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Impact of drip irrigation and fertigation on nitrogen and water use efficiency and in improving economics of fennel

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ABSTRACT

This experiment was conducted to study the "impact of drip irrigation and fertigation on nitrogen and water use efficiency and in improving economics of fennel" during the *Rabi* season 2021-22 and 2022-23 at Vegetable Research Farm, CCS HAU, Hisar., The primary plot treatment consisted of two fennel varieties: HF-143 and Hisar Swarup., using sub plot treatments at four distinct levels of irrigation scheduling *viz.,* I_1-0.6 IW/CPE, I_2-0.8 IW/CPE, I_3-1.0 IW/CPE and I_4-1.2 IW/CPE and three different nitrogen levels as sub-sub plots *viz.,* N_1-20 kg ha^{-1}, N_2-35 kg ha^{-1} and N_3-50 kg ha^{-1}. The findings indicated that among irrigation levels highest nitrogen use efficiency (60.04kg/kg), seed yield (1834.0 kg/ha), biological yield (6,163.8 kg/ha) was observed at irrigation level 1.2 IW/CPE. Nitrogen use efficiency and seed yield were at par with irrigation level 1.0 IW/CPE. Maximum water use efficiency (8.31 kg/ha/mm) was recorded with irrigation at 0.6 IW/CPE and harvest index (31.4 %) was with irrigation level at 1.0 IW/CPE. Among nitrogen levels highest nitrogen use efficiency (79.00 kg/kg), biological yield (5,820.1 kg/ha) and harvest index (28.6%) were observed with nitrogen at 20 kg/ha whereas, water use efficiency (7.51 kg/ha/mm) and seed yield (1640.8 kg/ha) were recorded with nitrogen at 50 kg/ha. Variety HF-143 resulted superior than Hisar Swarup in all aspects.The highest BCR was recorded with treatment combination $V_2I_4N_3$ (3.24), which tuned with $V_2I_3N_3$ (3.24).

Keywords: *Foeniculum vulgare* Mill, Fertigation, WUE, NUE, Economics

Fennel (*Foeniculum vulgare* Mill) belongs to *Apiaceae* family commonly known as "saunf,". It is originated in the Southern Mediterranean region (Meena *et al.,* 2016). It is primarily grown for its fragrant and flavorful seeds.

It is primarily grown in Gujarat and Rajasthan and in some parts of Uttar Pradesh, Madhya Pradesh, Haryana. In Haryana, it is primarily cultivated in the districts of Mahendergarh, Palwal, Rewari, and Hisar, which cover approximately 0.27 thousand hectares and yield 0.17 metric tonnes. During 2021-22, the country exported 1531 thousand tonnes of spices/spice products worth Rs.30,576 crore and 40 thousand metric tonnes fennel of around 41,186.17 lakhs rupees (Anonymous, 2022).

The two most significant inputs in agriculture are water and nutrients, and their effective management of these two resources is crucial for higher yields. Both area and yield can be increased if modern irrigation techniques, such as drip irrigation, are used to irrigate fennel. Drip irrigation improves yield, nutrient and water use efficiency, while also conserving water (Yang *et al.,* 2010). Different crops experience water consumption reductions of 30 to 70% with drip irrigation over surface irrigation (Lal *et al.,* 2013). Drip irrigation methods maintain ideal soil moisture levels, limit wetted area, prevent soil evaporation, and so have a smaller impact on the microclimate's relative humidity. Water and nutrient usage are related to water use efficiency, which is anticipated to rise under fractional management.

Fertigation is an important precision farming method that improves nutrient usage efficiency (Harisha *et al.,* 2017). Applying fertilizer to the soil

in small amounts at every moment increases fertilizer use effectiveness, helps sustain nutritional balance and optimal nutrient concentration, saves energy and labor, allows for nutrient application at crucial stages of crop growth, and reduces the risk of ground-water contamination. (Rajpoot *et a.,* 2021).

The findings of this research will assist in applying fertiliser to the fennel crop appropriately using drip irrigation and in optimizing the cost of technology inputs. Thus, the present study has been designed to study "impact of drip irrigation and fertigation on nitrogen and water use efficiency and in improving economics of fennel.

MATERIALS AND METHOD

Experimental Details

The current investigation was conducted at Research Farm and in the laboratory of Department of Vegetable Science, CCS Haryana Agricultural University, Hisar, Haryana to find out the impact of drip irrigation and fertigation on nitrogen and water use efficiency and in improving economics of fennel during 2021-22 and 2022-23. Hisar Swarup and HF-143, two fennel varieties were selected as the seed were procured from the Department of Vegetable Science at CCS Haryana Agricultural University in Hisar. Four distinct levels of irrigation scheduling *viz.,* I_1-0.6 IW/CPE, I_2-0.8 IW/CPE, I_3-1.0 IW/CPE and I_4-1.2 IW/CPE and three different nitrogen levels *viz.,* N_1-20 kg ha^{-1}, N_2-35 kg ha^{-1} and N_3-50 kg ha^{-1} were designed. There were 24 treatments with plot size 3m×1.35m and plant spacing 45 cm×20 cm. The fertilisers were calculated according to the treatment combinations. Nitrogen was supplied during the experiment through drip fertigation. According to the treatments, during field preparation, a half dose of urea-nitrogen and a full dose of phosphorus in SSP were administered as the foundation dosage. 30 days after seeding, the remaining half nitrogen dosage was administered in three sections at intervals of 15 days. Before field preparation, 40 mm of pre-sowing irrigation was used to enhance seed germination. The crop was irrigated and fertigated using a drip irrigation method. The Split-Split Plot Design was applied, and the experimental data was statistically analyzed using analysis of variance (ANOVA) techniques developed by Panse and Sukhatme (1985). OPSTAT software was utilized for data analysis (Sheoran *et al.*, 1998).

Before conducting the experiment, a composite sample of soil from 0-30 cm depth was taken randomly from 10 locations in the field. The soil samples were collected, mixed, dried, and determined for mechanical and chemical analyses. Table 1 displays the physicochemical parameters of the soil in the experimental field. The soil analysis data indicated that the soil in the experimental field had a sandy loam texture, was non-saline, lower in organic carbon and nitrogen, high in available phosphorus, and rich in accessible potassium.

Observations were noted on yield, nitrogen and water use efficiency, and economics of fennel crop.

Nitrogen and water use efficiency

Nitrogen use efficiency (kg/ha)

The nitrogen use efficiency of different treatments was calculated by using the following formula:

$$\text{Nitrogen use efficiency (kg/kg)} = \frac{\text{Seed yield (kg/ha)}}{\text{Total amount of nitrogen applied (kg/ha)}}$$

Table 1. Physico-chemical properties of soil of the experimental field

Component	Value		Method
Clay (%)	12.2		International pipette method (Piper, 1996)
Silt (%)	23.4		International pipette method (Piper, 1996)
Sand (%)	64.4		International pipette method (Piper, 1996)
Chemical Properties	2021-22	2022-23	
pH (1:2)	8.19	8.14	Glass electrode pH meter method (Jackson, 1973)
EC (dSm^{-1} at 25^{o} C)	0.36	0.34	Conductivity bridge method (Richards, 1954)
Organic carbon (%)	0.35	0.42	(Walkley and Black, 1934)
Available nitrogen (kg/ha)	144.0	135.0	Alkaline Permagnet method (Subbaiah and Asija, 1956)
Available phosphorus (kg/ha)	22.0	16.0	Olsen *et al.* (1954)
Available potassium (kg/ha)	422	416	Flame Photometer method (Richards, 1954)

Water use efficiency (kg ha^{-1} mm^{-1})

The water use efficiency of different treatments was calculated by using the following formula:

$$\text{Water use efficiency (kg ha}^{-1}\text{ mm}^{-1}) = \frac{\text{Seed yield (kg/ha)}}{\text{Water applied (mm)}}$$

Seed yield (kg/ha)

For each treatment, all 10 of the chosen plants' umbels were collected, shade-dried, and threshed. The seed production per plant was measured in grams, and the average weight of the five plants' cleaned seeds was noted.

Biological yield (kg/ha)

The entire aerial biomass of all plants in each plot on the basis of dry weight was measured to determine the biological yield per plot, which was then converted to biological yield per hectare.

Harvest index (%)

The Harvest index was determined by dividing the economic yield by the biological yield and multiplying the result by 100. The formula proposed by Donald and Hamblin (1976) is stated as under:

$$\text{Harvest index} = \frac{\text{Economic yield (kg/ha)}}{\text{Biological yield (kg/ha)}} \times 100$$

Economics of various treatments

Various treatment's economics were calculated in relation of gross returns, net profits (₹/ha) and benefit-cost ratio, on the premise of existing prices in the market for different inputs and outputs as per information acquired from the Department of Agricultural Economics of CCS HAU, Hisar.

RESULTS AND DISCUSSION

Nitrogen and water use efficiency

The highest nitrogen use efficiency (60.04 kg/kg) was obtained with 1.2 IW/CPE irrigation level which was statistically at par with 1.0 IW/CPE irrigation level at (59.74 kg/kg) shown in Table 2. Nitrogen use efficiency was significantly increased by 32.7 per cent with 1.2 IW/CPE irrigation scheduling at over others. More nutrients may be absorbed by the plant and assimilated into the biomass because of the root zone's lower soil moisture content. Singh *et al.* (2018). Nitrogen at 20 kg/ha recorded higher nitrogen use efficiency (79.00 kg/kg). Crops utilize only a portion of the applied nitrogen combined with the nutrients already in the

Table 2. Effect of irrigation levels and nitrogen fertigation on nitrogen (kg/kg) water use efficiency (kg/ha/mm) Seed yield (kg/hectare), Biological yield(kg/ha) and Harvest index (%) of two different fennel varieties

Treatments	Nitrogen use efficiency (kg/kg) Pooled	Water use efficiency (kg/ha/mm) Pooled	Seed yield (kg/hectare) Pooled	Biological yield (kg/ha) Pooled	Harvest index (%) Pooled
Varieties					
V_1: Hisar Swarup	48.4	6.7	1482.4	5121.8	28.8
V_2: HF- 143	56.9	8.0	1741.2	6260.6	27.7
C.D. at 5%	0.9	0.1	25.4	19.1	1.0
Irrigation scheduling					
I_1: Irrigation at 0.6 IW/CPE	40.4	8.3	1246.7	5230.7	23.9
I_2: Irrigation at 0.8 IW/CPE	50.4	7.7	1542.2	5544.2	27.9
I_3: Irrigation at 1.0 IW/CPE	59.7	7.3	1824.4	5826.0	31.4
I_4: Irrigation at 1.2 IW/CPE	60.0	6.1	1834.0	6163.8	29.9
C.D. at 5%	0.5	0.1	15.3	12.6	0.3
Nitrogen levels					
N_1: Nitrogen at 20 kg/ha	79.0	7.2	1580.2	5502.2	28.6
N_2:Nitrogen at 35 kg/ha	46.1	7.4	1614.4	5751.3	28.1
N_3: Nitrogen at 50 kg/ha	32.8	7.5	1640.8	5820.1	28.0
C.D. at 5%	0.3	0.4	6.7	8.1	0.1

Irrigation levels :- I_1: 0.6 IW/CPE, I_2: 0.8 IW/CPE, I_3: 1.0 IW/CPE and I_4: 1.2 IW/CPE through drip
Nitrogen levels:- N_1: @20 kg/ha, N_2: @35 kg/ha and N_3: @50 kg/ha

soil, therefore, nitrogen utilization efficiency increases as nitrogen levels decrease. (Hameed *et al.*, 2019). HF-143 resulted in higher nitrogen use efficiency (56.93 kg/kg) over Hisar Swarup during pooled data, respectively. HF-143 advocated the higher NUE by 15.0 per cent in HF-143 over Hisar Swarup. Because maximum yield was obtained in HF-143 and nitrogen use efficiency is directly proportionate to the seed yield.

Water use efficiency

Significantly higher water use efficiency (8.31 kg/ha/mm) was recorded in fennel with irrigation at 0.6 IW/CPE over other irrigation scheduling. As plants only consume the amount of water they need, lower irrigation levels led to greater water consumption efficiency because less water was lost through evaporation, leaching, and percolation, and more water was effectively used by plants for other activities like staying in the soil. Hassan and Ali (2014), Jat *et al*. (2015a) and Delazari *et al.* (2019). Maximum water use efficiency (7.51 kg/ha/mm) was recorded in fennel supplied nitrogen at 50 kg/ha. Higher WUE was observed with the higher nitrogen level. As better moisture availability in the field facilitates the consumption and absorption of nutrients. Kanwar et al. (2018) and Harisha et al. (2019). Variety HF-143 showed a higher water use efficiency (7.98 kg/ha/mm) than other. This might be due to the fact that water use efficiency is directly proportionate to the seed yield and maximum yield was obtained in HF-143. Shinde *et al*. (2010) and Patil and Gadge (2016).

Seed yield (kg/ha)

Data resulted in table 2 stated that seed yield of fennel crop was significantly influenced by varieties, irrigation and nitrogen levels. Among different irrigation levels, seed yield (1834.0 kg/ha) was recorded significantly higher when 1.2 IW/CPE irrigation was applied, which was statistically at par with 1.0 IW/CPE (1824.4 kg/ha) irrigation level. When irrigation is scheduled at 1.2 IW/CPE instead of 0.6 IW/CPE, there is a notable increase in seed production of 32.1% kg per hectare. When the right quantity of irrigation was applied at the right time to overcome moisture stress throughout the growing season, the soil remained properly wet, increasing yield. Meena *et al.* (2017) and Harisha *et al.* (2019).

The data pertained in nitrogen levels, concluded that significantly higher seed yield (1640.8 kg/ha) was observed in fennel when treated with nitrogen at 50 kg/ha. While comparing the effect of nitrogen levels the seed yield per plant and per hectare were significantly increased by 3.2 per cent at 50 kg/ha over 20 kg/ha. This might be attributed to adequate and enough fertilizer application by drip fertigation, which made it feasible to fulfill crop nutrient requirements at various growth stages, resulting in better growth and yields. Drip systems are suitable to provide water-soluble nitrogen fertilizer through fertigation. Similar results were resulted by Ehsanipour *et al.* (2012), El-Mekawy (2012). Between varieties, significantly higher seed yield of fennel (1,741.2 kg/ha) in HF-143 over Hisar Swarup (1,482.4 kg/ha). Seed yield kg per hectare was significantly increased by 14.9 per cent in HF-143 over Hisar Swarup. This is one to fact that variety HF-143 had bolder seed as compare to other variety.

Biological yield

The data relevant to biological yield (Table 2) indicated that among irrigation levels, significantly higher biological yield (6,163.8 kg/ha) was recorded in fennel crop when treated irrigation at 1.2 IW/CPE over other treatments. The biological yield of the fennel crop increased by 15.1% at 1.2 IW/CPE compared to 0.6 IW/CPE irrigation schedule. The optimal moisture state in the crop's complete root zone manifests in improved physiological activities of plant plants. Rao *et al.* (2010), Godara *et al.* (2013)

By comparing the effect of different nitrogen levels, it has been resulted that significantly higher biological yield (5,820.1 kg/ha) was recorded in fennel nitrogen supplied at 50 kg/ha over other nitrogen levels. Biological yield (kg/ha) was increased by 5.4 per cent at 50 kg/ha over 20 kg/ha nitrogen level. This may be possible as drip fertigation provides an efficient way of delivering crop nutrient requirements at different growth phases, leading to improved yields and growth.. Water soluble nitrogen fertilizers can be applied *via* fertigation through drip system. Similar results were obtained by El-Mekawy (2012), Godara *et al.* (2013), and Harisha *et al.* (2019).

Among varieties, significantly higher biological yield of fennel (6,260.6 kg/ha) was recorded in HF-143 over Hisar Swarup (5,121.8). Biological yield also significantly enhanced by 18.9 per cent in HF-143 over Hisar Swarup. This may be due to the genetic characterstics of different varieties. Similarly, harvest index significantly enhanced 3.8 per cent in

HF-143 over Hisar Swarup. Similar findings were also reported by Bhunia *et al.* (2009).

Harvest index

Result related to harvest index (Table 2) stated that higher harvest index (31.4 %) was observed in fennel crop when treated with irrigation level at 0.6 IW/CPE. On the contrary, by scheduling 0.6 IW/CPE irrigation it was increased by 23.9 per cent over others. The crop's seed yield is the consequence of various physiological processes that occur while the crop is growing. Solanki *et al.* (2017).

Among nitrogen levels, higher harvest index (28.6%) was observed in fennel crop when treated with nitrogen at 20 kg/ha which was increased by 2.1 per cent over other nitrogen levels, which may be possible as drip fertigation provides an efficient way of delivering crop nutrient requirements at different growth phases, leading to improved yields and growth. Water soluble nitrogen fertilizers can be applied via fertigation through drip system. Related results were obtained by Ehsanipour *et al.* (2012), El-Mekawy (2012), Meena *et al.* (2017). Variety HF-143 resulted higher harvest index (28.8%) over Hisar Swarup.

Economics of different treatment combinations

Economics of different treatments were calculated on fennel production with respect to variables costs (labor charges, tractor charges, and material inputs), fixed costs. Economics of different treatments were calculated for the respective two years of experimentation was presented in Tables 3. As irrigation levels increase from 0.6 to 1.2 IW/CPE, the cost of cultivation and gross returns increased. But net returns and BCR (Benefit to Cost Ratio) were slightly decreased with increase in irrigation level from 1.0 to 1.2 IW/CPE. Among different levels of nitrogen (20, 35 and 50 kg/ha) the cost of cultivation, gross returns, net returns and BCR were increased with increase level of nitrogen. HF-143 recorded the highest gross returns, net returns and BCR in comparison to other Variety i.e. Hisar Swarup.

Table 3. Effect of irrigation levels and nitrogen fertigation on economics of two different treatments of pooled data (2021-22 and 2022-23)

Treatments		Treatment cost (Rs.)	Common cost	Cost of cultivation	Yield	Gross return	Net return	B:C ratio
T_1	$V_1I_1N_1$	232	60,545	60,777	1014	101350	40573	1.67
T_2	$V_1I_1N_2$	406	60,545	60,951	1134	113350	52399	1.86
T_3	$V_1I_1N_3$	580	60,545	61,125	1172	117223	56098	1.92
T_4	$V_1I_2N_1$	232	60,545	60,777	1409	140874	80097	2.32
T_5	$V_1I_2N_2$	406	60,545	60,951	1425	142473	81522	2.34
T_6	$V_1I_2N_3$	580	60,545	61,125	1433	143339	82214	2.35
T_7	$V_1I_3N_1$	232	60,545	60,777	1676	167646	106869	2.76
T_8	$V_1I_3N_2$	406	60,545	60,951	1682	168233	107282	2.76
T_9	$V_1I_3N_3$	580	60,545	61,125	1719	171949	110824	2.81
T_{10}	$V_1I_4N_1$	232	60,545	60,777	1692	169204	108427	2.78
T_{11}	$V_1I_4N_2$	406	60,545	60,951	1708	170769	109818	2.80
T_{12}	$V_1I_4N_3$	580	60,545	61,125	1724	172412	111287	2.82
T_{13}	$V_2I_1N_1$	232	60,545	60,777	1358	135782	75005	2.23
T_{14}	$V_2I_1N_2$	406	60,545	60,951	1385	138477	77526	2.27
T_{15}	$V_2I_1N_3$	580	60,545	61,125	1418	141811	80686	2.32
T_{16}	$V_2I_2N_1$	232	60,545	60,777	1628	162842	102065	2.68
T_{17}	$V_2I_2N_2$	406	60,545	60,951	1662	166231	105280	2.73
T_{18}	$V_2I_2N_3$	580	60,545	61,125	1695	169538	108414	2.77
T_{19}	$V_2I_3N_1$	232	60,545	60,777	1934	193383	132606	3.18
T_{20}	$V_2I_3N_2$	406	60,545	60,951	1956	195553	134602	3.21
T_{21}	$V_2I_3N_3$	580	60,545	61,125	1978	197848	136723	3.24
T_{22}	$V_2I_4N_1$	232	60,545	60,777	1931	193085	132308	3.18
T_{23}	$V_2I_4N_2$	406	60,545	60,951	1964	196395	135444	3.22
T_{24}	$V_2I_4N_3$	580	60,545	61,125	1983	198268	137143	3.24

Irrigation levels :- I_1: 0.6 IW/CPE, I_2: 0.8 IW/CPE, I_3: 1.0 IW/CPE and I_4: 1.2 IW/CPE through drip
Nitrogen levels:- N_1: @20 kg/ha, N_2: @35 kg/ha and N_3: @50 kg/ha

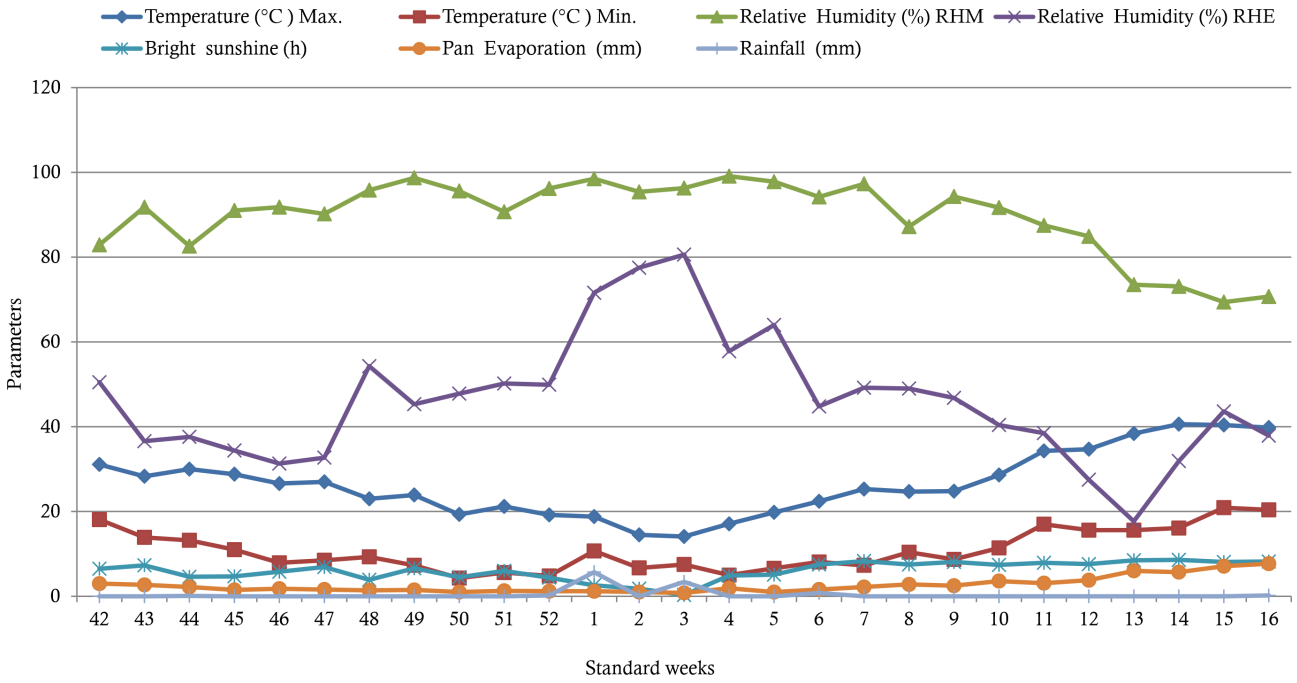

Fig. 1. Mean weekly meteorological data of Hisar district from November, 2021 to April, 2022 recorded at Experimental Station, CCS HAU, Hisar

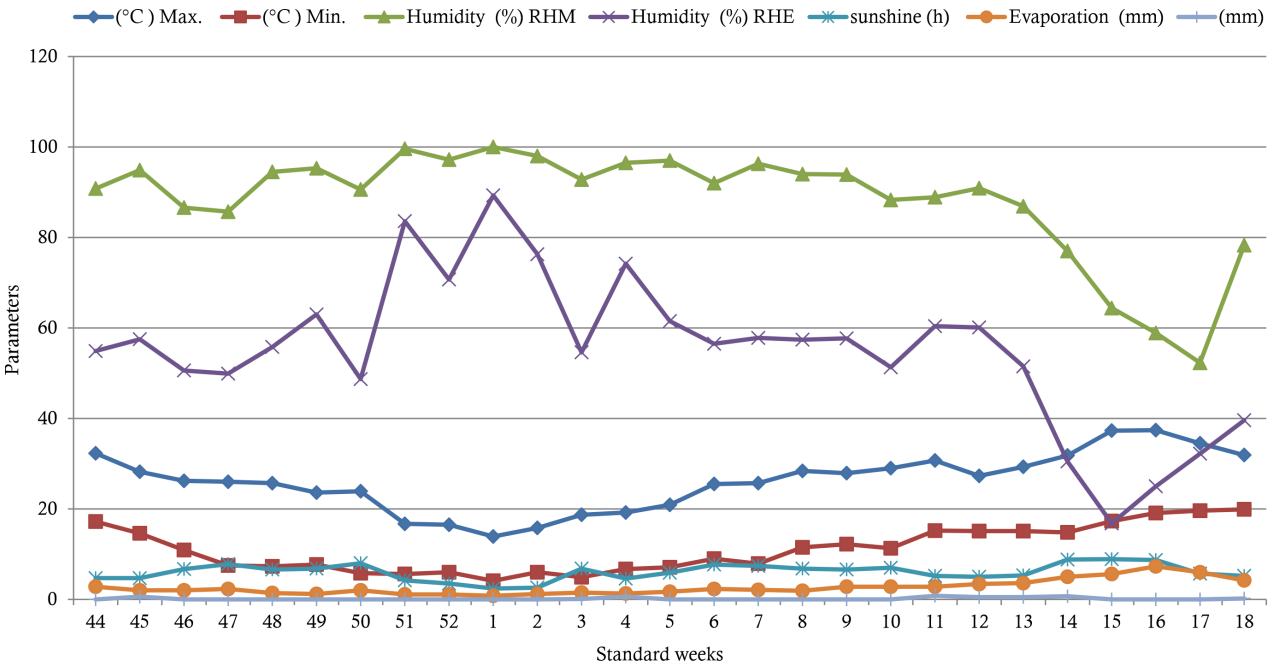

Fig. 2. Mean weekly meteorological data of Hisar district from November, 2022 to April, 2023 recorded at Experimental Station, CCS HAU, Hisar

The highest gross returns was obtained with treatment combination $V_2I_4N_3$ (₹ 1,98,268) followed by $V_2I_3N_3$ (₹ 1,97,848) during pooled data of both the years. Treatment combination $V_2I_4N_3$ (₹ 1,37,143) recorded highest net returns followed by $V_2I_3N_3$ (₹ 1,36,723). The highest BCR was recorded with treatment combination $V_2I_4N_3$ (3.24), which tuned with $V_2I_3N_3$ (3.24), respectively.

Based on the findings of two years' experiment, the results indicate that fennel variety HF-143, when

cultivated with irrigation scheduling 1.0 IW/CPE and nitrogen at 50 kg/ha in the western part of Haryana, was superior in yield parameters and BCR.

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