daily ETc also showed variability, ranging from 0.31 to 0.74 mm day^{-1} in GY1, 0.44 to 2.11 mm day^{-1} in GY2, and 0.34 to 1.12 mm day^{-1} in GY3. In case of broccoli, the estimated growth stage-wise daily ETc also showed variability, ranging from 0.53 to 0.58 mm day^{-1} in GY1, 0.66 to 1.49 mm day^{-1} in GY2, and 0.62 to 0.78 mm day^{-1} in GY3.

The temporal variation in crop evapotranspiration (ETc) results in corresponding shifts in the daily irrigation water requirements for all selected exotic vegetable crops in the study area. Similar findings were reported by Morgan *et al.,* (2017), who noted that peak crop evapotranspiration occurs under high atmospheric temperatures. The observed fluctuations in ETo highlight the increasing necessity of transitioning from traditional irrigation methods to more dynamic, climate-responsive scheduling systems. Such an approach is essential to optimize water usage, ensuring that irrigation practices align with the changing climatic conditions and crop water demands.

Trend of ET_O, ET_C and IWR

As per mean data presented in Table 2, the ETc variation throughout the growing period for the selected crops was recorded as 0.34 to 0.58 mm day^{-1} for Bok choy, 0.37 to 1.039 mm day^{-1} for Chinese cabbage, 0.36 to 1.32 mm day^{-1} for zucchini and 0.60 to 0.95 mm day^{-1} for Broccoli. Correspondingly, the irrigation water requirement which was calculated on daily basis ranged from 0.012 to 0.021 liters $plant^{-1}$ day^{-1} for Bok choy, 0.067 to 0.189 liters $plant^{-1}$ day^{-1} for Chinese cabbage, 0.013 to 0.047 liters $plant^{-1}$ day^{-1} for

Zucchini and 0.110 to 0.172 liters plant^{-1} day^{-1} for Broccoli across their respective growing seasons.

The similar variation of IWR was noted by Sharma *et al.,* (2021) for okra crop. Agronomic practices, including plant spacing and irrigation methods, also affect daily water requirements, contributing to temporal ETc variability. Therefore, real-time, data-driven irrigation scheduling is essential for optimizing water use, especially in regions with limited freshwater resources. As per mean data of all three growing years, the daily irrigation water requirement (IWR) was estimated highest at mid growth stage and lowest at initial growth stage of all selected Exotic vegetables crops. Similar finding was reported by Saxena *et al.,* (2020) for variation in ETc of field crops.

The pooled data analysis indicates variability in crop evapotranspiration (ETc) and irrigation water requirement (IWR) across different growth stages for exotic vegetable crops grown under drip irrigation. Daily irrigation water requirements varied across the crop cycle, ranging from 0.012–0.021 liters plant^{-1} day^{-1} for Bok choy, 0.067–0.189 liters plant^{-1} day^{-1} for Chinese cabbage, 0.013–0.047 liters plant^{-1} day^{-1} for Zucchini, and 0.110–0.172 liters plant^{-1} day^{-1} for Broccoli**.** These variations were closely aligned with fluctuations in ETc, which was found to be highest during the mid-growth stage due to increased canopy development and transpiration demand. The study demonstrates that ETc and IWR peaked during the mid-growth stage, necessitating precise irrigation scheduling to optimize water use efficiency. The findings emphasize the limitations of conventional irrigation methods, which often fail to account for dynamic crop water requirements. By integrating climatological parameters such as pan evaporation data and crop coefficients (Kc), this study establishes a robust framework for irrigation scheduling tailored to the stage-specific water demands of exotic vegetable crops. Implementing precision irrigation strategies based on real-time ETc estimations can significantly enhance water-use efficiency, reduce water losses, and support sustainable crop production. Such approaches are particularly crucial for regions like Punjab, where climate variability poses challenges to irrigation water management.

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REFERENCES

Ding, J., Li, S., Wang, H., Wang, C., Zhang, Y. and Yang, D. (2021) Estimation of Evapotranspiration and Crop Coefficient of Chinese Cabbage Using Eddy Covariance in Northwest China. *Water.,* 13, 2781. https://doi.org/10.3390/w13192781

Mehta, R. and Pandey, V. (2016). Crop water requirement (ETc) of different crops of middle Gujarat. *J. Agrometeorol.,* 18 (1): 83-87. https://doi.org/10.54386/jam.v18i1.906

Morgan, K.T., Obreza, T.A. and Halton, E.A. (2017). Citrus water requirements: linking irrigation scheduling and fertigation strategies. *Proc. Florida State Hort. Soc.,* 120:67-73.

Oliveira, R.M., Cunha, F.F., Silva, G.H., Andrade, L.M., Morais, C.V. and Ferreira P.M.O. (2020). Evapotranspiration and crop coefficients of Italian zucchini cultivated with recycled paper as mulch. *PLoS ONE.,* 15(5): e0232554. https://doi.org/10.1371/journal.pone.0232554

Satpute, S., Singh, M.C. and Garg, S. (2021). Assessment of irrigation water requirements for different crops in central Punjab, India. *J. Agrometeorol.,* 23(4): 481-484. https://doi.org/10.54386/jam.v23i4.183

Saxena, R., Tiwari, A., Mathur, P. and Chakravarty, N.V.K. (2020). An investigation of reference evapotranspiration trends for crop water requirement estimation in Rajasthan. *J. Agrometeorol.,* 22(4): 449-456. https://doi.org/10.54386/jam.v22i4.447

Sharma, V, Singh, P.K., Bhakar, S.R.., Yadav K.K, Lakhawat, S.S. and Singh, Manjeet. (2021). Pan evaporation and sensor-based approaches of irrigation scheduling for crop water requirement, growth and yield of okra. *J. Agrometeorol.,* 23 (4): 389-395. https://doi.org/10.54386/jam.v23i4.142.

Sharma, V., Changade, N.M., Suryakant, B.T., Yadav, K.K. and Yadav, B.K. (2023). Climatological approaches of irrigation scheduling for growing tomato crop under drip irrigation in Sub tropical region of Punjab. *J. Agrometeorol.,* 25 (4): 565-570. https://doi.org/10.54386/jam.v25i4.2269

Sharma, V., Changade, N.M., Singh, Y.P., and Madane, A.M. (2024). Response of drip irrigated spring capsicum crop to pan evaporation-based irrigation levels in combination with varying nitrogen doses. *J. Agrometeorol.,* 26 (3): 370-373. https://doi.org/10.54386/jam.v26i3.2635