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Nutrient and water management for bell pepper (*Capsicum annuum*) production: A study on drip irrigation in silty loam soils

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In Punjab, main source of irrigation water is canal water but its supply at farmer's field is limited as per availability of their irrigated area (Garg *et al*. 2021). Groundwater resource assessments by Anonymous (2019) revealed that 80% of Punjab's 138 evaluated blocks were classified as "over-exploited". Moreover, 95% of the extracted water in the state is used for irrigation. The efficient utilization of freshwater resources is critical for conserving both surface and groundwater reserves (Sharma *et al*. 2024). Bell pepper (*Capsicum annuum* L.), commonly referred to as capsicum, is a widely grown vegetable in Punjab, India, valued for its high vitamin C content and essential minerals. In open-field conditions, capsicum is typically cultivated during the autumn season (November) or the spring season (February). A notable advantage of the spring-transplanted crop is its ability to bypass frost protection requirements, allowing farmers to cultivate an additional short-duration crop during November to January. Key factors influencing capsicum growth and yield include the quantity and timing of water and fertilizer applications (Yildirim *et al*. 2012). Challenges such as poor-quality groundwater, inconsistent canal water supply, nutrient leaching and suboptimal irrigation practices exacerbate water management issues in agriculture. These challenges significantly constrain the availability of freshwater for irrigation, posing a critical limitation for crop production (Dhaloiya *et al*. 2022). In semi-arid regions, water and nutrient management are crucial for enhancing vegetable crop productivity (Jain *et al*. 2021). Consequently, adopting efficient water and nutrient management practices is essential to minimize water, fertilizer and evaporation losses in capsicum cultivation. Drip irrigation system, particularly surface and subsurface drip irrigation have been identified as effective methods for reducing irrigation water losses (Singh *et al*. 2022). While subsurface drip irrigation is globally recommended for vegetable crops (Rolbiecki *et al*. 2021), its application in capsicum cultivation has been underexplored. In India, farmers predominantly use flood irrigation for capsicum, although drip irrigation has the potential to increase fruit yield by 25–30% and reduce water use by up to 50% compared to conventional methods (Singh *et al*. 2022). Nitrogen is a critical determinant of crop growth and yield, with its efficacy influenced by the rate, timing, and method of application. Studies have demonstrated that fertigation can significantly enhance nitrogen use efficiency in various crops (Dass *et al*. 2023). Against this backdrop, the present study aims to evaluate the response of capsicum to varying irrigation and nitrogen levels under surface and subsurface drip irrigation systems in the trans-Gangetic region of Punjab.

An experiment was conducted during March–June, 2022 at Research farm, Lovely Professional University, Jalandhar, Punjab. The site was facilitated with surface and subsurface drip irrigation (drip/lateral line was buried at 20 cm depth below bed surface) along with fertigation system. The daily pan evaporation (mm/day) was acquired from the meteorological observatory. Soil was silty loam having uniform topography. The 18 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 @70% of crop evaporation (70% ET_C); I_2, Irrigation @85% of crop evapotranspiration (85% ET_c) and I_3, Irrigation @100% of crop evapotranspiration (100% ET_C) and three nitrogen levels (sub-sub plot) i.e. N_1, 70% recommended dose of nitrogen (RDN); N_2, 85% of RDN and N_3, 100% of RDN were taken in a split-split plot design with three replications. Control plot having furrow irrigation and fertilizer application through broadcasting was also included. The capsicum seedlings were transplanted on 10th March, 2022. The uniform water was supplied to each plot for better establishment of seedling during first week. After that, irrigation was

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supplied as per treatments. The total water applied under drip irrigated plots was calculated as:

$$V = \Sigma(ET_C \times C_a \times Wp)$$

Where ET_C, Crop evapotranspiration (Ep × Kp × Kc); V, Irrigation water requirement (L/day/plant); Ep, Pan evaporation (mm); Kp, Pan coefficient; Kc, Crop coefficient; C_a, Crop area (m^2). The full recommended dose of phosphorus and potassium was mixed in each plot before transplanting. The RDN as per treatment was supplied through fertigation at 4-day interval.

Data on plant height, number of branches/plant and yield were collected by selecting five plants/plot. Plant dry matter and fruit water use efficiency (WUE) were calculated using standard procedures. After the final harvest, soil samples were collected from a depth of 15–20 cm (half of the effective root zone) to assess the impact of various treatments on soil *p*H and electrical conductivity (EC) using standard analytical methods. All data were analyzed using CPCS software (Table 1).

The daily pan evaporation in the study area ranged from a minimum of 2.2 mm/day during the initial growth stage of capsicum to a maximum of 16.7 mm/day at the mid-growth stage. Temporal variations in climatic conditions led to an uneven pattern of daily pan evaporation, significantly influencing the daily water requirements of the capsicum crop. Plant height and the number of branches were observed to be significantly higher in the surface drip irrigation (SDI) and subsurface drip irrigation (SSDI) treatments compared to the control. The increased plant height under SDI and SSDI treatments can be attributed to the consistent availability of soil moisture and nitrogen at optimal levels, as opposed to the control plots where these resources were limited. The same trend of plant height under drip system was reported by Kaur *et al*. (2023) for potato and Singh *et al*. (2024) for maize crop. The maximum plant height (73 cm) and number of branches/plant (22) were recorded under treatment I_3 (irrigation @100% ET_c), which were at par with I_2 (irrigation @85% ET_c) and significantly higher than I_1 (irrigation @70% ET_c). Padron *et al*. (2015) have seen same trend of height of capsicum/bell pepper plant with respect to irrigation level. The similar trend of plant height and number of branch/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 fruit yield was significantly affected by type of drip system. The overall fruit yield was found 16.5% higher under SSDI plots as compared to SDI plots. This was due to less evaporation occurs from soil surface as well as continuous availability of moisture content in plant root zone under SSDI. Kaur *et al*. (2023) has also reported higher potato yield under SSDI over SDI.

The fruit yield was maximum under treatment in which irrigation scheduled @100% ET_C, which were at par with I_2 (irrigation @85% ET_C) and significantly higher than I_1 (irrigation @70% ET_C), the same trend of fruit yield was found for nitrogen levels (N_3>N_2>N_1) (Table 1). It showed that the more supply of water and nitrogen (through fertigation) under drip irrigation will improve crop yield. Result clearly indicates that, in study area during mid April to May month, the air temperature unevenly varies the daily crop water requirement of plant so varying water demand cannot be fulfilled by traditional approaches of irrigation scheduling (i.e. full irrigation @2 days interval) under drip system. Similar finding was recorded by Sezen *et al.* (2012) who reported maximum yield by adequate water supply and

Table 1 Growth, yield and WUE of bell pepper as influenced by irrigation and nitrogen level under SDI and SSDI

Treatment	Plant height (cm)	Branches/ plant	Fruit yield (t/ha)	Dry matter (%)	*p*H	EC (dS/m)	Irrigation water supplied (cm)	WUE (t/ha-cm)
Irrigation system								
SDI	67.6	16	13.9	10.7	8.15	0.139	57.4	0.289
SSDI	72.9	22	16.2	11.2	8.13	0.136	57.4	0.335
CD (*P*=0.05)	2.1	0.7	0.51	0.42	NS	0.001		
Irrigation levels								
I_1, 70% ET_C	67.9	20	13.1	10.5	8.10	0.135	40.1	0.333
I_2, 85% ET_C	70.9	21	15.5	11	8.10	0.135	48.7	0.311
I_3, 100% ET_C	72.9	22	15.7	11.4	8.11	0.134	57.4	0.294
CD (*P*=0.05)	2.6	1.8	0.42	0.23	NS	NS		
Nitrogen level								
N_1, 70% RDN	67.9	20	14.4	10.6	8.21	0.143	40.1	0.298
N_2, 85% RDN	71.7	21	14.9	11.2	8.21	0.144	48.7	0.311
N_3, 100% RDN	72.7	22	15.6	11.8	8.22	0.144	57.4	0.327
CD (*P*=0.05)	2.1	2.1	0.28	0.20	NS	NS		
Control	40	13.2	9.9				77	0.128

WUE, Water use efficiency; SDI, Surface drip irrigation; SSDI, Sub-surface drip irrigation; RDN, Recommended dose of nitrogen. Refer to methodology for Treatment details.

Table 2 Interaction effects of irrigation and nitrogen levels on crop productivity under surface and subsurface drip irrigation.

Irrigation level	Crop productivity (kg/m^2)					
	N_1		N_2		N_3	
	SDI	SSDI	SDI	SSDI	SDI	SSDI
I_1, 70% ET_C	0.00114	0.00139	0.00119	0.00142	0.00125	0.00154
I_2, 85% ET_C	0.00131	0.00160	0.00141	0.00159	0.00144	0.00163
I_3, 100% ET_C	0.00143	0.00170	0.00158	0.00175	0.00177	0.00178
CD (*P*=0.05); A (Drip system), 0.02; B (Irrigation levels), 0.084; C (Nitrogen levels), 0.06.						

N_1, 70% recommended dose of nitrogen (RDN); N_2, 85% of RDN and N_3, 100% of RDN; SDI, Surface drip irrigation; SSDI, Subsurface drip irrigation. ETc, Crop evapotranspiration.

uniform moisture content. WUE was significantly affected by SDI and SSDI. The maximum WUE was estimated as, 0.335 t/ha-cm under SSDI. The lowest WUE (0.128 t/ha-cm) was found under control plot. The water saving under drip (irrigation @100% of ET_C) irrigation was 24.4% over conventional irrigation method. 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 fruit yield and WUE is reduction in nitrogen losses occurred due to leaching as well as atmospheric reactions under SSDI or SDI as compared to control. Kaur *et al*. (2022) 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. The irrigation and nitrogen levels exerted non-significant effects on the *p*H and EC values of soil at a depth of 15–20 cm. The EC was found significantly lower in SSDI as compared to SDI. It is due that under SSDI, the direct application of water in plant root zone cease the adsorption of cations or anions preset in soil solution. The crop productivity achieved under surface drip irrigation (SDI) for the treatment I_3N_2 was statistically at par with the crop productivity observed under subsurface drip irrigation (SSDI) for the treatment I_2N_2 (Table 2). Similarly, the crop productivity obtained under SDI for the treatment I_3N_3 was statistically equivalent to that achieved under SSDI for I_3N_2. This indicates a potential saving of 15% in irrigation water and 15% of the recommended dose of nitrogen (RDN) under SSDI compared to SDI to achieve comparable crop productivity.

The comparable productivity under SSDI with reduced water and nitrogen inputs highlights its superior efficiency. By delivering water and nutrients directly to the root zone, SSDI minimizes losses, enhances nutrient uptake, and supports optimal growth. This efficient system promotes sustainability by reducing inputs without compromising yields, warranting further research on root-zone dynamics.

SUMMARY

The study demonstrates that both surface and subsurface drip irrigation combined with nitrogen fertigation significantly enhanced plant growth, fruit yield, and water use efficiency (WUE) of bell pepper compared to the control. In the selected study area, subsurface drip irrigation (SSDI) improved bell pepper fruit yield by 16.5% compared to surface drip irrigation (SDI). The most effective approach for water and nitrogen management was identified as irrigation at 85% of crop evapotranspiration combined with 85% of the recommended nitrogen dose under SSDI, achieving significant gains in fruit yield and WUE. Furthermore, SSDI demonstrated the potential to save 15% of irrigation water and 15% of the recommended nitrogen dose while maintaining comparable crop productivity to SDI. These findings illuminate the transformative potential of subsurface drip irrigation (SSDI) for bell pepper cultivation in the Indian Punjab. By conserving precious freshwater resources and curtailing nitrogen overuse inherent in traditional broadcasting methods. SSDI exemplifies sustainable agriculture, enhancing crop productivity while conserving freshwater and reducing nitrogen overuse. Its adoption offers a resource-efficient solution for bell pepper cultivation, supporting environmentally responsible farming.

REFERENCES

Anonymous. 2019. Annual Report by Department of Water Resources, River Development and Ganga Rejuvenation, Ministry of Jal Shakti, Govt of India.

Dass A, Nagavgade M and Tyagi N. 2023. Sub surface drip fertigation: A potential precision technology for improved productivity, quality and input use efficiency in agriculture. *Indian Journal of Agronomy* **68** (22nd Biennial National Symposium Special Issue): 51–64.

Dhaloiya A, Hooda R S, Kumar D, Malik A and Kumar A. 2022. Geoinformatics-based assessment of gross irrigation requirement of different crops grown in the south-western region of Haryana, India. *Current Directions in Water Scarcity Research* **7**: 299–316.

Garg N, Choudhary O P, Thaman S, Sharma V, Singh H, Vashistha M, Sekhon K S, Sharda R and Dhaliwal M S. 2022. Effects of irrigation water quality and NPK-fertigation levels on plant growth, yield and tuber size of potatoes in a sandy loam alluvial soil of semi-arid region of Indian Punjab. *Agricultural Water Management* **266**: 107604.

Jain N K, Yadav R S and Jat R A. 2021. Drip fertigation influences yield, nutrient uptake and soil properties of peanut (*Arachis hypogaea*). *The Indian Journal of Agricultural Sciences* **91**(2): 258–62.

Kaur A, Singh K B, Gupta R K, Alataway A, Dewidar A Z and Mattar M A. 2023. Interactive effects of nitrogen application and irrigation on water use, growth and tuber yield of potato under subsurface drip irrigation. *Agronomy* **13**: 11. doi.org/10.3390/agronomy13010011

Padron R A R, Guedes J V C, Swarowsky A, Nogueria C U, Cerquera R R and Diaz-Perez J C. 2015. Supplemental irrigation levels in bell pepper under shed mesh in open field crop coefficient, yield, fruit quality and water productivity. *African Journal of Agriculture Research* **10**(44): 4117–25.

Rolbiecki R, Rolbiecki S, Figas A, Jagosz B, Stachowski P, Sadan H A, Prus P and Pal-Fam F. 2021. Requirements and effects of surface drip irrigation of mid-early potato cultivar courage on a very light soil in central Poland. *Agronomy* **11**(1): 33.

Sezen S M, Yazar A, Tekin S, Eker S and Kapur B. 2011. Yield and quality response of drip irrigated pepper under Mediterranean climatic conditions to various water regimes. *African Journal of Biotechnology* **10**(8): 1329–39.

Sharma V, Changade N M, Tarate S B and Yadav B K. 2024. Response of tomato (*Solanum lycopersicum*) to varying levels of irrigation and nitrogen under trickle fertigation. *The Indian Journal of Agricultural Sciences* **94**(2): 161–66. https://doi.org/10.56093/ijas.v94i2.144416

Singh A, Dass A, Dhar S, Sudhishri S, Shekhawat K, Meena M C, Nithinkumar K and Devi A D. 2024. Sub-surface drip fertigation of nitrogen coupled with crop residue incorporation enhanced the growth and yield of maize in an alluvial soils. *Indian Journal of Agronomy* **69**(2): 144–50

Singh A, Kumar S, Dhaloiya A, Kumar N, Mor A, Kumar A, Dhanger P and Dagar H. 2022. Soil water dynamics and yield response of broccoli (*Brassica oleracea*) under drip irrigation with different irrigation frequency. *The Indian Journal of Agricultural Sciences* **92**(12): 1447–52.

Yildirim M, Demirel K and Behar B. 2012. Effect of restricted water supply and stress development on growth of bell pepper under draught conditions. *Journal of Agronomy and Crop Sciences* **3**(1): 1–9.