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Studies on impact of different levels and frequencies of nitrogen fertigation on capsicum (*Capsicum annuum*) crop

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Irrigation is one of crucial inputs for crop production mostly in semi-arid and arid regions. Irrigation method includes sub-surface, surface, and pressurized irrigation method. Among all the irrigation methods, drip irrigation is the most proficient and effective method, which saves 40–70% of the water in comparison with border and furrow irrigation method (Bhuriya *et al.* 2015). Two most important components of crop production are water and fertilizer, which play half the role in crop productivity, enhancement, and excessive use any of them will harm the crop productivity (Yousaf *et al.* 2017). Use of precision irrigation methods for irrigation can come a long way in tackling water scarcity challenges in the region with continuously declining groundwater (Mehla *et al.* 2022).

Nitrogen plays an important role in increasing the productivity, crop growth, and quality of fruits. Generally, nitrogen exists in many different forms (organic and inorganic), but the majority of plants absorb nitrogen in nitrate form (inorganic), which is its most beneficial form (Leghari *et al.* 2016). When nutrients or fertilizers are applied through drip irrigation, it not only helps to boost yield but also reduce the fertilizer use by 30% as compared to traditional methods (Sivanappan and Ranghaswami 2005). The present challenge of researchers is to determine the appropriate fertigation and irrigation techniques in drip irrigated vegetable crops owing to their capacity to apply nutrients and water. Hence, the current experiment was planned to study the impact of different nitrogen fertigation dosages and frequencies on drip-irrigated capsicum (*Capsicum annuum* L.) crop.

The experiment was conducted during the spring-summer months of 2019–20 at Research Farm of Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana. The daily meteorological data like temperature, rainfall, and pan evaporation were also measured during the entire growing season of the crop to optimize irrigation scheduling. The experiment was conducted in a single plot having an area of 225 m^2, which was divided into 27 plots. Experiment was laid out in a split plot design (SPD) comprised of 9 treatments (Table 1) with three replications. The 60-days-old seedlings of cv. Kranti procured from Centre for Quality Planting Material, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana were planted on a flat bed with plant-to-plant and row-to-row spacing of 0.3 m × 0.6 m in the experimental field on 23 February 2020 (Fig. 1).

The initial average phosphorous, nitrogen, and potassium present in the soil was 15.2, 115.9, and 227.5 kg/ha. The initial *p*H and EC (1:2) was 8.1, 8.3, 8.5, 8.6, and 0.28, 0.25, 0.23, 0.22/dSm in the soil profile of 0–15, 15–30, 30–45 and 45–60 cm depth. Based on the meteorological data and the formula given in equation (1), water (ml/plant), irrigation timing (h/plant) was calculated and on that basis

Table 1 Different treatments imposed in the experimentation with notations

Treatment	Notations used
75% RDN with every irrigation fertigation frequency	FF_1FL_1
75% RDN with weekly fertigation	FF_2FL_1
75% RDN with fortnightly fertigation	FF_3FL_1
100% RDN with every irrigation fertigation frequency	FF_1FL_2
100% RDN with weekly fertigation	FF_2FL_2
100% RDN with fortnightly fertigation	FF_3FL_2
125% RDN with every irrigation fertigation frequency	FF_1FL_3
125% RDN with weekly fertigation	FF_2FL_3
125% RDN with fortnightly fertigation	FF_3FL_3

RDN, Recommended dose of nutrients.

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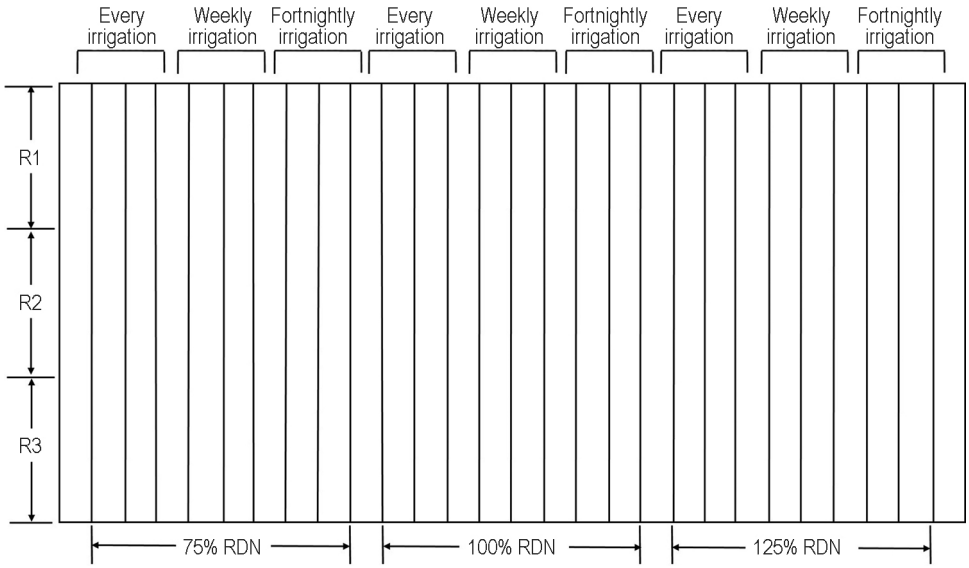

Fig. 1 Layout of the experimental field configuration showing different treatments with replications. RDN, Recommended dose of nutrients.

irrigation pump (min) was estimated in each treatment at all-time nutrition, weekly, and fortnightly fertigation. The irrigation pump continued to run after the fertigation, which was applied with the venturi, until each treatment received the necessary amount of irrigation.

Irrigation and fertigation scheduling: Utilizing the following formula given by Schwab *et al.* (1996) was used to estimate the total amount of water that will be applied to the crop.

$$V = \frac{K_c \times K_p \times E_p\, PP_p \times RR \times P}{E_a \times 10 \times 85} \quad (1)$$

where V, Amount of water to be applied (ml/plant); K_c, K_p, and E_p, Crop coefficient, pan coefficient (0.85), and pan evaporation (mm). Crop coefficient (K_c) for capsicum were taken as 0.6, 1.05, and 0.9 for the crop age of 15–30, 30–90, and 90–120 days. PP and RR, Plant-to-plant and row-to-row spacing; E_a, Irrigation efficiency and P represents the area shaded by crop (%).

After calculating the water requirement of a plant, Irrigation time can be calculated as:

$$V = \frac{\text{Water requirement/plant (litre)}}{\text{Application rate (litre/h)}} \quad (2)$$

Through drippers, nitrogen doses were supplied to the crop at every irrigation, weekly and fortnightly fertigation interval. Nitrogen dosage was applied in different treatments (Table 2).

Table 2 Amount of urea applied to each micro plot for various fertigation levels

Treatment	75% RDN	100% RDN	125% RDN
With every irrigation	0.78 g	1.02 g	1.28 g
Weekly nutrition	5.34 g	7.14 g	8.96 g
Fortnightly nutrition	10.78 g	14.28 g	17.92 g

RDN, Recommended dose of nutrient.

Yield parameters and economic analysis: At different development stages of capsicum crop, yield and other attributes were measured i.e. average plant height, fruit length, fruit weight, number of fruits/plant, fruit width, and fruit yield. The relationship between irrigation water and yield is represented by WUE, whereas the NUE is a measure of the relationship between nitrogen applied and the yield. Economic feasibility of the crop under different treatments, was calculated in terms of the benefit: cost (B:C) ratio and the net returns (₹/ha).

$$\text{WUE (kg/m}^3) = \frac{\text{Weight of the fruit (kg/ha)}}{\text{Amount of water applied (m}^3\text{/ha)}} \quad (4)$$

$$\text{NUE (kg/kg)} = \frac{\text{Weight of the fruit (kg/ha)}}{\text{Amount of nitrogen applied (kg/ha)}} \quad (5)$$

Statistical analysis was done using standard procedure using split-plot design (SPD) using ANOVA with critical difference (CD) at 5%.

Soil nitrogen at harvesting: The maximum available nitrogen (140.1 kg/ha) was found in the soil after harvest under all-time nutrition with 125% fertigation level, whereas the minimum nitrogen available in the soil (122.4 kg/ha) was measured at 75% RDN with fortnightly fertigation treatment. The maximum mean fertigation level was recorded at 125% RDN with an 8.59% increase in the average nitrogen level when compared to 75% RDN. However, only 4.71% increase in the mean fertigation frequency from every irrigation to fortnightly fertigation.

Amount of water applied and drip discharge: Throughout all the different treatments, the same quantum of water was applied through the drip system, which was recorded as 2.3 litres/h. Irrigation timing (h) was calculated from the equation (2). The total water applied in a whole season (Feb–June) was 86.25 litres/plant and 3622.5 litres/plot under drip irrigation. However, the irrigation period per plant during the entire cropping season was 37.50 h. The maximum amount of water applied per plant was observed in the month of May and the water requirement was increasing day by day with the growing season until May.

Yield attributes

Plant height: The height of the capsicum plant was measured after every interval of 30 days of transplanting (DAT) i.e. 30, 60, 90, and 120 days. The maximum and minimum plant height (25.80, 43.64, 72.60, 82 cm) and

(16.86, 38.0167.20, 76.61 cm) were measured under FF_1FL_3 and FF_3FL_1 treatment at 30, 60, 90 and 120 DAT (Fig. 2). The main reason for the better growth at 125% RDN compared to the other treatments could be due to the capsicum's effective root system for absorbing nutrients under higher fertigation levels, which contributed to creating a favourable nutritional condition in the roots of capsicum plants and enabled more efficient plant growth.

Average fruit weight, fruit length, fruit width, and number of fruits/plant: All these fruit parameters were higher in 125% nitrogen fertigation as compared to the 75 and 100% of fertigation levels. Among the different frequencies, every irrigation fertigation showed the higher results as compared to other fertigation frequencies. The maximum and minimum (54.48 g, 41.85 g) fruit weight was observed at 125 and 75% RDN. The average fruit length decreased from 7.46 cm to 7.16 cm with decreasing fertigation frequency with every irrigation (FF_1) to fortnightly nutrition (FF_3). Average fruit width increased from 6.13–6.61 cm with increasing fertigation level from 75–125% RDN. The average maximum number of fruits/plant (30.83) was recorded in the FF_1FL_3 treatment, whereas the minimum number of fruits/plant (21.54) was found in the FF_3FL_1 treatment. However, the treatment with fertigation frequency weekly and fortnightly with fertigation levels of 100 and 125% RDN were statistically similar to each other in terms of the average number of fruits/plant. These results are confirming to the previous reports showing that 125% RDN level recorded the highest average fruit length, weight, and diameter in drip-irrigated chili crops as related to the 75 and 100% NPK (Ramachandrappa *et al.* 2010).

Fruit yield: The present results showed that the highest fruit yield was registered at FF_1FL_3 treatment, while the lowest fruit yield was found at 75% with fortnightly fertigation. The average fruit yield increases from 158.42–170.29 q/ha as the fertigation level increases from 75–125%. However, a decrease in fertigation frequency decreased the average fruit yield from every irrigation (172.50 q/ha) to fortnightly (157.15 q/ha) fertigation frequency (Table 3). The current investigation outcomes agree with Kumar *et al.* (2017) who noted that maximum fruit yield obtained under 125% RDN which is at par with 100% RDN in drip-irrigated tomato crops.

Water use efficiency and nitrogen use efficiency: The estimated values of water use efficiency (WUE) and nitrogen use efficiency (NUE) are shown in Table 3. The maximum water use efficiency (3.72 kg/m^3) was measured under FF_1FL_3 treatment while nitrogen use efficiency was registered the maximum (134.8 kg of capsicum/kg of nitrogen used) at FF_1FL_1 treatment. NUE increases 59.64% at 75% RDN as compared to 125% RDN. Compared to the fertigation levels and frequency, a significant reduction was observed in NUE when the fertigation level and frequency increased from 75–125% RDN and with every irrigation to fortnightly fertigation. However, with the increase in the fertigation level, the WUE showed an increasing trend from 75–125% RDN, while a decrease in fertigation frequency from with every irrigation to fortnightly fertigation. These findings were supported by Ashwini *et al.* (2020), the maximum WUE (4.17 kg/m^3) was found under 125% RDN with every irrigation and at par with weekly nutrition fertigation in chili crops. Vijayakumar *et al.* (2010) confirmed that the maximum fertilizer use efficiency was observed under 75% RDN and potash fertigation in hot chili crops.

Economic analysis: To calculate the economic feasibility of the crop under different treatments, the treatments economics were calculated in terms of the benefit: cost (B: C) ratio and the net returns (₹/ha) as the most lucrative approach to be recommended. Following by 100% RDN, the net return (₹3,66,237) was with a benefit-cost ratio (of 2.34), and the highest net return (₹3,78,401)

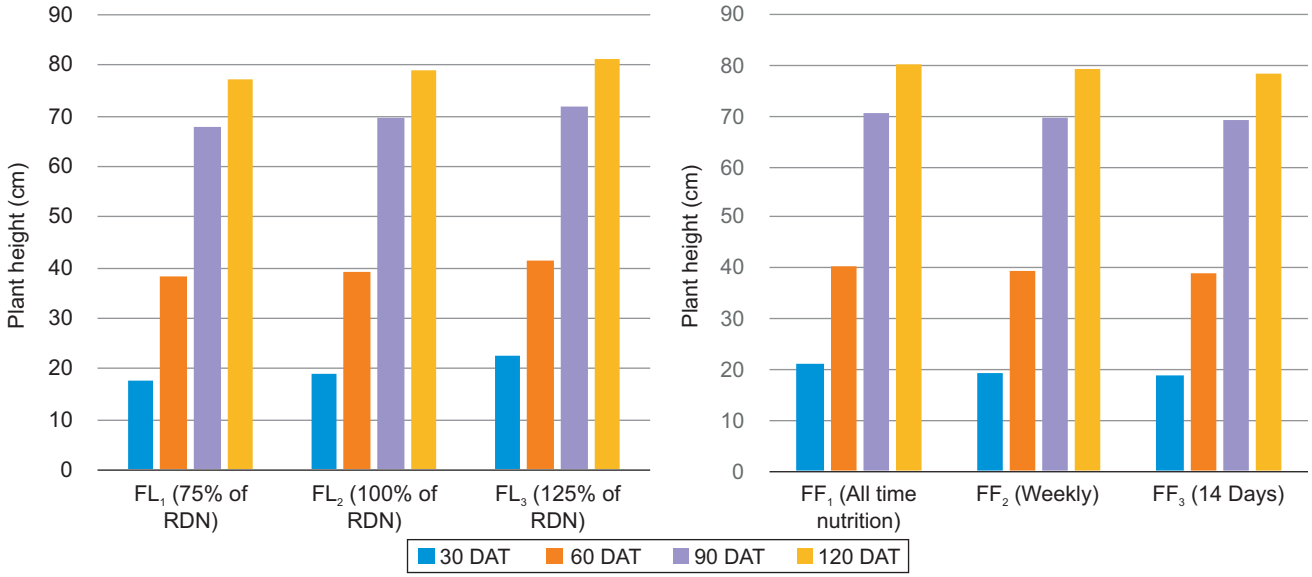

Fig. 2 Plant height under different fertigation levels and frequency.

FL, Fertigation level; FF, Fertigation frequency; RDN, Recommeded dose of nutrient; DAT, Days of transplanting.

Table 3 Fruit yield, water use efficiency and nitrogen use efficiency under different treatments of capsicum crop

Treatment	75% RDN (FL_1)	100% RDN (FL_2)	125% RDN (FL_3)	Mean of fertigation frequency
Fruit yield (q/ha)				
With every irrigation (FF_1)	164.82	174.27	178.40	172.50
Weekly nutrition (FF_2)	157.29	170.35	172.92	166.86
Fortnightly nutrition (FF_3)	153.16	158.73	159.55	157.15
Mean of FL	158.42	167.78	170.29	
Factors	Fertigation level (FL)	Fertigation frequency (FF)	Interaction of FL × FF	
CD (P=0.05)	9.33	6.25	NS	
SEm	2.31	20.07	NS	
Water use efficiency (kg/m^3)				
With every irrigation (FF_1)	3.44	3.63	3.72	3.59
Weekly nutrition (FF_2)	3.28	3.55	3.61	3.48
Fortnightly nutrition (FF_3)	3.19	3.31	3.33	3.28
Mean of FL	3.30	3.50	3.55	
Factors	Fertigation level (FL)	Fertigation frequency (FF)	Interaction of FL × FF	
CD (P=0.05)	0.19	0.13	NS	
SEm	0.048	0.042	NS	
Nitrogen use efficiency (kg/kg)				
With every irrigation (FF_1)	134.80	106.90	85.04	108.91
Weekly nutrition (FF_2)	128.64	104.49	82.43	105.19
Fortnightly nutrition (FF_3)	125.27	97.36	76.05	99.56
Mean of FL	129.57	102.92	81.17	
Factors	Fertigation level (FL)	Fertigation frequency (FF)	Interaction of FL × FF	
CD (P=0.05)	7.11	4.21	NS	
SEm	1.76	1.35	NS	

RDN, Recommended dose of nutrient.

was recoded at 125% RDN with benefit-cost ratio of (2.41) at with every irrigation frequency, while the minimum net return (₹3,03,125) was formed at 75% RDN with fortnightly fertigation having B:C ratio (1.94) (Supplementary Table 1).

The results of this experiment revealed that fertigation through drip irrigation at 125% RDN with every irrigation fertigation frequency was highly responsible for achieving the maximum average fruit weight, fruit length, fruit width, and number of fruits/plant of capsicum followed by 100% RDN. Among various treatments, plant height increases with increase in the fertigation level and decreases with the fertigation frequency.

SUMMARY

Capsicum is a major nutrient-rich vegetable crop grown all over India. The drip irrigation method is the best suited for capsicum crop, particularly due to water scarcity. A study was carried out during 2019–20 at Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana to examine the influence of three different nitrogen fertigation level (75, 100, and 125% RDN) and three different combinations of fertigation frequency i.e. with every irrigation, weekly and fortnightly, with drip irrigation on different parameters of capsicum crop. Urea was applied on the experimental fields as the major source of nitrogen. Fertigation level of 125% RDN applied with every irrigation (FF_1FL_3) obtained the highest fruit yield (178.4 q/ha), while the lowest yield (158.2 q/ha) was recorded with 75% RDN in FF_1FL_1 treatment. In comparison to fertigation frequency with every irrigation and 75% RDN, 33.7% and 34.5% more yield was obtained in 100 and 125% RDN treatment. Average plant height, fruit width, fruit length, fruits/plant, and fruit weight were found maximum at 125% RDN, followed by 100% RDN under with every irrigation. The experiment results showed that the highest water use efficiency (3.7 kg/m^3) was obtained with treatment FF_1FL_3, while lowest (3.2 kg/m^3) was found in FF_3FL_1 treatment. However, the treatment with 75% RDN with every irrigation fertigation frequency showed maximum nitrogen use efficiency (134.8). The nitrogen use efficiency increased when the nitrogen fertigation level decreased from 125–75%.

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