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Short Communication

Response of drip irrigated spring capsicum crop to pan evaporation-based irrigation levels in combination with varying nitrogen doses

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The scarcity of water and decline in its quality worsen due to poor irrigation practices, excessive use of fresh water, and climate change in various parts of Indian Punjab. Ministry of Jal Shakti in 2019 reported that Punjab groundwater resources indicated, 80% of total 138 assessed blocks were 'Over-exploited', and it also highlighted that 95 % of the water extracted in the state was for irrigation purposes. Over exploitation of ground water results depletion of aquifers as well as it does not support sustainable vegetable production in Punjab. Capsicum is a popular vegetable crop grown under irrigated conditions. It is a rich source of vitamin c and other minerals. The main advantage of spring transplanted crop over autumn transplanted crop is that, it does not require protection from frost and provide a opportunity for farmers to take any other short duration crop (between Nov to Jan). However, high temperature and evaporation losses during the mid growth stage require frequent application of irrigation water for batter development of capsicum fruit. Irrigation water and nitrogen are the key factors that limit productivity of the vegetable crops (Yildirim *et al*., 2012). Therefore, it is very essential to select the optimum level of water and nitrogen for drip fertigated capsicum crop (Jain *et al.,* 2021; Satpute *et al.,* 2021; Saxena *et al.,* 2020). Furthermore, in water scare region subsurface drip is recommended by researchers worldwide, but studies on the feasibility subsurface drip in capsicum production are limited. Nitrogen is a responsible factor for growth and yield. Response of crop can change with respect to their varying dose as well as timing and way of application (Yildirim *et al*., 2012)). Many studies already reported that water and fertilizer use efficiency could be increased by drip irrigation along with fertigation technique (Kapoor and Sandal 2021; Sharma *et al.,* 2021). Considering the aforementioned factors, this study aims to evaluate how spring capsicum responds to different levels of irrigation and nitrogen under surface and subsurface drip systems.

A two-year field experiment was conducted at Lovely Professional University, Jalandhar, Punjab, from February 5 to June 5 in 2022 and 2023, to determine the optimal pan evaporation-based irrigation and nitrogen fertilization levels for drip-irrigated capsicum. The study site, located at 31.25°N latitude, 75.70°E longitude, and 280 m altitude, experiences a humid subtropical climate with an annual mean temperature of 23.1°C and 957 mm precipitation. The soil, characterized as silty loam with uniform topography, was equipped with both surface (drip/lateral line on the bed surface) and subsurface drip irrigation systems (drip/lateral line buried 20 cm below the bed surface), along with a fertigation system.

The eighteen treatments comprising two types of drip system (main-plot treatment) i.e surface drip irrigation (SDI) and subsurface drip irrigation (SSDI), three irrigation regimes (sub-plot treatments) i.e I_1: irrigation at 70 % of daily pan evaporation (0.70 Epan), I_2: irrigation at 85 % of daily pan evaporation (0.85 Epan) and I_3 : irrigation at 100 % of daily pan evaporation (1.0 Epan) and three nitrogen fertigation doses (sub-sub plot) i.e N_1 : 84 kg ha^{-1}, N_2 : 102 kg ha^{-1} and N_3 : 120 kg ha^{-1} were taken in split-split plot design with three replications. A control plot was also taken in which irrigation water was supplied through flood irrigation and recommended dose of fertilizer (RDN) through broadcasting as per farmer's practice. The capsicum seedlings were transplanted in two rows / bed (size 10 m × 0.75 m) at intra-row spacing of 30 cm during 05 February during both years.

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Estimation of irrigation water requirement (IWR)

Irrigation was scheduled based on daily pan evaporation data. Sharma *et al.,* (2023) previously recommended this pan evaporation approach for estimating the irrigation water requirement in the study area. The following formula was used to determine the daily irrigation water requirement.

$$V = \Sigma\,(Ep \times Kp \times Kc \times C_a \times Wp) \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where, V = irrigation water requirement (liter day^{-1} $plant^{-1}$), Ep = Pan Evaporation (mm day^{-1}), Kp = Pan coefficient, Kc = Crop coefficient, C_a = Crop area (m^2). In this study, the recommended dose of phosphorus and potassium was directly applied through broadcasting before transplanting. While as per treatments, the selected dose of nitrogen was supplied through drip fertigation in equal splits (15) at 4 days' time interval. The urea fertilizer was taken as a source of nitrogen during this study.

Five plants per plot were tagged to measure plant height, number of branches, and yield. Plant dry matter and fruit capsaicin content were determined using standard procedures. Water use efficiency was calculated by dividing crop yield (t ha^{-1}) by total water applied (cm). After harvesting, soil samples were taken from each plot up to 15 cm depth to analyze the effects of treatments on soil properties like pH and electrical conductivity (EC) using standard methods. Data analysis was conducted using CPCS software.

Daily irrigation water requirement (IWR) of drip irrigated capsicum crop

In the study area, daily pan evaporation ranged from 2 to 7.4 mm day^{-1} in 2022 and 1.02 to 8.4 mm day^{-1} in 2023, influencing crop evapotranspiration, which varied from 1 to 5.8 mm day^{-1} in 2022 and 0.5 to 6.4 mm day^{-1} in 2023. These variations, due to changes in temperature, humidity, sunshine, and wind, significantly impact the irrigation needs of capsicum. This aligns with Sharma *et al.,* (2023), who reported similar trends for tomatoes. Modern irrigation scheduling, based on daily pan evaporation, is essential to meet varying crop water needs, ensuring optimal growth and yield. In the study area, the average daily irrigation water requirement as presented in Fig 1, ranged from 0.341 to 0.711 liters per plant per day in 2022 and 0.102 to 0.785 liters per plant per day in 2023, with the highest demand during flowering and fruit-setting stages, consistent with Lakhawat *et al.,* (2024) for guava.

Growth, yield and water use efficiency of drip irrigated capsicum

The plant height and number of branches per plant was significantly higher in SDI and SSDI plot as compared control. The increase in plant height under SDI or SSDI plots is might be due to the availability of soil moisture (20 to 22.8 %) as well as soil temperature (27 to 29.6^{0}C) at optimum level over control plot. The same trend of plant height under surface and subsurface drip irrigation was reported by Kaur *et al.,* (2023) for potato crop. On individual effect basis, the maximum plant height (73.1 cm) and number of branches per plant (23) were recorded under treatment I_3, which were at par with I_2 and significantly higher than I_1 (Table 1). Which indicates that, the slightly reduction in irrigation level (15% less than full irrigation level) under drip irrigation will not affect significant growth of plant in selected region while irrigating capsicum at severe water deficit level (30% less than full irrigation level) in retards the plant growth. The similar trend of plant height and number of branches per plant was observed for nitrogen levels ($N_3 > N_2 > N_1$). It indicates the direct relation between plant growth and amount of nitrogen supplied. The crop yield was significantly affected by type of drip system. The overall crop yield was found 15.7 % higher under SSDI plots as compared to SDI plots. This was due to less evaporation losses from soil surface as well as continuous availability of moisture content in plant root zone (no water stress) under SSDI. Kaur *et al.,* (2023) has also reported higher potato yield under SSDI over SDI. The crop yield was maximum under I_3, which were at par with I_2 and significantly higher than I_1, the same trend of crop yield was found for nitrogen levels. ($N_3 > N_2 > N_1$) it shows that the more supply of water and nitrogen under drip irrigation will improve crop yield. During mid-April to May in the study area, daily variations in air temperature significantly affected the crop water requirements of capsicum plants. Traditional irrigation scheduling methods, such as full irrigation every two days under a drip system, failed to meet varying water demands necessary for optimal growth and development. This finding aligns with previous studies by Sharma *et al.,* (2023) and Lakhawat *et al.,* (2024). The control plot exhibited the lowest yield, likely due to

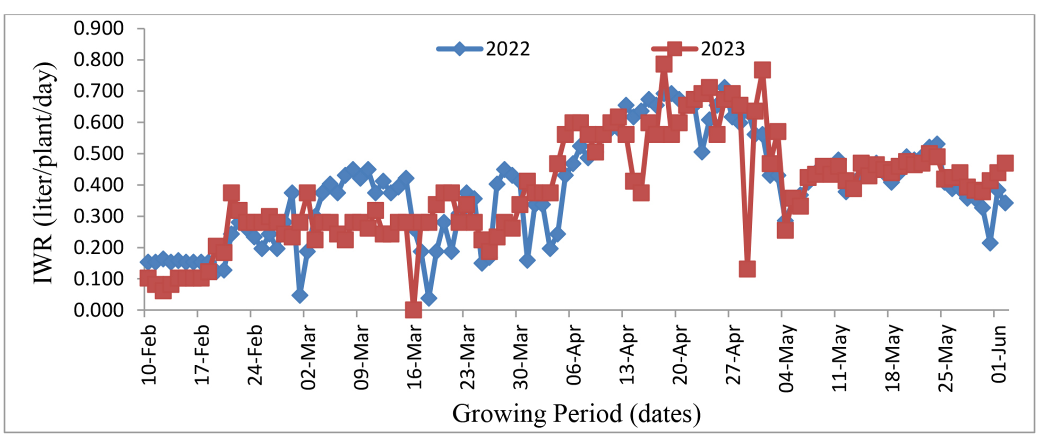

Fig 1: Irrigation water requirement (IWR) of drip irrigated capsicum crop during 2022 and 2023.

Table 1: Growth, yield and water use efficiency of capsicum as influenced by irrigation and nitrogen level under surface and subsurface drip irrigation (Pooled data basis)

Treatment	Plant height (cm)	Branches plant^{-1}	Fruit yield (t ha^{-1})	Dry matter (%)	pH	EC (dS m^{-1})	Water use efficiency (t ha^{-1}-cm)
Irrigation systems							
SDI	68.4	17	14.1	10.8	8.13	0.117	0.486
SSDI	73.9	21	16.3	11.3	8.10	0.135	0.562
CD (P=0.05)	3.2	0.7	0.51	0.42	NS		
Irrigation levels							
I_1 = 0.7 E_{pan}	68.9	20	13.4	10.6	8.12	0.159	0.577
I_2 = 0.85 E_{pan}	71.8	22	15.6	11.1	8.12	0.152	0.636
I_3 = 01 E_{pan}	73.1	23	15.8	11.5	8.11	0.131	0.544
CD (P=0.05)	2.6	1.7	0.42	0.23	NS		
Nitrogen levels							
N_1 = 84 kg ha^{-1}	68.3	20	14.6	10.7	8.22	0.173	0.629
N_2 = 102 kg ha^{-1}	72	21	15.2	11.3	8.23	0.149	0.582
N_3 = 120 kg ha^{-1}	73	23	15.9	11.9	8.23	0.132	0.548
CD (P=0.05)	2.1	2.1	0.28	0.20	NS		0.198
Control	41.4	14	10.1			0.084	0.629

Table 2: Crop yield of capsicum as influenced by irrigation and nitrogen level under surface and subsurface drip irrigation (interaction effects).

Irrigation level	Fruit yield (t ha^{-1})		
	N_1 = 84 kg ha^{-1}	N_2 = 102 kg ha^{-1}	N_3 = 120 kg ha^{-1}
Surface drip irrigation system (SDI)			
I_1 = 0.7 E_{pan}	11.5	12.0	12.6
I_2 = 0.85 E_{pan}	13.3	14.3	14.6
I_3 = 01 E_{pan}	14.5	16.0	17.9
Mean	13.1	14.1	15.0
Subsurface drip irrigation system (SSDI)			
I_1 = 0.7 E_{pan}	14.1	14.4	15.6
I_2 = 0.85 E_{pan}	16.2	16.1	16.5
I_3 = 01 E_{pan}	17.2	17.7	18.0
Mean	15.8	16.0	16.7
CD (P=0.05)			
A (Drip system)	0.57		
B (Irrigation levels	0.21		
A (Nitrogen levels)	0.17		

increased water losses and nutrient leaching, resulting in reduced nutrient availability. As per daily pan evaporation data received from CLASS-A pan evaporimeter, the total amount of irrigation water was supplied as 290, 261 and 232 mm for irrigation level I_3, I_2 and I_1 respectively. The water use efficiency was significantly affected by SDI and SSDI (Table 1). On individual effect basis, the maximum water use efficiency was estimated as, 0.636 t ha^{-1} cm under I_2. The lowest water use efficiency (0.198 t ha^{-1}cm) was found under control plot. The water saving under drip irrigated plot where irrigation schedule at 100% of E_{pan} was found 43.15 % over conventional irrigation practice (flood irrigation). It was due to that, under SSDI and SDI, the minimum water losses occurred through infiltration, percolation and surface evaporation. The second reason for increasing crop yield and water use efficiency is reduction in nitrogen losses occurred due to leaching as well as atmospheric reactions under SSDI OR SDI as compared surface irrigation with fertilizer application through broadcasting. Kaur *et al.,* (2023) reported the unproductive water losses of soil evaporation were much higher in surface irrigation method than in drip irrigation for tomato crop. The dry matter was found 4.6 % higher under SSDI as compared to SDI. Lingaiah *et al*., (2005) report same result for dry matter under SSDI for cabbage crop. The irrigation and nitrogen levels exerted non-significant effects on the pH and EC values of soil at a depth of 15-20 cm. The EC was found significant lower in SSDI as compared to SDI. It is due that under SSDI, the direct application of water in plant root zone ceases the adsorption of cations or anions preset in soil solution.

The data presented in Table 2 indicated that, the crop yield obtained under SSI for I_3N_2 was statically at par with crop yield obtained under SSDI for I_2N_2 Similarly the crop yield obtained under SSI for I_3N_3 was statically at par with crop yield obtained under SSDI for I_3N_2 which clearly indicates that under subsurface drip irrigation, there may be saving of 15 % of irrigation water and 15 % of RDN over SDI in order to produce same crop yield. Capsicum, like many crops, has specific water needs that vary with growth stages and environmental conditions. Pan evaporation helps in accurately determining these needs, preventing both under- and over-irrigation.

Accurate irrigation scheduling based on pan evaporation data ensures that the capsicum plants receive adequate water at the right time, promoting healthy growth, reducing plant stress, and thereby enhancing both yield and quality. By aligning irrigation with the actual evapotranspiration needs of the crop, water use efficiency is significantly improved. Pan evaporation-based irrigation scheduling optimizes drip-irrigated spring capsicum crops by determining precise water needs based on real-time climatic conditions. This scientific method ensures sustainable water management in water-scarce regions, conserving water by applying it only when necessary and in required amounts. In the study area with limited availability of fresh water resources, adopting subsurface drip irrigation can increase capsicum crop yield by 15.7% compared to surface drip irrigation. Irrigating spring capsicum crops at 85% Epan was identified as the optimal irrigation level for subsurface drip irrigation, resulting in maximum water use efficiency (0.636 t ha^{-1}-cm) and a significant crop yield (15.6 t ha^{-1}). The results clearly indicate that pan evaporation-based irrigation scheduling can be effectively used for drip-irrigated capsicum crops, achieving water savings of 43 to 54% compared to conventional irrigation practices. The interaction effects show that the crop yield under SDI for I_3N_3 was statistically on par with the yield under SSDI for I_2N_2. This highlights that, in the selected study area, scheduling irrigation at 85% of Epan under subsurface drip irrigation, combined with applying 102 kg ha^{-1} of nitrogen through fertigation (I_2N_2), can achieve similar yields for spring capsicum compared to the I_3N_3 combination undersurface drip irrigation. Therefore, adopting pan evaporation-based irrigation scheduling levels will undoubtedly assist irrigation managers, policymakers, and farmers in conserving available freshwater resources.

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