

# **Study of Nitrogen Fertigation through drip irrigation on capsicum crop**

**BY**

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**(2018AE08M)**

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## **CERTIFICATE – I**

This is to certify that this thesis entitled “**Study of nitrogen fertigation through drip irrigation on capsicum crop**” submitted for the degree of **Master of Technology** in the subject of **Agricultural Engineering (Soil and Water Engineering)** to the **Chaudhary Charan Singh Haryana Agricultural University, Hisar**, is a bonafide research work carried out by **Mr. Krishan Kanahiya (2018AE08M)** under my supervision and that no part of this dissertation has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.

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## **CERTIFICATE – II**

This is to certify that this thesis entitled “**Study of nitrogen fertigation through drip irrigation on capsicum crop**” submitted by **Mr. Krishan Kanahiya (2018AE08M)** to the **Chaudhary Charan Singh Haryana Agricultural University, Hisar** in partial fulfillment of the requirements for the degree of **Master of Technology** in the subject of **Soil and Water Engineering**, has been approved by the Student’s Advisory Committee after an oral examination on the same.

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### List of abbreviations and symbols used in the report

'	Minute (for angle)	$K_p$	Pan coefficient
%	Percent	kPa	Kilopascal
"	Second (for angle)	L	Liter
~	Approximately	L	Dimension of length
2-D	Two dimension	@	At the rate
A	Area of cross-section	m	Meter
CCS	Chaudhary Charan Singh	Mha	Million hectare
DAT	Days after transplanting	Min	Minute
dS	Deci siemens	ml	Milliliter
e.g.	For example	cm	Centimeter
$E_a$	Irrigation efficiency	CPE	Cumulative pan evaporation
EC	Electrical conductivity	N	Nitrogen
$EC_e$	Electrical conductivity of soil (saturated paste)	NUE	Nitrogen use efficiency
$E_{pan}$	Pan evaporation	O.C	Organic carbon
ET	Evapotranspiration	°C	Degree Celsius
FAO	Food and agriculture organization	P	Phosphorous
Fig	Figure	RDF	Recommended dose of fertilizer
g	Gram	RDN	Recommended dose of nitrogen
H	Hour	S	Second
Ha	Hectare	SWT	Soil water tension
HAU	Haryana Agricultural University	T	Tonnes, times
i.e.	that is	V	Volume of water
K	Potassium	WSF	Water soluble fertilizer
$K_c$	Crop coefficient	$\rho_b$	Bulk density
WUE	Water use efficiency	kg	Kilogram

## CHAPTER-I

### INTRODUCTION

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India is the seventh largest country in terms of area and second most populous in the world. Agriculture is the backbone of Indian economy since agriculture contributed 17% of the Indian GDP. Agriculture with its allied sectors is the largest source of livelihood in India since about 70% of rural households still depend on agriculture for their livelihood (FAO, 2019).

Efficient management of water and sustainable development in India is a complex challenge, which is going to increase day by day. Well-organized administration of water resources is indispensable to meet the increasing competition for water between agricultural and non-agricultural sectors, and present day, 80% share of water used for agriculture purpose must be reduced to 70% in the coming decades (Hakkim, 2014). Around 50% of the increase in demand for water by the year 2025 can be met by increasing the effectiveness of irrigation (Seckler *et al.*, 1998). Inadequate amount of available water in soil and subsequently in plants during crop growth period hampers different physiological processes in plants and finally affects the crop yield adversely (Kramer, 1959).

In general, the farmers raise their crops by adopting surface method of irrigation, in which, appreciable quantity of water is lost due to evaporation and percolation, resulting in low application and distribution efficiencies. In furrow and border irrigation systems, the loss of applied irrigation water from reservoir to the field under unlined irrigation system is 71% (Navalawala, 1991). Drip irrigation and subsurface drip irrigation are the modern irrigation methods of water and fertilizer-saving (Phene *et al.*, 1991; Solomon and Jorgensen 1992; Lamm 1995, 2002; Camp 1998; Ayars *et al.*, 1999). According to Schwab *et al.* (1993), drip irrigation is one of the latest techniques for applying water to row planted widely spaced crops, especially in the areas of water scarcity. It is the technique of irrigation, in which, water is applied directly to every individual plant on a steady and incessant basis. Subsurface drip-irrigation treatment results in a wider spread of roots across the bed as compared to drip system of irrigation (Zotarelli *et al.*, 2009). Drip irrigation offers great opportunity for precise application of water and nutrients to the crop and it is superior to other conventional methods of irrigation, especially in fruits and vegetable crops owing to precise and direct application

of water in the root zone (Bhella, 1988; Raina *et al.*, 1998). Drip fertigation is an effective way to supply water-soluble fertilizers in split doses to meet water and nutrients requirement of capsicum (Nijamudeen *et al.*, 2013). This technology not only uses each drop of water most efficiently but also results in good crop growth and yield. This method is also suitable for hilly and undulated tracts, coastal sand terrains and to a great extent in water scarce areas. Drip irrigation also referred to as tickle irrigation or micro-irrigation is gaining popularity as perhaps the most efficient method of water application (Bucks *et al.*, 1982). About 18 million hectares are under fruit, vegetable and plantation crops and the present area under drip is only about 55,000 hectares, therefore, the potential and prospects of drip irrigation will be very high in the coming years (Sivianppan, 1994) as drip method saves irrigation water, increases water and fertilizer use efficiency, decreases tillage requirement and helps in getting higher crop yield with better quality produce.

Plant nutrition plays an important role in enhancing growth, yield and quality of fruits, as nitrogen being a macro nutrient for all terrestrial plants is an essential constituent of nucleic acid, coenzymes, cell membranes, protein (builds up from amino acids that involve in catalization of chemical responses and transportation of electrons) and chlorophyll (enables the process of photosynthesis) present in many major portions of the plant body. Nitrogen compounds comprise of 40 to 50% of the dry matter of protoplasm and the living substance of plant cells (Togun *et al.*, 2003). Plants involve this element in many of the physiological processes like cell division, protein synthesis and photosynthesis, as it imparts green colour in plants, which promotes vegetative growth and development in plants. Moreover, it also stimulates root expansion. Plants uptake nitrogen in the form of nitrate, which is the most useful form for most of the plants and the plants utilize nitrogen in the form of nitrite and ammonia (Leghari, 2016).

Supplying fertilizers through drip besides increasing yield saves about 30% applied fertilizers (Sivanappan and Ranghaswami, 2005). On the other hand, when the nutrients are applied by other methods like broadcasting, the fertilizer use efficiency would be very less due to various losses. Drip system of irrigation alters the application rates and frequencies to suit the crop requirement at different growth stages, which increases the fertilizer use efficiency. Fertigation provides essential nutrients directly to the active root zone, thus minimizing the nutrients loss, which helps in improving the productivity and quality of the produce. Water use efficiency in drip irrigation on an average has been observed 68-77% and fruit yield 3.7-12.5% higher than surface system of irrigation with 31-37% saving of water (Singandhupe *et al.*, 2003).

Capsicum (*Capsicum annuum* var. *grossum*), also known as bell pepper or *Shimla Mirch*, is one of the popular vegetables grown throughout India. The cultivated capsicum, a frost sensitive herbaceous plant, is annual in temperate region but its plants keep growing and producing fruits over several years in tropical areas where the climatic conditions remain round the year favourable (Govindarajan, 1985). It is often consumed by rich people because of its high price in the market, thus, its cultivation is confined to peri-urban areas only. The area under cultivation of sweet peeper in the world is 1408105 hectares with production of 18087500 tonnes (Swarup, 2006), while in India, sweet peeper is grown in an area of 34000 hectares with a production of 487 thousand metric tonnes (National Horticulture Board 2018-19). In India, Karnataka produced the highest volume of capsicum in the financial year 2019. The South Indian states were estimated to produce capsicum of about 21 thousand tonnes that year. The major capsicum producing states are Karnataka, Andhra Pradesh, Maharashtra, Tamil Nadu, West Bengal, Madhya Pradesh, Gujarat, Punjab and Haryana. In Haryana, production of capsicum is about 40.05 thousand tonnes (National Horticulture Board 2017-18).

Capsicum is rich source of vitamin A and vitamin C with plenty of minerals like calcium, magnesium, phosphorous and potassium. Besides, coloured capsicums are also rich in carotidal and iron. A medium size capsicum (150 g) contains very low calories (30 kcal) with 2 g of dietary fiber and no fat. Coloured capsicums are rich in antioxidants, which help in fighting against cold, asthma, bronchitis, respiratory infections, muscular degeneration, angina, arteriosclerosis and cancer (Govindarajan, 1985). The mature green, red and yellow fruits of capsicum are eaten raw or widely used in stuffing, baking, salads, pizza and soup preparation, and stews for imparting flavour. In some parts of world, they are also used for making pickles and canned in brine with cucumber. Capsicums after stuffing with potato and cooking in tomato purees is a very popular dish in some European countries. Diced green or red capsicums are sometimes mixed with sweet corn or other vegetables for making different dishes (Shoemaker and Teskey, 1955).

The ability of drip irrigation to apply water as well as fertilizers on demand offers great scope for efficient resource management as well as challenge to researchers to identify suitable irrigation and fertigation schedules for drip-irrigated crops. Considering the importance of capsicum and drip irrigation to supply water, the present experiment entitled *Study of nitrogen fertigation through drip irrigation on Capsicum crop* was conducted with following objectives:

1. To study the effect of nitrogen fertigation dose on capsicum crop
2. To study the effect of nitrogen fertigation frequency on capsicum crop

## CHAPTER-II

### REVIEW OF LITERATURE

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An experiment was conducted at Research Farm of the Department of Vegetable Science, CCS Haryana Agricultural University, Hisar (Haryana) to study the effect of nitrogen fertigation levels on productivity of capsicum under drip irrigation system during spring-summer of the 2019-20. The available literature pertaining to the above study has been reviewed in this chapter under following headings:

#### 2.1 Irrigation strategies

##### 2.1.1 Water Saving

Merits of drip system of irrigation were compared by Sivanappan and Padmakumari (1980) with furrow system of irrigation and found that about one-third to one-fifth of the normal quantity of water was enough for the plots irrigated by drip system as compared to normal quantity of water applied to plots under surface irrigation in vegetable crops. In the irrigated agriculture, where water is not a yield-limiting factor, nitrogen fertilizer requirement is high and greater than for the dry-land production areas (Rauschkolb *et al.*, 1984). Drip system of irrigation saved water 45% higher than furrow irrigation method in tomato crop (Bangal *et al.*, 1987). Drip irrigated melons grown under poly houses produced 60% more fruits with one-third of the water and used one-half of the fertilizer as compared to furrow surface irrigated plants (Guy and Enrique, 1995). The fertigation in chilli with 100% recommended dose of nitrogen saved 40% water (Singh *et al.*, 1999). Water deficit between flowering and fruit development period reduced final fruit production (Jaimezet *et al.*, 2000). The highest irrigation water was saved with drip irrigation at 0.5  $E_{pan}$  in red pepper as compared to check basin method of irrigation (Manjunatha *et al.*, 2001; Cetin and Bilgel, 2002; Tiwari *et al.*, 2003). Singandhupe *et al.* (2003) recorded 31-37% water saving in tomato crop under drip system of irrigation at Rahuri (Maharashtra). Araki and Yamaguchi (2007) studied the effects of drip irrigation on growth, yield of tomato, and found the drip system more efficient with 23% water saving as compared to surface method of irrigation. Drip irrigation saves 58.6% water over check basin method of irrigation on red hot pepper crop (Mahajan *et al.*, 2007). However, Kong *et al.* (2008) obtained water consumption by bell pepper under subsurface drip irrigation lower by 6.7% in 2007 and 7.3% in 2008 than that under drip irrigation. In okra crop, Patel *et al.* (2009) found that

applying 100% recommended dose of nitrogen under drip system of irrigation at 0.8 pan evaporation reduced water use by 18% as compared to surface system of irrigation. Singh *et al.* (2010) recorded 35.3% irrigation water saving with drip irrigation at 0.75×E irrespective of fertigation treatments. The reduction in water consumption through drip method of irrigation over surface method varied from 30 to 70% (Fanish *et al.*, 2011). The percent of water saving through drip fertigation treatment was 33.94% over the conventional irrigation method (Kumari *et al.*, 2014). The drip irrigation system is extremely profitable as it saves 40-70% water as compared to surface irrigation method, *i.e.*, flood, sprinkler, furrow. Drip method also reduces labour cost and protects the plants from diseases by minimizing humidity in the atmosphere (Bhuriya *et al.*, 2015).

### 2.1.2 Water Use Efficiency

The highest water use efficiency was obtained with drip irrigation at 0.5  $E_{pan}$  owing to more yield of red pepper along as compared to check basin method of irrigation (Manjunatha *et al.*, 2001). In cabbage, Sharanappa *et al.* (2000) recorded significantly higher water use efficiency (54.17 g/L) when irrigation was applied either daily or once in two days (51.49 g/L) by drip method as compared to 12.32 g/L in furrow method of irrigation. Higher water use efficiency (68-76.8%) was recorded with drip irrigation than furrow method of irrigation (Singandhupe *et al.*, 2003). Cabbage plants subjected to drip irrigation at 1.0 and 0.8  $E_{pan}$  were found superior in water use efficiency (Lingaiah *et al.*, 2005). Through drip irrigation system, the water use efficiency increased by 23.21% at 0.5  $E_{pan}$  over check basin method of irrigation when half of the recommended amount of nitrogen (75 kg/ha) was applied (Mahajan *et al.*, 2007). Applying nitrogen @ 150 kg/ha in bell pepper is optimal fertigation practice for water-use efficiency of the crop (Kong *et al.*, 2008). Among the treatments, *i.e.*, T<sub>1</sub> (Water soluble fertilizer applied at 80% RDF (recommended dose of fertilizer), T<sub>2</sub> (WSF applied at 70% RDF), T<sub>3</sub> (WSF applied at 60% RDF), T<sub>4</sub> (Conventional fertilizer applied at 80% RDF), T<sub>5</sub> (Conventional fertilizer applied at 70% RDF) and T<sub>6</sub> (Conventional fertilizer applied at 60% RDF) and the treatment T<sub>2</sub> showed the maximum water use efficiency (5.24 q ha<sup>-1</sup>cm<sup>-1</sup>), which was statistically at par with treatment T<sub>4</sub> (5.19 q ha<sup>-1</sup>cm<sup>-1</sup>), therefore, the water use efficiency of T<sub>2</sub> and T<sub>4</sub> treatments was significantly superior to the water use efficiency of rest of the treatments (Kumari *et al.*, 2014). Among the drip irrigation levels, Kumar *et al.* (2016) found the highest field water use efficiency (6148.31 kg/ha/cm) at 65% irrigation level, indicating comparatively more efficient use of irrigation water with a possibility saving of 35% water in brinjal crop (1.58 litre/plant/day).

### 2.1.3 Nitrogen Use Efficiency

A decrease in nitrogen use efficiency was noticed by Stark *et al.* (1983) with higher rates of applied nitrogen and also noticed an improvement in nitrogen-fertilizer use efficiency by applying nitrogen with irrigation water. Nitrogen application affected both shoot and root growth rate, whereas, the later was less affected (Bar-Tal *et al.*, 1990). The percentage of applied nitrogen intake by crops is below 40% (Zhang *et al.* 1996). Application of too much nitrogenous fertilizer did not increase crop production (Camp *et al.*, 1997; Thompson *et al.*, 2002 a, b; Sorensen *et al.*, 2004; Mahajan and Singh, 2006; Cabello *et al.*, 2009). Application of nitrogen 120 kg/ha in capsicum crop through drip irrigation in ten equal splits at 8 days interval saved 20-40% nitrogen as compared to furrow irrigation method when nitrogen was applied in two equal splits at planting and one month after planting (Singandhupe *et al.*, 2003). Badar *et al.*, (2007) obtained the average nitrogen recovery across the fertigation frequencies 60 and 54% in tomato crop under subsurface drip irrigation and NUE 221 and 194 kg yield/kg with applied nitrogen 200 and 300 kg/ha, respectively. Under drip irrigation system, the nitrogen use efficiency increased by 38.7% at 0.5  $E_{pan}$  over check basin method of irrigation when half of the recommended amount of nitrogen was applied (Mahajan *et al.*, 2007).

### 2.1.4 Yield and its attributes

Tomato gave 4.8% higher yield under drip irrigation system than furrow irrigation method (Bangal *et al.*, 1987). Nitrogen fertilizer in either organic or inorganic form and its application method play a vital role in enhancing the growth and productivity of acid lime (Beridze, 1990). Payerol and Bhangoo (1990) obtained maximum yield of Anaheim chilli with nitrogen application 240 kg/ha, which declined with further increased in nitrogen rate under trickle irrigation system. Gutal *et al.* (1990) observed higher red pepper yield under drip system of irrigation as compared to surface irrigation method. Hartz *et al.* (1993) studied the response of bell pepper (*Capsicum annuum* L.) to five rates of nitrogen fertigation between 0 and 336 kg/ha at two drip-irrigated sites [University of California, Davis (UCD) and West Side Field Station, Five Points (WSFS)] in California during the year 1992 and recorded peaked fruit yield and fruit size with nitrogen 252 kg/ha, however, the additional dose of nitrogen retarded crop productivity at both the sites. The effect of subsurface drip irrigation and drip irrigation on crop yield proves that subsurface drip irrigation generally results in higher crop yield (Hanson *et al.*, 1997; Hanson and May 2004; Gencoglan *et al.*, 2006; Patel and Rajput 2009). In swingle (*citrus aurantifolia*) crop, the percent increase in plant height, plant girth and canopy volume was maximum with 100% nitrogen fertigation (31, 52.30 and 48.26%) as compared to 80% nitrogen

fertigation treatment (30, 49.2 and 46.9%) and the percent increase in plant height, plant girth and canopy volume was better in band placement treatment as compared to the percent increase in plant height, plant girth and canopy volume with 80% nitrogen fertigation (Shirgure *et al.*, 1999). The fertigation in chilli with 100% recommended dose of nitrogen produced 52% higher yield over check basin method and only 50% nitrogen applied through fertigation produced equivalent amount of fruit to check basin (Singh *et al.*, 1999). In cabbage, Shekar and Sridhara, (2000) recorded highest yield of 68.98 t/ha with daily drip irrigation. Singandhupe *et al.* (2003) obtained 3.7-12.5% higher fruit yield of tomato crop under drip system of irrigation at Rahuri (Maharashtra). Deolanker *et al.* (2004) studied that dry matter per plant, girth of head and average weight of head were significantly superior due to drip over surface irrigation in cabbage and obtained the highest head yield of cabbage per unit applied nutrients with drip irrigation at 60% NPK level through briquette form of fertilizer. In cabbage, plants subjected to drip irrigation at 1.0 and 0.8  $E_{pan}$  were observed superior in plant height, dry matter production, head diameter and head weight (Lingaiah *et al.*, 2005). Shorter irrigation intervals from 3 to 6 days could result in higher crop yield and water use (Sezen *et al.*, 2005, 2006; Sensoy *et al.*, 2007), however, different subsurface drip irrigation frequencies from one to seven days only had a slight effect on corn yield. Badar *et al.* (2007) studied the effect of fertigation frequency from subsurface drip irrigation on yield of tomato grown on sandy soil and the highest total fruit yield 67.75, 65.13 and 63.29 t/ha with the frequency of 1, 3 and 7 days, respectively, however, the yield with longest duration was significantly lower than these values (54.32 t/ha). Application of the same quantity of water and 100% recommended dose of nitrogen through drip irrigation system increased 28.4% yield of red hot pepper (277.4 q ha<sup>-1</sup>), in check basin method of irrigation, the highest red hot pepper yield was obtained 216.1 q ha<sup>-1</sup> at 100% recommended dose of nitrogen, while through drip irrigation at 1.0  $E_{pan}$ , the yield was highest at 75% of recommended nitrogen (Mahajan *et al.*, 2007). Kong *et al.* (2008) obtained root length 11.8 and 12.5% obviously higher in 2007 and 2008 under subsurface drip irrigation than that under drip irrigation by under four nitrogen fertigation levels, *i.e.*, 0, 75, 150 and 300 kg/ha, respectively. The productivity gain for different crops through drip irrigation was recorded in the range of 20 to 90%, thus, it could be made possible to increase the yield potential of crops by three folds with same quantity of water and all these emphasize the need for water conservation and improvement in water-use efficiency to achieve *More Crop per Drop of Water* (Fanish *et al.*, 2011). Under drip irrigation system, Pandey *et al.* (2012) obtained higher yield of chilli (*Capsicum annuum* L.) when planting was done at closer spacing of 30 cm (58.77%) as compared to the crop planted at 45 cm spacing, while the drip irrigation along significantly increased yield 10.50 kg/m<sup>2</sup> and net income 60.30% as compared to

flood irrigation. In guava, Sharma *et al.* (2013) obtained the maximum fruit yield of 21.6 t/ha and water productivity of 17.8 kg/ha-mm under drip irrigation at 100% ET<sub>c</sub> with 120% of the recommended dose of nitrogen and the highest fruit yield of 18.7 t/ha with drip irrigation at 100% of the crop evapo transpiration (ET<sub>c</sub>), and the maximum fruit yield of 16.9 t/ha was registered with 100% of recommended dose of nitrogen. Through drip irrigation, Imamsaheb *et al.* (2014) obtained highest yield from treatments with plant spacing of 20x72 cm and drip lateral spacing of 1.5 m for chilli crop and plant spacing of 20x72 cm and drip lateral spacing of 2.5 m for okra crop which was 55% higher over control. Patil and Das (2015) recorded significantly highest fruit yield of capsicum (87.20 q ha<sup>-1</sup>) at 100 EPR along with the application of 75% RD of nitrogen through drip irrigation over rest of the treatments in Ludhiana.

## **2.2 Fertigation Strategies**

Drip fertigation allows nutrients placement directly to the root zone through the emitters near plant roots during critical periods of nutrients requirement (Imas *et al.*, 1997). Goncalves *et al.* (2000) applied nitrogen fertilizers through fertigation and conventional method while using two sources of nitrogen (urea and ammonium sulphate) and observed that crop yield response to urea was better than ammonium sulphate and the fertigation results were better than the conventional application of fertilizers in broccoli crop. Fertigation was recognized as a very effective and convenient means of maintaining optimal fertility and water supply and also enables the application of soluble fertilizers and other chemicals along with irrigation water, uniformity and more efficiency (Jayabal *et al.*, 2000; Patel and Rajput, 2000; Narda and Chawla, 2002). Segars (2003) studied that when fertilizers were applied along with water through drip irrigation system, there was a considerable saving of fertilizers besides increased yield and saving of water as compared to surface method of irrigation.

### **2.2.1 Yield and its attributes**

Fertigation, which combines irrigation with fertilizer, is well recognized as the most effective and convenient means of maintaining optimum fertility level and water supply according to the specific requirement of each crop and resulting in higher yield and better quality fruits (Smith *et al.*, 1979; Syvertsen and Smith, 1996). Papadopoulos (1988) obtained highest yield (58130 kg/ha and specific gravity 1.071) of good quality of potato with nitrogen fertigation (combined irrigation with fertilization) of 130 mg per litre of water. In strawberry crop, Hochmuth *et al.* (1996) recorded an increase in March (the largest production month) and total-season yield (0.76 and 0.54 kg/ha/day) with increasing nitrogen fertigation, respectively. Inside the plastic house, Qawasmi *et al.* (1999) obtained the highest yield of bell pepper (*Capsicum annum*) with the

addition of nitrogen 150 kg/ha and the crop irrigated on weekly bases with the amount of water equivalent to 80% of the pan evaporation reading due to increased rate and uptake of applied nitrogen by the plants and at the same time stimulated the uptake of potassium and phosphorus through the synergistic effect of nitrogen on both the nutrients. Thompson *et al.* (2002) reported that on rates of nitrogen (60-500 kg/ha) significantly affected the marketable yield of broccoli across all the treatments (three irrigation levels- low, medium, and high) ranged from 3 to 18 mg/ha. Antony and Singandhupe (2004) reported that drip irrigation at 100% CPE was beneficial for capsicum var. California Wonder plants in terms of yield, better plant morphological characters *viz.*, plant height, number of branches, root fitnesses, root length, *etc.* and the yield was found to have significant positive correlation with total dry matter (TDM,0.865) and net photosynthesis (0.840). Hebbar *et al.* (2004) obtained 19.9% higher yield of tomato with drip irrigation (71.9 mg/ha) as compared to furrow system of irrigation (59.50 mg/ha) and found a significant increase in fruit yield (79.2 mg/ha) under fertigation with 100% water-soluble fertilizers over control (furrow-irrigated) and drip irrigation. In bhindi crop, Bhanu *et al.* (2005) obtained higher yield (4188 and 4153 kg/ha) with the treatment combination of drip irrigation at  $1.0 E_{pan}$  and nitrogen fertigation of 120 kg/ha. Onion yield was not significantly affected in daily, alternate day and weekly fertigation though there was a trend of lower yield (Rajput and Patel, 2006). Shashidhara (2006) obtained significantly higher dry chilli yield with the application of 100% RDF through fertigation. Applying nitrogen @ 150 kg/ha in bell pepper is optimal fertigation practice for improving fruit yield (Kong *et al.*, 2008). Through drip irrigation, Patel *et al.* (2009) obtained highest fruit yield of okra (20796 kg/ha) at 0.8 pan evaporation fraction, which was 46.25% higher over that registered for surface irrigation. Brahma *et al.* (2010) recorded significantly higher growth, yield and economics of broccoli crop under drip irrigation fulfillment at 100% evaporation and 200 kg/ha recommended dose of nitrogen through fertigation in comparison of conventional fertilization. Gupta *et al.* (2010) observed that the treatment combination of 80% ET through drip and 80% recommended NPK through fertigation registered maximum fruit yield of 366.48 q/ha with high quality fruits. Singh *et al.* (2010) noted an increase in fruit yield of capsicum by 38.6% over control grown on sandy loam soil inside the polyhouse through drip irrigation at  $0.75 \times E_{pan}$  along with fertigation of 100% recommended nitrogen. Ramachandrappa *et al.* (2010) recorded significantly higher growth, yield (19.10 t/ha) and yield attributes of green chilli at 90 days after transplanting with mono-ammonium phosphate (MAP) and potassium nitrate (KNO) at 125% recommended NPK fertigation, which was also at par with MAP and KNO at 100% recommended NPK fertigation (19.74 t/ha), MAP and MOP at 125% recommended NPK fertigation (19.01 t/ha) and urea, SSP and MOP at 125% recommended NPK

fertigation (19.10 t/ha). Vijayakumar *et al.* (2010) obtained highest yield, shoot length and number of branches from chilli crop receiving irrigation water through drip at 75% of pan evaporation with fertigation of 75% recommended nitrogen and potassium. In cabbage crop, Vasu (2011) obtained maximum dry matter production of 4793 kg ha<sup>-1</sup> with the application of 125% RDF of nitrogen and potassium through fertigation at daily interval, which was statistically at par with 100% RDF of nitrogen and potassium through fertigation at daily interval (4553 kg ha<sup>-1</sup>) and observed to be higher under daily fertigation of nitrogen and potassium with 100 and 125% recommended dose of 16.92 and 15.53 t ha<sup>-1</sup>, respectively. Khalkho *et al.* (2013) obtained highest yield of chilli crop 9.14 t/ha irrigation at 60% available soil moisture (ASM) level. In chilli, the maximum yield of 458 g/plant, which was worked out as 18.32 t/ha for the treatment where 85% of the irrigation requirement was met out by one lateral for each row of crop (Nesthad *et al.*, 2013). Nijamudeen *et al.* (2013) obtained maximum yield of 62.2 t/ha at nitrogen dose of 400 kg/ha and potash dose of 360 kg/ha applied through fertigation. The highest total fruit yield (25.49 t ha<sup>-1</sup>) of chilli crop was recorded under the treatment site specific drip fertigation with daily drip irrigation for low fertility area, whereas, there was no significant difference between the total yield under the treatments site specific drip fertigation and recommended dose of drip fertigation both with daily drip irrigation for high fertility area (25.66 and 25.67 t/ha, respectively) and the yield parameters like fruit length, fruit girth, fruit weight and number of fruits per plant also varied in the same trend as that of total green fruit yield (Hakkim, 2014). Rathore *et al.* (2014) observed an improvement in growth parameters and yield attributes with increasing dose of nitrogen up to 120 kg/ha applied through drip irrigation. In tomato, Gupta *et al.* (2015) obtained higher fruit yield (989.3 q/ha), average fruit weight (53.0 g), fruit length (4.48 cm) and fruit diameter (4.75 cm) at 80% ET and fertigation with 60% recommended dose of NPK under drip irrigation. In cabbage crop, Rajak *et al.* (2015) observed higher plant height, number of unfolded leaves, diameter of head, volume of head and leaf area index with drip irrigation at 80% ET and fertigation 75% RDF and obtained highest yield (340.73 q ha<sup>-1</sup>) with the treatment combination of drip irrigation with 80% ET and fertigation 75% RDF. In banana, Pramanik *et al.* (2016) obtained maximum fruit yield through drip system of irrigation at 60% cumulative pan evaporation and 80% of recommended dose of NPK fertigation. Reddy *et al.* (2016) obtained maximum plant height, number of branches per plant (cm), leaf area and leaf area index, number of fruits per plant, length of fruit (cm), girth of fruit (cm), fruit weight (g) dry fruit yield per plant (g), dry fruit yield per hectare (t) of the chilli crop with the application of water soluble fertilizers as well as normal fertilizers through fertigation with mulching. Under drip irrigation on chilli crop, Brahmanapuduru (2017) obtained maximum yield (24.80 t ha<sup>-1</sup>), number of fruits per plant

(78.44), fruit weight per plant (261.35 g), fruit diameter (1.18 cm), primary branches (11.8), secondary branches (50.6) and stem girth (2.26 cm) with the application of 80% ET with 100% fertilizer level. Under drip irrigation, Kumar *et al.* (2017) studied the effect of quality of irrigation water and level of fertigation on nitrogen use efficiency (NUE) and water use efficiency (WUE) and obtained maximum yield (61.53 t ha<sup>-1</sup>) from tomato crop receiving nitrogen fertigation @ 125% RDN with good quality irrigation water. In tomato, Ankush *et al.* (2018) found irrigation and fertigation scheduled at 75% ET and 75% recommended dose of fertigation a good alternate for saving water and nutrients, simultaneously enhancing nutrients uptake, growth, yield and quality of fruit. Agarwal *et al.* (2018) obtained maximum cabbage yield of 230.98 q ha<sup>-1</sup> by applying 80% water soluble fertilizers (WSF) at 0.8 cumulative pan evaporation (CPE) water through drip, which was 30.43% more over conventional method of irrigation. In tomato, Ankush *et al.* (2018) found irrigation and fertigation scheduled at 75% ET and 75% recommended dose of fertigation a good alternate for saving water and nutrients, simultaneously enhancing nutrients uptake, growth, yield and quality of fruit. In bell pepper, Kumar *et al.* (2018) obtained maximum fruit diameter (7.31 cm), pericarp thickness (0.70 cm), average fruit weight (150.40 g), average fruit volume (236.31 cc), number of fruits per plant (20.78), yield per plant (3.11 kg) and yield per 1000 m<sup>2</sup> (8.90 t) due to the main effect of F<sub>3</sub> fertigation treatment (250:250:250 kg/ha). Maind *et al.* (2018) obtained highest plant growth and yield of chilli in respect of plant height (88.86 cm), stem diameter (5.03 cm), number of leaves per plant (847.00), leaf area (973.33 cm<sup>2</sup>), plant spread (66.90 cm) and fruit yield (14.03 t ha<sup>-1</sup>) at irrigation level 1.0 PE in combination with 100% RDF and also noticed a reduction in days taken to flower initiation (20.84), days to 50% flowering (68.90) and days to first harvesting (37.23) at Parbhani, Maharashtra. From the field experiments conducted in two consecutive years, Reddy and Tiwari (2018) observed the maximum growth attributes, yield and yield attributes with nitrogen 100 kg/ha applied through fertigation. Mushtaq *et al.* (2019) obtained maximum yield of capsicum cv. Nishat-1 (75.51 t/ha) and Shalimar Capsicum Hybrid-2 (85.34 t/ha) with fertigation treatment (75% RDF + 75% recommended dose of micronutrients (5 ml per litre of micronutrient mixture), which resulted in 42.28 and 46.63% increased yield in cultivar and hybrid as compared to control treatment (soil application of 100% recommended dose of NPK fertilizers), respectively. Singh *et al.* (2020) observed a significant response of capsicum to fertigation and irrigation levels with respect to production under greenhouse conditions and the crop gave average yield of 3 kg/plant and 101.6 t/ha under the treatment F<sub>1</sub>I<sub>1</sub> (100% irrigation of crop evapotranspiration and 120% dose of fertilizers).

### 2.2.2 Water Use Efficiency (WUE)

In bhindi crop, the water use efficiency was recorded maximum (8.23 and 8.10 kg/ha/mm) with the treatment combination of drip irrigation at 1.0  $E_{pan}$  and nitrogen fertigation of 120 kg/ha (Rekha *et al.*, 2005). In chilli, higher water use efficiency (WUE) was observed when the crop received irrigation water through drip at 40% PE with 100% RDF (Shashidhara, 2006). In okra, Patel *et al.* (2009) recorded highest water use efficiency (30.48 kg/ha/mm) at 0.8 pan evaporation under drip irrigation system. Gupta *et al.* (2010) observed the highest water use efficiency (29.40 q/ha/cm) of capsicum with the treatment combination of 60% ET through drip + 80% recommended NPK through fertigation. Sharma *et al.* (2012) observed maximum water use efficiency (35.1 kg/ha/mm) in guava crop with drip irrigation at 80% of evapo-transpiration. In chili, Khalkho *et al.* (2013) recorded the highest water use efficiency (0.37 t/ha/cm) by both the treatments ( $T_1$  - 70 and  $T_2$  - 60% available soil moisture). Rathore *et al.* (2014) obtained higher production and water-use efficiency due to the enhanced yield under nitrogen 120 kg/ha supplied through drip irrigation. Gupta *et al.* (2015) noted higher water use efficiency (49.9 q/ha/cm) at 80% ET and fertigation with 60% recommended dose of NPK in tomato crop. In cabbage crop, Rajak *et al.* (2015) noticed maximum water use efficiency (154.76 q/ha/mm) with the treatment combination of drip irrigation at 60% ET and fertigation 75% RDF. Through drip irrigation, Pramanik *et al.* (2016) recorded higher water use efficiency with water savings of 38.3-41.5% as compared to surface system of irrigation at 60% cumulative pan evaporation and 80% of recommended dose of NPK fertigation in banana. Kumar *et al.* (2017) obtained the maximum water use efficiency (26.0 kg m<sup>-3</sup>) with good quality irrigation treatment receiving nitrogen fertigation @ 125% recommended dose of nitrogen. Agarwal *et al.* (2018) recorded maximum water use efficiency and water saving in 0.6 CPE water by drip (103.36 q/ha/mm and 73.35%) system of irrigation, respectively. Singh *et al.* (2020) recorded highest water use efficiency (8.7 q/ha/cm) with the treatment combination of 120% dose of fertilizer and 80% irrigation of crop evapo-transpiration ( $ET_c$ ) in yellow coloured capsicum.

### 2.2.3 Fertilizer use efficiency

In tomato, Hebbar *et al.* (2004) recorded higher fertilizer-use efficiency (226.48 kg yield/kg of NPK) under fertigation with water-soluble fertilizers as compared to drip and furrow-irrigated (control) treatment. The fertilizer use efficiency (FUE), which was higher at lower level of fertilizer application as compared to higher level of fertilizer, increased by 25% in 50% RDF and 9% in 75% RDF as compared to 100% RDF (Shashidhara, 2006). Araki and Yamaguchi (2007) studied the effects of drip irrigation on growth and yield of tomato, which resulted in saving of

30% fertilizer usage as compared to soil application. Brahma *et al.* (2010) reveal that fertigation with 100% recommended doses of nitrogen was the most efficient treatment with fertigation efficiency of 55.44 and 57.31%, respectively. Gupta *et al.* (2010) found the fertilizer use efficiency of capsicum maximum (NUE-4.89 q/kg N, PUE-6.53 q/kg P and KUE-9.79 q/kg K) with the treatment combination of 80% ET through drip + 60% recommended NPK through fertigation, however, the combined effect of drip irrigation and fertigation was found superior to their individual effects. Ramachandrappa *et al.* (2010) worked out the fertilizer use efficiency significantly higher in 75% recommended NPK fertigation (T<sub>7</sub>: 71.6, T<sub>4</sub>: 64.1, T<sub>1</sub>: 68.8 kg kg<sup>-1</sup> NPK) followed by 100% recommended NPK fertigation (T<sub>2</sub>, T<sub>5</sub> and T<sub>8</sub>) and 125% recommended NPK fertigation (T<sub>3</sub>, T<sub>6</sub> and T<sub>9</sub>). In chili, Vijayakumar *et al.* (2010) noted the highest fertilizer use efficiency under drip irrigation at 75% of pan evaporation with fertigation of 75% recommended dose of nitrogen and potash. In cabbage crop, Vasu (2011) recorded highest fertilizer use efficiency with daily fertigation of 75% recommended dose of nitrogen and potash, while the highest water productivity (7.92 kg m<sup>-3</sup>) in daily fertigation with 100% RDF. In tomato, Gupta *et al.* (2015) recorded higher fertilizers use efficiency (10.9, 18.3 and 27.4 q/kg) at 80% ET and fertigation with 60% recommended dose of NPK. In cabbage crop, the fertilizer use efficiency was found maximum (193.42 kg/kg of nutrient) with the treatment combination of drip irrigation with 80% ET and fertigation 50% RDF (Rajak *et al.*, 2015). Agarwal *et al.* (2018) recorded maximum fertilizer use efficiency (58.98 q/kg) and fertilizer saving (45.45%) under 80% water-soluble fertilizer (WSF) supplied by drip system of irrigation. In tomato, Ankush *et al.* (2018) noted nutrient use efficiency as high as 90% under fertigation treatment as compared to conventional methods (40 to 60%). Singh *et al.* (2020) recorded highest fertilizer use efficiency (0.69 q/ha/kg of NPK) with the treatment combination of 100% irrigation of crop evapotranspiration (ET<sub>c</sub>) and 120% dose of fertilizer.

Reviews presented in this chapter indicate that a good extent of research work has been conducted on response of vegetable crop including capsicum to different irrigation and fertigation level. Limited extent of work has been carried out to investigate the effect of fertigation level and fertigation frequency on a capsicum crop grown in open field. The number of studies analyzed that the nitrogen fertilizer and its application method, plays a vital role in enhancing growth and productivity of capsicum crop and combination of different nitrogen levels and fertigation frequency needs to be studied further.

## CHAPTER-III

### MATERIALS AND METHODS

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The details of location and layout of experiment, weather conditions prevailing during experimental period, soil properties, treatment details, yield parameters, observations recorded, and estimation methods followed for the analysis of data are presented in this chapter.

#### 3.1 Location

The experiment entitled *Study of nitrogen fertigation through drip irrigation on Capsicum crop* was conducted at Research Farm of the Department of Vegetable Science, CCS Haryana Agricultural University, Hisar (Haryana) during spring-summer of 2019-20. The experimental site is geographically Hisar, Haryana situated in Asian Continent at 29°10' N latitude and 75°46' E longitude with an altitude of 215.2 meters above the mean sea level and falls in the semi-arid subtropical region with extreme hot dry winds during summer and severe cold in winter months. The maximum and minimum temperature shows a wide degree of fluctuation during summer and winter months. The district area forms a part of Indo-Genetic plain. The area as a whole is almost flat alluvial plain dotted with sand hummocks and sand dunes. A view of experimental site is shown in Figure 3.1.



**Figure 3.1:** A view of experimental site.

### 3.2 Climatic conditions

The maximum temperature of 45 to 48°C is quite common during summer months. On the other hand, the temperature below freezing point accompanied by frost may also occur occasionally during December to February months. The weather data on temperature, rainfall and pan evaporation during the four months of crop duration in spring-summer season are given in Appendix I.

### 3.3 Physico-chemical soil properties

The soil of experimental field was sandy loam in texture, and it was prepared well to a fine tilth before planting of the experimental material. The study was carried out during 23<sup>rd</sup> February 2020 to 21<sup>th</sup> June 2020. Various physico-chemical soil properties were determined with their standard determination method and references, has been given in Table 3.1. Soil samples were taken from different plots at four depths (0-15, 15-30, 30-45 and 45-60 cm).

**Table 3.1:** Method used for determining various physico-chemical properties of soil at the experimental site

Soil Property	Method used	Reference
Bulk density	Core sampler	Richards, 1954
Soil Texture	International pippete method	Gee and Bauder, 1986
EC <sub>1:2</sub>	EC meter	Richards, 1954
pH	pH meter	Richards, 1954
Infiltration rate	Cylinder infiltrometer	Haise <i>et al.</i> , 1956
Nitrogen in soil	Alkaline potassium permanganate method	Subbiah and Asija, 1956
Phosphorus	Olsen's method	Olsen <i>et al.</i> , 1954
Potassium	Neutral normal ammonium acetate method	Richards, 1954
Organic Carbon	Wet digestion method	Walkley, 1935
Moisture content	Gravimetric method	Michael, 2008

### **3.3.1 Bulk density**

The weight of soil mass per unit volume is known as the bulk density of soil and also known as apparent specific gravity. The core sampler method (Rechards, 1954) was adopted to determine the bulk density of soil. Core samples from different depths, *i.e.*, 0-15, 15-30, 30-45 and 45-60 cm, were collected for the determination of bulk density of the soil.

### **3.3.2 Soil texture**

Proportion of sand, silt and clay in a soil mass determines the texture of a soil. The international pipette method (Gee and Bauder, 1986) was used to determine soil texture. For this, the soil samples were collected from the field at four depths (0-15, 15-30, 30-45 and 45-60 cm).

### **3.3.3 Electrical conductivity**

Electrical conductivity, which is the reciprocal of electrical resistance, was measured in 1:2 soil and water (distilled) suspension using EC meter.

### **3.3.4 pH of soil**

pH value is a measure of hydrogen ion activity of the soil water system and expresses acidity and alkalinity of the soil. Soil pH was determined by using glass electrode pH meter.

### **3.3.5 Basic infiltration rate**

The rate at which infiltration becomes constant is called as basic infiltration rate. It is also called a constant infiltration rate, which depends upon the type of soil. Infiltration rate of a soil determines the maximum rate at which the irrigation should be applied. Cylinder infiltrometer (Single ring infiltrometer) method was used to determine the basic infiltration rate of the soil.

### **3.3.6 Available N, P, K and organic carbon of soil**

For determining the available nitrogen, phosphorus, potassium and organic carbon, soil samples were collected from four different depths (0-15, 15-30, 30-45 and 45-60 cm) from randomly selected micro plots. Methods for determining these components of soil are indicated in Table 3.1.

### **3.3.7 Field capacity**

It is the amount of water held in soil after excess water has been gravity drained and the rate of downward movement has relatively stable, which usually takes place within 1–3 days after a rain or irrigation. At field capacity, the soil moisture tension depending on the soil texture ranges from 0.10 to 0.33 bars. Field capacity is the upper limit of available soil moisture. The field capacity is greatly influenced by soil texture, finer the soil particles higher the water retention due to very large surface area and vice versa.

### 3.3.7 Permanent wilting point

The permanent wilting point is the point when there is no water available to the plant. At this limit, if no additional water is supplied to the soil, most of the plants die. The moisture content at the permanent wilting point varies with soil texture.

### 3.4 Treatment details

Irrigation was applied through drip irrigation system. Treatment were comprised of different combination of three fertigation frequency viz., all time nutrition, weekly nutrition, fortnightly nutrition and three nitrogen fertigation levels viz., 75, 100 and 125%. A summary of different treatments with abbreviation has been given in Table 3.2 and a picture of different treatments under drip system has been shown in Figure 3.2.

**Table 3.2:** Different treatments of nitrogen fertigation of capsicum through drip irrigation system

Sr. No.	Treatments	Abbreviation
1.	All time nutrition with 75% of the RDN	FL <sub>1</sub> FF <sub>1</sub>
2.	Weekly nutrition with 75% of the RDN	FL <sub>1</sub> FF <sub>2</sub>
3.	Fort nightly nutrition with 75% of the RDN	FL <sub>1</sub> FF <sub>3</sub>
4.	All time nutrition with 100% of the RDN	FL <sub>2</sub> FF <sub>1</sub>
5.	Weekly nutrition with 100% of the RDN	FL <sub>2</sub> FF <sub>2</sub>
6.	Fort nightly nutrition with 100% of the RDN	FL <sub>2</sub> FF <sub>3</sub>
7.	All time nutrition with 125% of the RDN	FL <sub>3</sub> FF <sub>1</sub>
8.	Weekly nutrition with 125% of the RDN	FL <sub>3</sub> FF <sub>2</sub>
9.	Fort nightly nutrition with 125% of the RDN	FL <sub>3</sub> FF <sub>3</sub>

RDN – Recommended dose of nitrogen

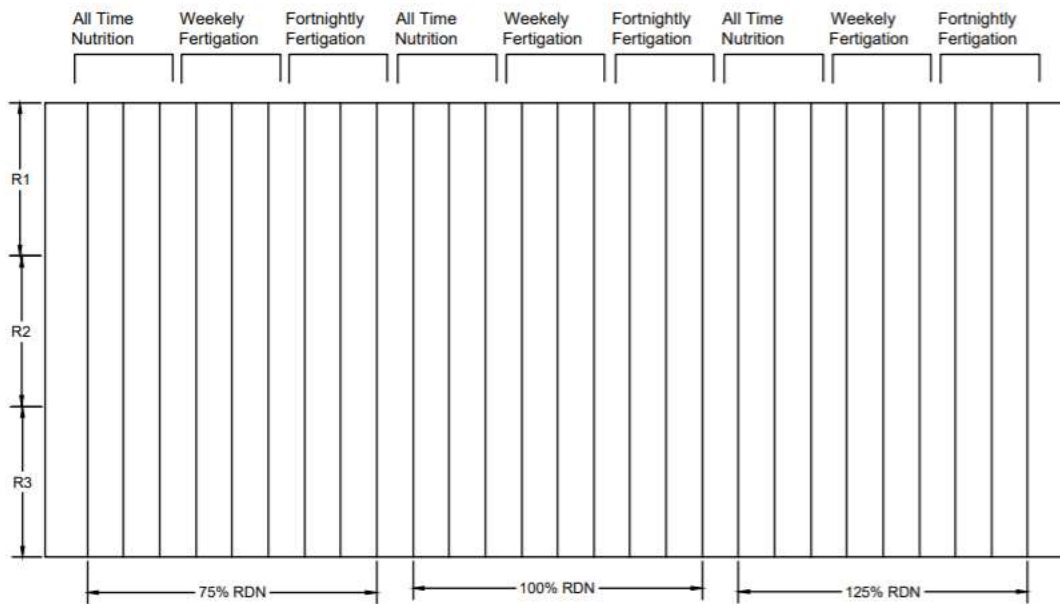


**Figure 3.2:** Experiment set up of capsicum under drip system.

### **3.5 Layout of experiment set up**

The field was ploughed three to four times with harrow every time followed by planking and thereafter, the rotavator was used to bring the field to a fine tilth. The treatments were laid out in Split plot design with three replications as shown in Figure 3.3. The seedlings of capsicum cv.

Kranti variety were purchased from the Agricultural Tourism Centre, CCS Haryana Agricultural University, Hisar. The 70 days old seedlings were transplanted in the field on February 21, 2020 at a row-to-row spacing of 60 cm and plant-to-plant 30 cm. After 10 days of transplanting, the gaps due to the mortality of seedlings were filled with the healthy seedlings again purchased from the Agricultural Tourism Centre in order to maintain the desired plant density in the field. All the experiments are carried out at a total plot size of 225 m<sup>2</sup>.



**Figure 3.3:** Layout of the experimental set up showing different treatments with replications

### 3.6 Discharge measurement

The discharge of water by the drippers was randomly checked to maintain uniform distribution of water through drip irrigation. The discharge of the dripper was usually maintained 2.3 liter per hour.

### 3.7 Irrigation scheduling

The amount of water required to apply to the crop was estimated by using the formula of Schwab *et al.* (1993) given as under:

$$V = \frac{E_p \times K_c \times K_p \times PP \times RR \times P}{10 \times E_a \times 85} \quad (3.1)$$

Where,

V= Volume of water to be applied (ml/plant)

E<sub>p</sub>= Pan Evaporation (mm)

$K_c$  = Crop coefficient (given in Table 3.3)

$K_p$  = pan coefficient as 0.85

PP = plant to plant spacing (30 cm)

RR = row to row spacing (60 cm)

$E_a$  = irrigation efficiency (assumed as 90%)

P = % of area shaded by crop (minimum value was taken as 15%).

**Table 3.3:** Crop coefficient ( $K_c$ ) for capsicum (Allen *et al.*, 1998)

S. No.	Crop Age (Days)	$K_c$
1.	15-30	0.6
2	31-60	1.05
3	60-90	1.05
4	90-120	0.9

The amount of water calculated from the above formula was applied daily through drip irrigation.

The length of irrigation time was determined by following formula:

$$\text{Irrigation time (h)} = \frac{\text{Water requirement per plant (l)}}{\text{Application rate (l h}^{-1}\text{)}}$$

### 3.8 Fertigation scheduling

Nitrogen application was split in equal doses and applied through drippers at all time nutrition, weekly and fortnightly interval in the form of urea. Nitrogen applied in different treatment has been shown in Table 3.4.

**Table 3.4:** Amount of urea (g/plot) applied in each micro-plot for different levels of nitrogen fertigation

	Fertigation Frequency			
	Treatment	All time nutrition	Weekly nutrition	Fortnightly nutrition
Fertigation Level	75% of RDN	0.78 g	5.34 g	10.78 g
	100% of RDN	1.02 g	7.14 g	14.28 g
	125% of RDN	1.28 g	8.96 g	17.92 g

### **3.9 Soil moisture and EC measurement**

Soil samples were collected from different locations of the field from 0-15, 15-30, 30-45 and 45-60 cm depth in vertical direction and at a distance of 0, 15 and 30 cm in horizontal direction from the dripper. Soil moisture was determined by gravimetric method, in which, samples were dried in oven for 24 hour at 105°C. Weight of the soil was noted before and after drying the samples, and the moisture content was calculated by using the following formula:

$$\text{Moisture content (\%)} = \frac{W_1 - W_2}{W_2} \times 100$$

Where,

$W_1$  = Weight of soil sample before drying (g)

$W_2$  = Weight of soil sample after drying (g)

Electrical conductivity (EC) of the soil samples was measured in the form of EC in 1:2, in which, one part of the soil and 2 part of water were taken. For measurement of EC in 1:2, 25 g of soil from the dried sample was taken in a beaker and distilled water (50 ml) was added. A solution was made and kept for 24 hour and then, the water was filtered and its EC was measured with the help of EC meter.

### **3.10 Yield and yield parameters**

#### **3.10.1 Plant height**

The height of randomly selected five plants was measured in centimeter with the help of meter scale from ground level to top point of the plant at every 30 days interval (Appendix II) and average height of the plants was calculated.

#### **3.10.2 Number of branches per plant**

The total number of branches of randomly selected five plants was counted manually at the time of last picking and average number of branches per plant was calculated.

#### **3.10.3 Average fruit weight**

Weight of ten randomly selected fruits from each treatment was recorded at every harvesting and was expressed in grams as shown in Appendix-III. The average fruit weight was calculated.

#### **3.10.4 Fruit length**

The length of ten randomly selected fruits from each treatment was taken at harvest with the help of Vernier caliper and the average fruit length was calculated.

### 3.10.5 Fruit thickness

The fruit thickness of ten randomly selected fruits from each treatment was taken at harvest with the help of Vernier Caliper and the average fruit thickness was calculated.

### 3.10.6 Number of fruits per plant

The number of fruits harvested from five randomly selected plants at each picking per treatment was summed up and the average number of fruits per plant was calculated as presented in Appendix IV.

### 3.10.7 Fruit yield

The weight of fruits harvested from five randomly selected plants at each picking per treatment was summed up and the average fruit yield per plant was obtained by dividing total fruit yield with number of plants from which the total accounted (Appendix V).

## 3.11 Water use efficiency

Water use efficiency (WUE) represents the relation between yield and irrigation water. WUE of different treatments was calculated in term of fruit yield per hectare to the amount of water used per hectare. The WUE may be calculated by using the following formula:

$$\text{WUE (kg m}^{-3}\text{)} = \frac{\text{Weight of fruit (kg ha}^{-1}\text{)}}{\text{Amount of water applied (m}^3\text{ ha}^{-1}\text{)}}$$

## 3.12 Nitrogen use efficiency

Nitrogen use efficiency (NUE) represents the relationship between yield and amount of nitrogen applied. NUE of different treatment was calculated in terms of fruit yield per hectare to the amount of nitrogen applied per hectare. The NUE may be calculated by using the following formula:

$$\text{NUE (kg kg}^{-1}\text{)} = \frac{\text{Weight of fruit (kg ha}^{-1}\text{)}}{\text{Amount of nitrogen applied (kg ha}^{-1}\text{)}}$$

## 3.13 Economics Analysis

In order to evaluate the economic feasibility of different treatments, the economics of treatment was worked out in terms of net returns (Rs ha<sup>-1</sup>) and the Benefit/Cost (B:C) ratio so that the most remunerative treatment could be recommended. This was calculated on treatment yield basis and prevailing market price of inputs and outputs. The net return was calculated by subtracting cost of cultivation from gross returns for each treatment.

The experiment entitled *Study of nitrogen fertigation through drip irrigation on Capsicum crop* was conducted at Research Farm of the Department of Vegetable Science, CCS Haryana Agricultural University, Hisar (Haryana) during spring-summer season of 2019-20. Data so obtained on different parameters was compiled, tabulated and analyzed statistically by using split plot design in 3 replications. In this chapter, the results have been interpreted with the help of appropriate tables and figures under the following headings:

#### 4.1 Basic soil physical and chemical properties

The basic physical and chemical properties of initial soil of experimental field have been given in Table 4.1. Highest percentage (72%) of soil particles was observed, under sand composition, and the minimum were found as clay amounting only 9%. Soil texture of the experimental field was sandy loam. Bulk density and pH of soil varied from 1.52 to 1.55 g/cm<sup>3</sup> and 8.1 to 8.6, respectively at various depths as shown in Table 4.1. EC<sub>1:2</sub> was found to be maximum (0.28 dS/m) in soil at 0-15 cm depth and later it decreased gradually with increase in soil depth (0.25 to 0.22 dS/m from a depth of 15 to 60 cm). Nitrogen and potassium content varied from 126.1 to 105.7 and 270 to 200 kg/ha from top to bottom, respectively. Organic carbon in the soil of experimental field was recorded maximum (0.51%) on top soil and it decreased gradually with the increase in depth of soil. Basic infiltration rate in the soil was recorded 2.89 cm per hour. Average nitrogen in soil after harvest at 125% of fertigation level with all time nutrition fertigation was found to be maximum (140.1 kg ha<sup>-1</sup>) while the average value of minimum available nitrogen (122.4 kg ha<sup>-1</sup>) was found at 75% of RDN with fortnightly fertigation frequency.

**Table 4.1:** Physical and chemical properties of experimental site

Parameters/ Properties	Soil depth (cm)				
	0-15	15-30	30-45	45-60	Average
Sand (%)	72	72	72	72	72
Silt (%)	19	19	19	19	19
Clay (%)	9	9	9	9	9

<b>Texture</b>	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam
<b>Bulk density (g cm<sup>-3</sup>)</b>	1.54	1.55	1.55	1.52	1.54
<b>pH</b>	8.1	8.3	8.5	8.6	8.3
<b>EC<sub>1:2</sub> (dS m<sup>-1</sup>)</b>	0.28	0.25	0.23	0.22	0.24
<b>N (kg ha<sup>-1</sup>)</b>	126.1	119.3	112.5	105.7	115.9
<b>P (kg ha<sup>-1</sup>)</b>	12.2	14.5	16.6	17.8	15.2
<b>K (kg ha<sup>-1</sup>)</b>	270	230	210	200	227.5
<b>Organic carbon (%)</b>	0.51	0.48	0.42	0.40	0.45
<b>Basic infiltration rate</b>	2.89 cm h <sup>-1</sup>				
<b>Available average nitrogen in soil after harvesting (kg ha<sup>-1</sup>)</b>					
<b>Treatment</b>	<b>FF<sub>1</sub> (All time nutrition)</b>	<b>FF<sub>2</sub> (Weekly)</b>	<b>FF<sub>3</sub> (14 Days)</b>	<b>Mean of FL</b>	
<b>FL<sub>1</sub> (75% of RDN)</b>	128.2	126.8	122.4	125.8	
<b>FL<sub>2</sub> (100% of RDN)</b>	133.4	131.7	126.5	130.5	
<b>FL<sub>3</sub> (125% of RDN)</b>	140.1	135.6	133.9	136.6	
<b>Mean of FF</b>	133.9	131.4	127.6		

#### 4.2 Drip discharge and amount of water applied

In drip system, same amount of water was applied in all treatments and average drip discharge was recorded 2.3 l h<sup>-1</sup>. Water required by plant per day was calculated by using the equation 3.1 and data presented in Appendix I. Therefore, the total water required by a plant during the whole period was 86.25 liters and for one plot (7.56 m<sup>2</sup>) it was 3622.5 liters under drip system of irrigation.

#### 4.3 Moisture content at regular interval

In drip irrigation, the amount of water applied per plot during the crop duration was calculated by using the equation 3.1 as described in section 3.7. The data on soil moisture was recorded at radial distance of 0, 15 and 30 cm from the dripper and depth variation of 0-15, 15-30, 30-45 and 45-60 cm in different treatments during the experiment period. The estimated moisture content is given in Table 4.2. The field capacity of soil was observed as 21%. The moisture content from 30 to 120 DAT at 0-15, 15-30, 30-45, 45-60 cm depth and radial distance of 0, 15 and 30 cm varied from 18.13 to 13.53%, respectively. Maximum and minimum moisture content (18.78 and 11.10%) was recorded under FL<sub>1</sub>FF<sub>3</sub> and FL<sub>3</sub>FF<sub>1</sub> treatment. Maximum and

minimum moisture content (18.42 and 13.07%) was recorded at different depth and different radial distance of 30 Days after transplanting. Similarly, in 45, 60, 75, 90, 105 and 120 DAT, the maximum and minimum moisture content was recorded at different depths between 0-15, 15-30, 30-45 and 45-60 cm at different radial distance was (18.49, 13.12%), (18.45, 11.43%), (18.78, 11.11%), (18.29, 11.10%), (18.17, 11.33%) and (17.84, 11.43%), respectively. Average moisture content has been described in Table 4.2. Average moisture content at different depths and different radial distance was found minimum (12.66%) at 125% of RDN with all time nutrition treatment, while, average moisture content was found maximum (18.28%) at FL<sub>1</sub>FF<sub>3</sub> treatment.

**Table 4.2:** Observed Moisture content (%) of the soil profile in drip irrigated capsicum at different depth and radial distance on 30, 45, 60, 75, 90, 105 and 120 days after transplanting

Treatments	Depth(cm)	30 DAT			45 DAT			60 DAT			75 DAT			90 DAT			105 DAT			120 DAT			Average Soil Moisture		
		Radial distance (cm)			Radial distance (cm)			Radial distance (cm)			Radial distance (cm)			Radial distance (cm)			Radial distance (cm)			Radial distance (cm)			Radial distance (cm)		
		0	15	30	0	15	30	0	15	30	0	15	30	0	15	30	0	15	30	0	15	30	0	15	30
<b>FL<sub>1</sub>FF<sub>1</sub></b>	0-15	18.13	16.87	15.42	18.23	16.51	15.39	18.11	16.63	15.27	17.82	16.41	15.12	18.07	17.42	15.49	17.91	16.79	15.47	17.79	17.25	15.69	18.01	16.84	15.41
	15-30	17.29	16.21	14.39	16.70	15.98	14.26	17.81	16.12	14.59	17.29	15.8	14.83	17.73	16.29	14.42	17.43	15.89	14.14	17.56	16.43	14.22	17.40	16.10	14.41
	30-45	16.95	15.67	13.89	16.12	15.32	13.64	16.75	15.76	13.46	16.85	15.16	14.13	16.91	15.45	13.99	16.81	15.39	13.73	16.97	15.87	13.82	16.77	15.52	13.81
	45-60	16.42	14.41	13.67	15.98	14.78	13.12	16.31	14.13	13.07	16.34	14.54	13.89	16.35	14.31	13.59	16.54	14.39	13.24	16.34	14.37	13.29	16.33	14.42	13.41
<b>FL<sub>1</sub>FF<sub>2</sub></b>	0-15	18.33	17.66	15.11	18.04	16.43	15.19	17.89	16.19	14.45	18.48	17.45	15.34	18.18	17.12	15.49	17.82	16.55	15.28	17.85	16.72	15.14	18.13	16.87	15.14
	15-30	17.78	15.78	14.65	17.49	15.78	14.69	17.38	15.39	14.13	17.51	15.62	14.63	17.17	15.56	14.56	17.28	15.96	14.14	17.42	16.65	14.65	17.43	15.82	14.49
	30-45	16.65	15.63	13.54	16.98	15.68	13.41	16.39	15.49	13.86	16.98	15.21	13.95	17.05	15.19	14.06	16.34	15.13	13.79	16.36	15.49	13.96	16.68	15.40	13.80
	45-60	16.36	14.74	13.56	16.61	14.28	13.13	16.32	14.11	13.73	16.49	14.28	13.33	16.39	14.18	13.29	15.78	14.11	13.56	16.01	14.34	13.44	16.28	14.29	13.43
<b>FL<sub>1</sub>FF<sub>3</sub></b>	0-15	18.22	16.57	16.15	18.49	16.29	16.58	18.45	16.13	15.10	18.78	16.52	16.39	18.29	16.47	15.63	18.17	16.29	15.25	17.89	16.03	15.03	18.28	16.33	15.73
	15-30	18.18	17.16	16.04	17.70	15.90	16.32	17.38	16.15	15.03	18.44	17.56	16.25	18.11	16.80	15.25	17.42	16.22	15.16	17.65	16.75	14.92	17.84	16.65	15.57
	30-45	17.72	16.77	15.24	17.37	15.62	16.01	17.32	16.12	14.97	17.11	15.91	14.78	16.98	15.81	14.67	16.88	15.98	15.01	17.47	15.75	14.59	17.26	15.99	15.04
	45-60	17.16	16.23	15.05	16.95	15.39	15.79	16.94	16.04	14.79	16.75	15.86	14.65	16.66	15.76	14.58	16.57	15.76	14.78	17.02	15.68	14.53	16.86	15.82	14.88
<b>FL<sub>2</sub>FF<sub>1</sub></b>	0-15	18.32	17.75	16.27	18.10	16.49	16.73	17.82	16.97	15.29	18.26	17.16	16.23	18.18	17.21	15.58	17.58	16.80	15.39	17.56	17.01	15.39	17.97	17.06	15.84
	15-30	18.26	17.40	16.14	17.86	16.13	16.59	17.79	16.77	15.29	18.27	17.04	16.09	17.86	16.59	15.31	17.78	16.57	15.26	17.32	16.46	15.29	17.88	16.71	15.71
	30-45	17.86	16.99	15.56	17.58	15.98	16.31	17.58	16.59	15.28	17.47	16.46	15.16	17.34	16.36	15.12	17.24	16.27	15.25	17.36	16.35	15.07	17.49	16.43	15.39
	45-60	17.19	16.34	15.03	16.99	15.52	15.87	17.11	16.25	14.90	17.01	16.14	14.88	16.86	16.01	14.85	16.83	15.92	15.07	16.47	15.91	14.83	16.92	16.01	15.06

<b>FL<sub>2</sub>FF<sub>2</sub></b>	0-15	18.31	17.63	16.33	17.98	16.40	16.60	17.92	16.56	15.21	18.01	16.91	15.87	17.93	16.86	15.34	17.19	16.52	15.25	17.77	16.60	15.25	17.87	16.78	15.69
	15-30	18.23	17.35	16.23	17.76	16.13	16.54	17.46	16.47	15.08	17.98	16.60	15.40	17.62	16.50	15.22	17.52	16.22	15.15	17.48	16.24	15.08	17.72	16.50	15.53
	30-45	17.83	16.89	15.43	17.47	15.84	16.16	17.45	16.35	15.12	17.30	16.24	15.02	17.17	16.14	14.98	17.06	16.05	15.01	17.16	16.33	14.93	17.35	16.26	15.24
	45-60	17.16	16.26	14.98	16.94	15.43	15.82	17.03	16.14	14.85	16.93	15.97	14.83	16.77	15.79	14.80	16.69	15.69	14.94	16.71	15.55	14.78	16.89	15.83	15.00
<b>FL<sub>2</sub>FF<sub>3</sub></b>	0-15	18.14	17.56	16.19	17.95	16.37	16.68	17.82	16.35	15.05	18.06	17.40	16.05	17.86	16.67	15.35	17.62	16.56	15.30	17.08	16.46	14.89	17.83	16.77	15.64
	15-30	18.32	17.22	16.05	17.66	15.99	16.48	17.37	16.09	14.93	18.05	17.03	16.01	17.75	16.20	15.26	17.48	16.26	15.05	17.40	16.03	14.98	17.72	16.40	15.54
	30-45	17.76	16.82	15.56	17.41	15.81	16.25	17.42	16.31	15.21	17.28	16.15	15.09	17.15	16.05	15.01	17.03	15.95	14.95	16.78	15.92	14.92	17.26	16.14	15.28
	45-60	17.15	16.28	14.94	16.90	15.36	15.78	16.93	16.01	14.78	16.80	15.88	14.70	16.71	15.78	14.61	16.62	15.70	14.84	16.18	15.77	14.56	16.76	15.83	14.89
<b>FL<sub>3</sub>FF<sub>1</sub></b>	0-15	18.26	16.43	14.83	18.22	16.73	15.89	17.93	15.63	14.74	18.28	15.83	13.84	15.92	14.21	13.76	17.43	15.64	14.67	17.84	15.32	14.42	17.74	15.68	14.57
	15-30	18.04	15.89	14.49	17.91	16.19	15.56	17.63	14.78	14.83	17.99	16.90	15.52	15.68	13.98	12.89	17.15	14.21	13.98	17.33	16.32	13.84	17.39	15.47	14.43
	30-45	16.79	15.32	13.78	16.51	15.98	14.82	15.49	14.45	13.85	16.39	15.56	14.74	14.23	13.84	12.12	15.42	14.01	13.12	14.38	16.45	12.73	15.60	15.09	13.59
	45-60	15.85	14.76	13.07	15.22	14.31	13.42	14.75	13.76	12.62	15.89	14.73	13.61	13.11	12.71	11.10	14.14	13.67	12.73	13.64	16.07	11.43	14.66	14.29	12.66
<b>FL<sub>3</sub>FF<sub>2</sub></b>	0-15	18.12	17.60	16.33	18.06	16.63	16.72	17.82	16.60	15.35	16.93	15.87	15.93	17.96	16.63	15.25	17.83	16.21	15.32	16.74	15.73	14.11	17.67	16.47	15.57
	15-30	17.93	17.34	15.64	17.40	15.89	16.72	17.58	16.12	15.15	15.47	14.53	13.56	16.66	15.74	14.76	16.58	14.93	13.56	15.23	14.63	13.57	16.69	15.60	14.71
	30-45	17.68	16.82	15.33	17.47	15.88	16.27	17.43	16.33	15.27	16.32	14.05	13.11	15.84	14.73	13.61	15.24	13.67	12.45	14.78	13.76	12.84	16.39	15.03	14.13
	45-60	16.74	15.53	14.74	16.96	15.46	15.79	17.09	16.11	14.89	14.83	13.76	11.46	14.75	13.41	12.53	14.23	12.57	11.33	13.83	12.73	11.65	15.49	14.22	13.20
<b>FL<sub>3</sub>FF<sub>3</sub></b>	0-15	18.42	17.52	16.38	17.94	16.44	16.69	17.76	16.47	15.86	18.05	17.36	14.87	17.17	16.62	15.33	17.81	16.5	15.18	17.78	16.47	15.02	17.85	16.77	15.62
	15-30	18.22	17.29	16.05	17.76	16.02	16.61	16.34	16.12	13.43	17.84	16.65	13.67	16.93	15.72	15.29	16.83	15.65	13.79	17.15	16.16	14.84	17.30	16.23	14.81
	30-45	17.93	16.99	15.53	17.57	15.74	16.06	15.98	15.13	12.44	16.56	15.46	12.42	15.62	14.76	14.41	15.33	14.64	13.64	16.65	15.72	14.79	16.52	15.49	14.18
	45-60	17.26	16.13	14.95	16.94	15.69	15.69	14.66	14.62	11.43	15.85	14.65	11.11	15.11	14.51	13.62	14.64	13.64	12.45	15.54	14.43	13.53	15.71	14.81	13.25

#### 4.4 Yield and its attributes

##### 4.4.1 Plant height (cm)

Plant height was measured at 30, 60, 90 and 120 days after transplanting and presented in Table 4.3 to Table 4.6. The perusal of data reveals that some of the fertigation treatments differed significantly after days of sowing. Maximum plant height at 30, 60, 90 and 120 days after planting was recorded with fertigation treatment 125% recommended nitrogen dose applied at all time nutrition (25.80, 43.64, 72.60 and 82.00 cm), while the minimum plant height was recorded with fertigation treatment of 75% recommended nitrogen dose applied at fortnightly interval (16.86, 38.01, 67.20 and 76.61 cm). The interaction effect of level and frequency of fertigation on plant height was observed non-significant. Graphical presentation of plant height under fertigation level and fertigation frequency is shown in Figure 4.1.

**Table 4.3:** Plant height (cm) influenced by levels and frequencies of fertigation at 30 days after planting

Treatments	FF <sub>1</sub> (all time nutrition)	FF <sub>2</sub> (Weekly)	FF <sub>3</sub> (14 Days)	Mean of FL
FL <sub>1</sub> (75% of RDN)	18.45	17.86	16.86	17.72
FL <sub>2</sub> (100% of RDN)	18.93	18.85	18.70	18.82
FL <sub>3</sub> (125% of RDN)	25.80	21.73	20.40	22.64
<b>Mean of FF</b>	21.06	19.48	18.65	

##### CD at 5% level of significance

Fertigation level = 1.50

Fertigation Frequency = 1.50

Interaction of FL x FF = NS

**Table 4.4:** Plant height (cm) influenced by levels and frequencies of fertigation at 60 days after planting

Treatments	FF <sub>1</sub> (all time nutrition)	FF <sub>2</sub> (Weekly)	FF <sub>3</sub> (14 Days)	Mean of FL
FL <sub>1</sub> (75% of RDN)	38.30	38.16	38.01	38.16
FL <sub>2</sub> (100% of RDN)	39.61	39.31	39.20	39.37
FL <sub>3</sub> (125% of RDN)	43.64	40.41	40.35	41.46
<b>Mean of FF</b>	40.51	39.30	39.18	

##### CD at 5% level of significance

Fertigation level = 2.03

Fertigation Frequency = NS

Interaction of FL x FF = NS

**Table 4.5:** Plant height (cm) influenced by levels and frequencies of fertigation at 90 days after planting

Treatments	FF <sub>1</sub> (all time nutrition)	FF <sub>2</sub> (Weekly)	FF <sub>3</sub> (14 Days)	Mean of FL
FL <sub>1</sub> (75% of RDN)	68.45	67.48	67.20	67.71
FL <sub>2</sub> (100% of RDN)	71.11	69.58	68.63	69.77

FL <sub>3</sub> (125% of RDN)	72.60	71.70	71.40	71.90
<b>Mean of FF</b>	70.72	69.58	69.07	

**CD at 5% level of significance**

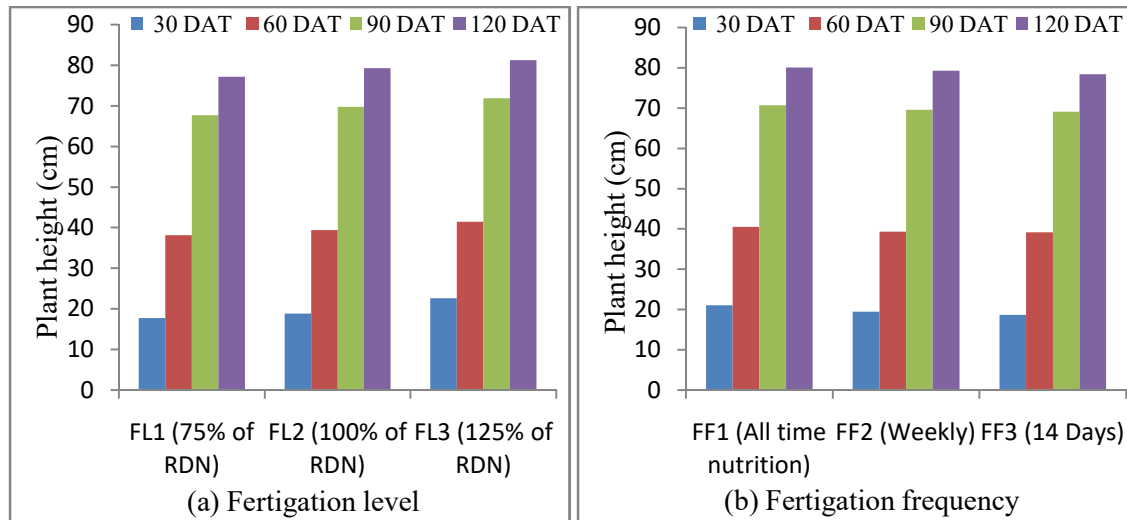
Fertigation level = 1.16  
 Fertigation Frequency = 1.16  
 Interaction of FL x FF = NS

**Table 4.6:** Plant height (cm) influenced by levels and frequencies of fertigation at 120 days after planting

Treatments	FF <sub>1</sub> (all time nutrition)	FF <sub>2</sub> (Weekly)	FF <sub>3</sub> (14 Days)	Mean of FL
FL <sub>1</sub> (75% of RDN)	77.98	76.95	76.61	77.18
FL <sub>2</sub> (100% of RDN)	80.14	79.31	78.35	79.26
FL <sub>3</sub> (125% of RDN)	82.00	81.46	80.35	81.27
<b>Mean of FF</b>	80.04	79.24	78.43	

**CD at 5% level of significance**

Fertigation level = 1.24  
 Fertigation Frequency = 1.24  
 Interaction of FL x FF = NS



**Figure 4.1:** Plant height (cm) of capsicum with (a) fertigation level and (b) fertigation frequency at different days after transplanting

**4.4.2 Number of branches and first flowering**

Numbers of days to first flowering, number of primary and secondary branches were observed in different treatments (Table 4.7). First flowering appeared at 35 DAT in FL<sub>3</sub>FF<sub>1</sub>, 37 DAT in FL<sub>2</sub>FF<sub>1</sub>, FL<sub>2</sub>FF<sub>2</sub>, FL<sub>3</sub>FF<sub>2</sub>, FL<sub>3</sub>FF<sub>3</sub> and 40 DAT in FL<sub>1</sub>FF<sub>3</sub> treatment. Maximum number of primary (5.25) and secondary (7.10) branches were observed in FL<sub>3</sub>FF<sub>1</sub>, whereas, minimum number of primary (4.21) and secondary (5.40) branches were observed in FL<sub>1</sub>FF<sub>3</sub>. Among the

fertigation treatments, it can be observed that number of branches increased with the increase in fertigation level.

**Table 4.7:** Number of days to first flowering and number of primary and secondary branches per plant in different treatments

Treatments	Day to flowering after transplanting	No. of primary branches	No. of secondary branches
FL <sub>1</sub> FF <sub>1</sub>	38	4.38	5.54
FL <sub>1</sub> FF <sub>2</sub>	39	4.3	5.49
FL <sub>1</sub> FF <sub>3</sub>	40	4.21	5.4
<b>Mean</b>	39	4.29	5.47
FL <sub>2</sub> FF <sub>1</sub>	37	4.91	6.57
FL <sub>2</sub> FF <sub>2</sub>	37	4.88	6.38
FL <sub>2</sub> FF <sub>3</sub>	38	4.85	5.89
<b>Mean</b>	37	4.88	6.28
FL <sub>3</sub> FF <sub>1</sub>	35	5.25	7.1
FL <sub>3</sub> FF <sub>2</sub>	37	5.19	6.88
FL <sub>3</sub> FF <sub>3</sub>	37	5.12	6.78
<b>Mean</b>	36	5.18	6.92

#### 4.4.3 Average fruit width (cm)

Variation in fruit weight due to fertigation level and fertigation frequencies (Table 4.8) was observed. Among the fertigation frequency, the average fruit width was found maximum (6.78 cm) with the treatment FL<sub>3</sub>FF<sub>1</sub> (125% of RDN and all time nutrition), while, the average fruit width was observed minimum (6.05 cm) under the treatment FL<sub>1</sub>FF<sub>3</sub>. Increasing fertigation level from 75 to 125% increased the average fruit width from 6.13 to 6.61 cm. The fruit width decreased from 6.46 to 6.26 cm with decreasing fertigation frequency from all time nutrition to fortnightly. Detailed information for the variation of fruit width with respect to fertigation level and fertigation frequency has been shown graphically in Figure 4.2. The interaction effect of fertigation level and frequency on average fruit width was observed non- significant.

**Table 4.8:** Average fruit width (cm) of capsicum influenced by fertigation level and frequency

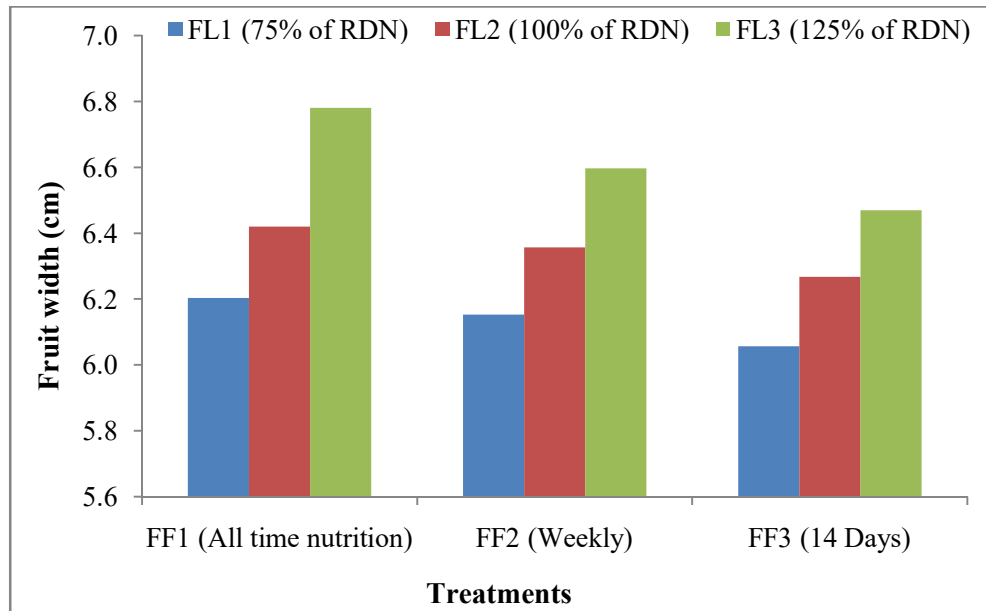
Treatments	FF <sub>1</sub> (all time nutrition)	FF <sub>2</sub> (Weekly)	FF <sub>3</sub> (14 Days)	Mean of FL
FL <sub>1</sub> (75% of RDN)	6.20	6.15	6.05	6.13
FL <sub>2</sub> (100% of RDN)	6.42	6.35	6.26	6.34
FL <sub>3</sub> (125% of RDN)	6.78	6.59	6.47	6.61
<b>Mean of FF</b>	6.46	6.36	6.26	

#### CD at 5% level of significance

Fertigation level = 0.13

Fertigation Frequency = 0.09

Interaction of FL x FF = NS



**Figure 4.2:** Fruit width (cm) of capsicum with different fertigation level and frequency

#### 4.4.4 Fruit length (cm)

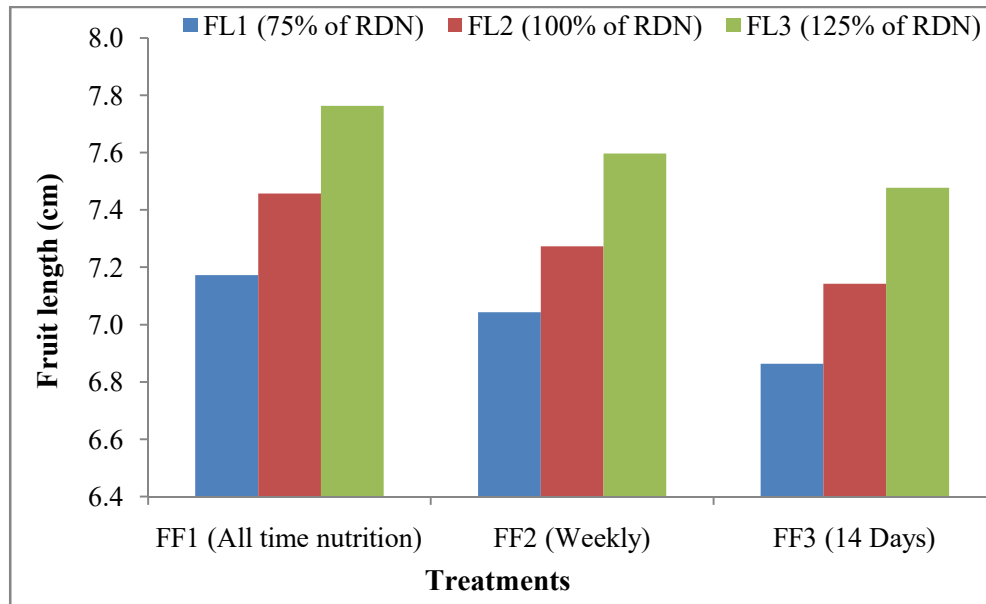
The data presented in Table 4.9 reveal that the maximum average fruit length (7.61 cm) was recorded with fertigation at 125% of RDN, which was superior to other treatments. Fruit length of 7.02 and 7.29 cm was registered with the application of fertigation 75 and 100% of RDN. For the variation of fertigation level and fertigation frequency, the coefficient of deviation at 5% level of significance was found to be 0.20 and 0.16. Maximum fruit length was observed with all time nutrition fertigation (7.76 cm) at 125% of RDN, while, the minimum fruit length was recorded at fortnightly fertigation (6.86 cm) at 75% of RDN. As the fertigation frequency decreased from daily FF<sub>1</sub> to fortnightly FF<sub>3</sub>, the fruit length decreased from 7.46 to 7.16 cm. The interaction effect of level and frequency of fertigation on average fruit length was observed to be not significant. Graphical presentation of fruit length under fertigation level and frequency is shown in Figure 4.3.

**Table 4.9:** Average fruit length (cm) influenced by fertigation level and frequency

Treatments	FF <sub>1</sub> (all time nutrition)	FF <sub>2</sub> (Weekly)	FF <sub>3</sub> (14 Days)	Mean of FL
FL <sub>1</sub> (75% of RDN)	7.17	7.04	6.86	7.02
FL <sub>2</sub> (100% of RDN)	7.45	7.27	7.14	7.29
FL <sub>3</sub> (125% of RDN)	7.76	7.59	7.47	7.61
<b>Mean of FF</b>	7.46	7.30	7.16	

**CD at 5% level of significance**

Fertigation level = 0.20  
 Fertigation Frequency = 0.16  
 Interaction of FL x FF = NA



**Figure 4.3:** Fruit length (cm) of capsicum with different fertigation level and frequency

#### 4.4.5 Number of fruits per plant

The perusal of data presented in Table 4.10 and Fig 4.4 shows that the treatment FL<sub>3</sub>FF<sub>1</sub> resulted in maximum number of fruits per plant (30.83), while, the average minimum number of fruits per plant (21.54) was observed with treatment FL<sub>1</sub>FF<sub>3</sub>. Average number of fruits per plant for the treatment FL<sub>2</sub>FF<sub>2</sub> (26.75) and FL<sub>2</sub>FF<sub>3</sub> (25.63) were statistically at par with each other. Similarly, for the treatment FL<sub>3</sub>FF<sub>2</sub> (27.83 g) and FL<sub>3</sub>FF<sub>3</sub> (27.17) were found statistically at par with each other in respect of number of fruits per plant. For the variation of fertigation level and frequency, the coefficient of deviation at 5% level of significance was found to be 0.91 and 1.34. The interaction effect of level and frequency of fertigation on average fruit number per plant was observed non-significant.

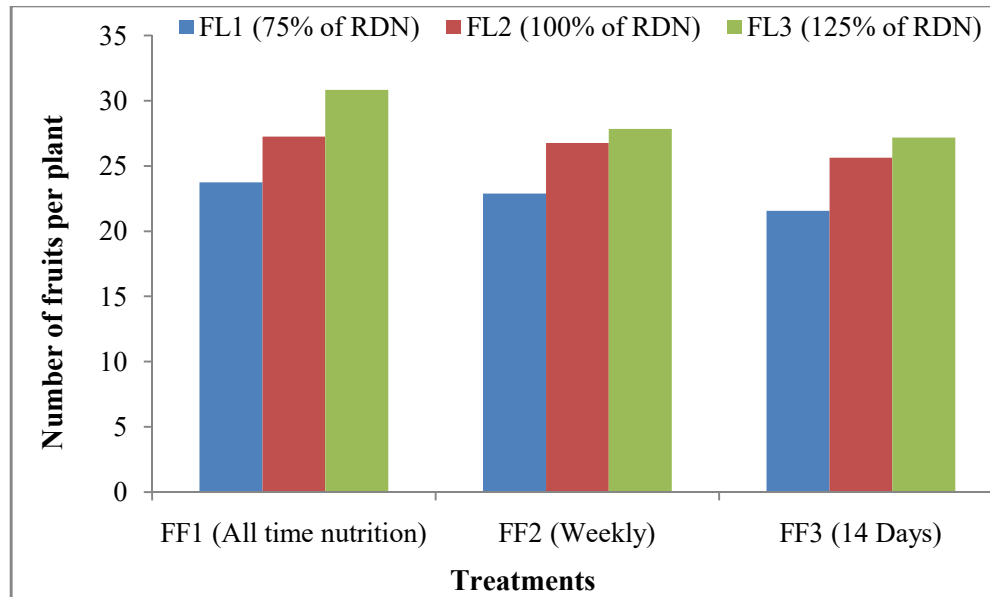
**Table 4.10:** Average number of fruit per plant influenced by fertigation level and frequency

Treatments	FF <sub>1</sub> (all time nutrition)	FF <sub>2</sub> (Weekly)	FF <sub>3</sub> (14 Days)	Mean of FL
FL <sub>1</sub> (75% of RDN)	23.75	22.87	21.54	22.72
FL <sub>2</sub> (100% of RDN)	27.25	26.75	25.63	26.54
FL <sub>3</sub> (125% of RDN)	30.83	27.83	27.17	28.61
<b>Mean of FF</b>	27.27	25.82	24.78	

#### CD at 5% level of significance

Fertigation level = 0.91

Fertigation Frequency = 1.34  
 Interaction of FL x FF = NS



**Figure 4.4:** Average number of fruits per plant of capsicum with different fertigation level and frequency

#### 4.4.6 Average fruit weight (g)

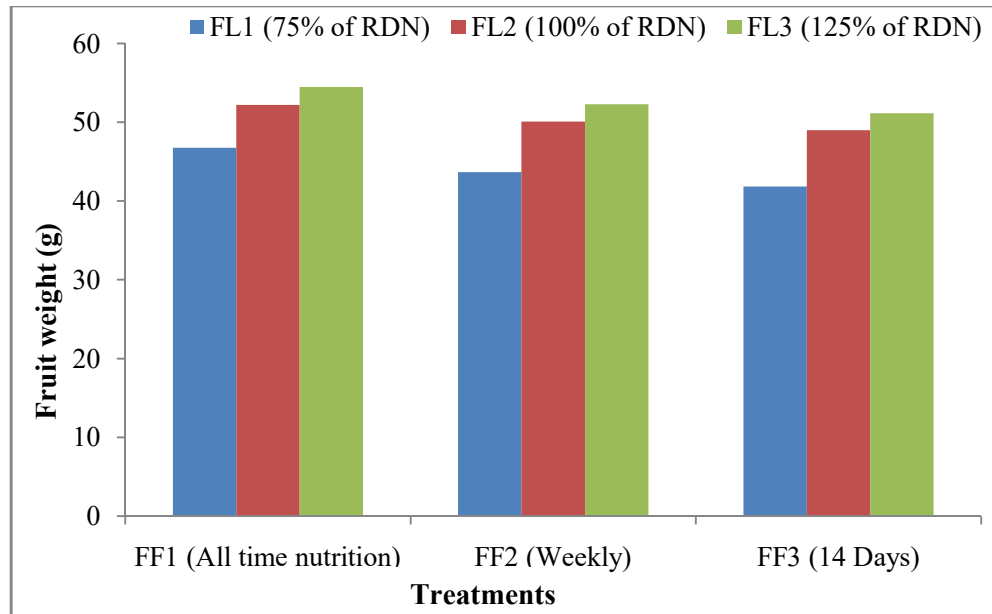
A critical examination of data presented in Table 4.11 shows that the treatment FL<sub>3</sub>FF<sub>1</sub> resulted in maximum fruit weight (54.48 g), while the minimum average fruit weight (41.85 g) was registered with treatment FL<sub>1</sub>FF<sub>3</sub>. Increasing fertigation level from 75 to 125% increased the average fruit weight from 44.09 to 52.63 g. The fruit weight decreased from 51.14 to 47.32 g with decreasing fertigation frequency from all time nutrition to fortnightly. For the variation of fertigation level and fertigation frequency, the coefficient of deviation at 5% level of significance was found to be 0.89 and 0.72. The interaction effect of level and frequency of fertigation on average fruit weight was observed non-significant. Graphical presentation of fruit weight under fertigation level and frequency is shown in Figure 4.5.

**Table 4.11:** Average fruit weight (g) influenced by fertigation level and frequency

Treatments	FF <sub>1</sub> (all time nutrition)	FF <sub>2</sub> (Weekly)	FF <sub>3</sub> (14 Days)	Mean of FL
FL <sub>1</sub> (75% of RDN)	46.74	43.68	41.85	44.09
FL <sub>2</sub> (100% of RDN)	52.21	50.08	48.98	50.42
FL <sub>3</sub> (125% of RDN)	54.48	52.26	51.14	52.63
<b>Mean of FF</b>	51.14	48.67	47.32	

**CD at 5% level of significance**  
 Fertigation level = 0.89

Fertigation Frequency = 0.72  
 Interaction of FL x FF = NS



**Figure 4.5:** Fruit weight (g) of capsicum with different fertigation level and frequency

#### 4.4.7 Fruit yield (q/ha)

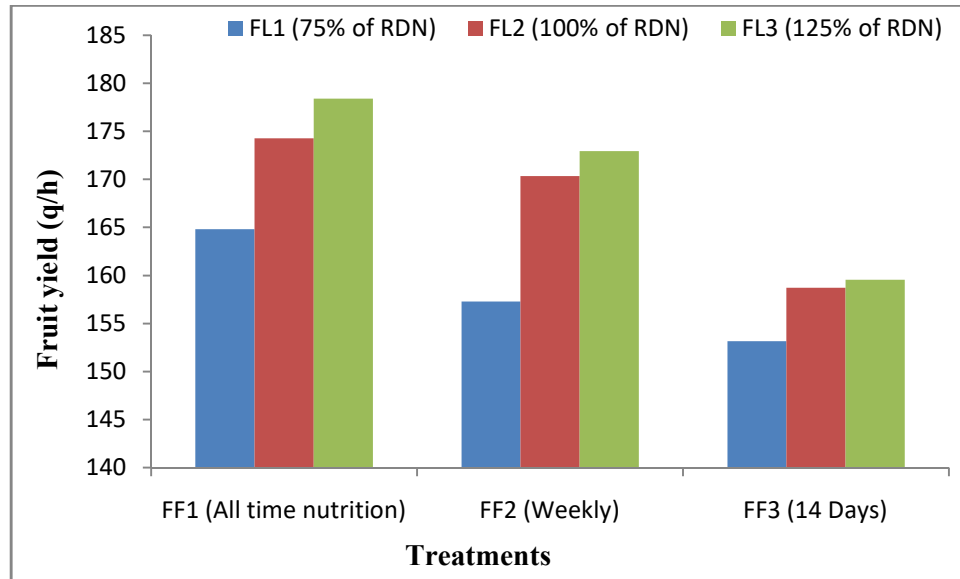
During the entire fruiting season, the total number of fruit pickings performed from 23rd February to 21st June 2020 was eight under all treatments. The data regarding total fruit yield at different fertigation levels and frequency have been presented in Table 4.12 and Figure 4.6. A critical examination of data indicates that the maximum fruit yield (178.40 q/ha) was obtained at 125% of RDN with all time nutrition, while the minimum fruit yield (153.16 q/ha) was obtained at 75% of RDN with fortnightly fertigation frequency. The decrease in fertigation frequency decreased the fruit yield from 172.50 to 157.15 q/ha. The interaction effect of level and frequency of fertigation on average fruit yield was observed non-significant.

**Table 4.12:** Fruit yield (q/ha) of capsicum as influenced by fertigation level and frequency

Treatments	FF <sub>1</sub> (all time nutrition)	FF <sub>2</sub> (Weekly)	FF <sub>3</sub> (14 Days)	Mean of FL
FL <sub>1</sub> (75% of RDN)	164.82	157.29	153.16	158.42
FL <sub>2</sub> (100% of RDN)	174.27	170.35	158.73	167.78
FL <sub>3</sub> (125% of RDN)	178.40	172.92	159.55	170.29
<b>Mean of FF</b>	172.50	166.86	157.15	

#### CD at 5% level of significance

Fertigation level = 9.33  
 Fertigation Frequency = 6.25  
 Interaction of FL x FF = NS



**Figure 4.6:** Fruit yield (q/ha) of capsicum with different fertigation level and frequency

#### 4.5 Water use efficiency ( $\text{kg m}^{-3}$ )

Water and nitrogen use efficiency was calculated for each of the treatments and has been presented in Table 4.13 and Figure 4.7. The maximum water use efficiency ( $3.72 \text{ kg m}^{-3}$ ) was observed in  $\text{FL}_3\text{FF}_1$  treatment, while, the minimum water use efficiency was obtained under the treatment  $\text{FL}_1\text{FF}_3$  ( $3.19 \text{ kg m}^{-3}$ ). With the increase of fertigation level from 75 to 125%, the water use efficiency showed an increasing trend from 3.30 to  $3.55 \text{ kg m}^{-3}$ , while the decrease in fertigation frequency from daily to fortnightly it reduced the water use efficiency from 3.59 to  $3.28 \text{ kg m}^{-3}$ .

**Table 4.13:** Water use efficiency (WUE) of capsicum crop in different treatments

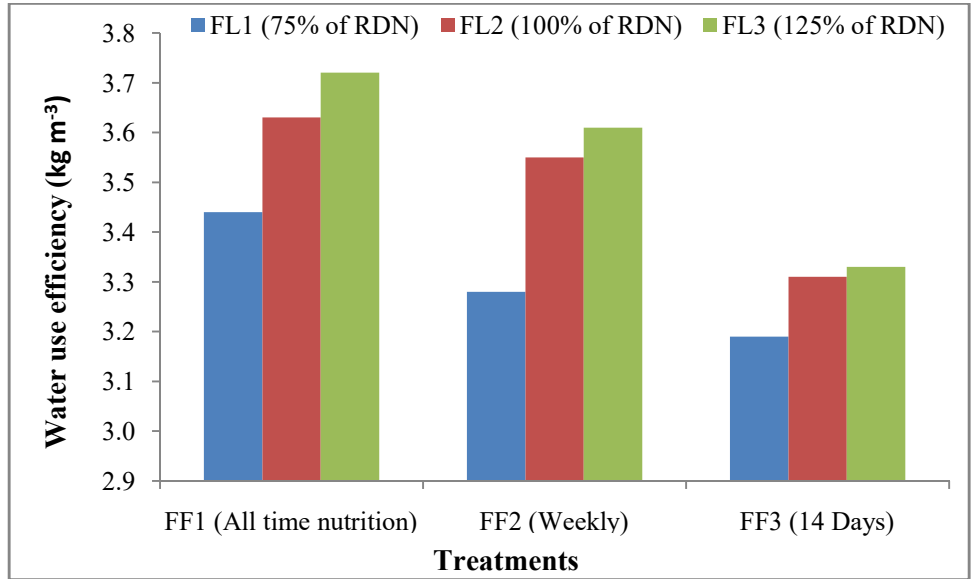
Fertigation level	Fertigation frequency			
	FF <sub>1</sub> (all time nutrition)	FF <sub>2</sub> (Weekly)	FF <sub>3</sub> (14 Days)	Mean of FL
FL <sub>1</sub> (75% of RDN)	3.44	3.28	3.19	3.30
FL <sub>2</sub> (100% of RDN)	3.63	3.55	3.31	3.50
FL <sub>3</sub> (125% of RDN)	3.72	3.61	3.33	3.55
<b>Mean of FF</b>	3.59	3.48	3.28	

#### CD at 5% level of significance

Fertigation level = 0.19

Fertigation Frequency = 0.13

Interaction of FL x FF = NS



**Figure 4.7:** Water use efficiency of capsicum with different fertigation level and frequency

#### 4.6 Nitrogen use efficiency (%)

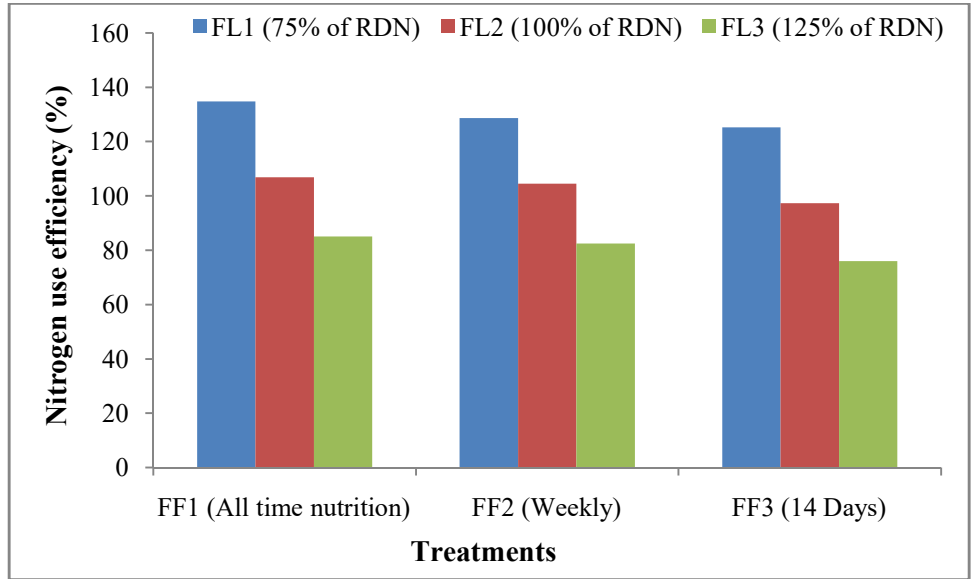
Nitrogen analysis was done after harvesting (120 DAT) of the crop. Effect of all time nutrition, weekly and fortnightly fertigation and level of fertigation (75, 100 and 125%) on capsicum crop has been presented in Table 4.14. The maximum nitrogen use efficiency was registered with treatment FL<sub>1</sub>FF<sub>1</sub> (134.80 kg of capsicum per kg of nitrogen used), while, the minimum nitrogen use efficiency was registered with treatment FL<sub>3</sub>FF<sub>3</sub> (76.05 kg of capsicum per kg of nitrogen used). Graphical presentation of fruit length under fertigation level and frequency is shown in figure 4.8.

**Table 4.14:** Nitrogen use efficiency (NUE) of capsicum crop in different treatments

Fertigation level	Fertigation frequency			Mean of FL
	FF <sub>1</sub> (all time nutrition)	FF <sub>2</sub> (Weekly)	FF <sub>3</sub> (14 Days)	
FL <sub>1</sub> (75% of RDN)	134.80	128.64	125.27	129.57
FL <sub>2</sub> (100% of RDN)	106.90	104.49	97.36	102.92
FL <sub>3</sub> (125% of RDN)	85.04	82.43	76.05	81.17
<b>Mean of FF</b>	108.91	105.19	99.56	

#### CD at 5% level of significance

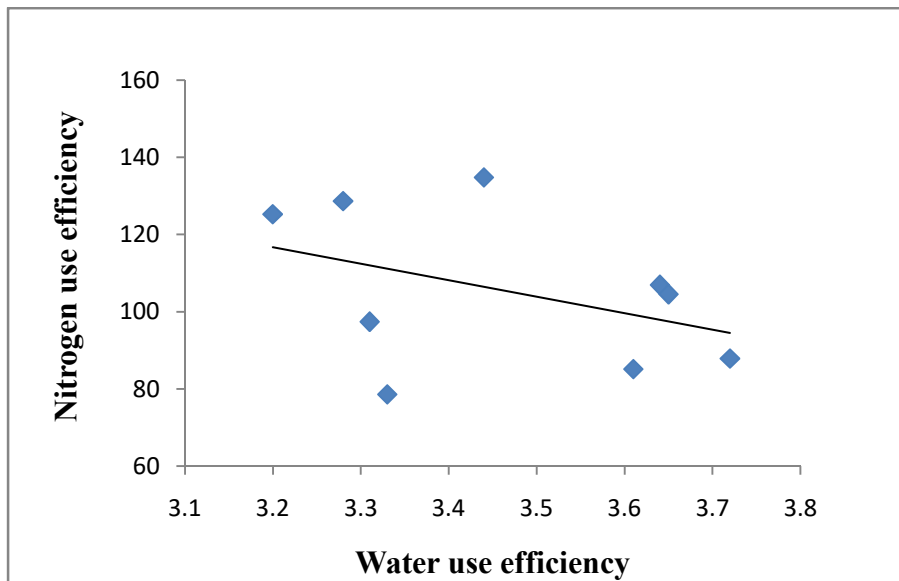
Fertigation level = 7.11  
 Fertigation Frequency = 4.21  
 Interaction of FL x FF = NS



**Figure 4.8:** Nitrogen use efficiency of capsicum with different ferigation level and frequency

#### 4.7 Relationship between water use efficiency and nitrogen use efficiency

The relation between water and nitrogen use efficiency presented in Fig.4.9 illustrates that the nitrogen use efficiency increased linearly with the increase in water use efficiency. The  $R^2$  value for the relation between both the parameters was 0.929 and followed the path equation ( $y = 38.42x - 112.3$ ).



**Figure4.9:** Relation between Water use efficiency and Nitrogen use efficiency

#### 4.8 Economics Analysis

Economics of the treatments presented in Table 4.15 indicated that the highest net returns (Rs. 3,78,401) with benefit cost ratio (2.41) for capsicum crop were obtained at 125% of fertigation level with all time nutrition frequency followed by 100 % of fertigation level (Rs. 3,66,237) with benefit cost ratio (2.34) in all time nutrition frequency. On the other hand minimum net returns (Rs. 3,03,125) with benefit cost ratio (1.94) for capsicum crop were obtained at 75% of fertigation level with fortnightly fertigation frequency.

**Table 4.15: Effect of nitrogen levels and its frequency on economics in drip irrigated capsicum**

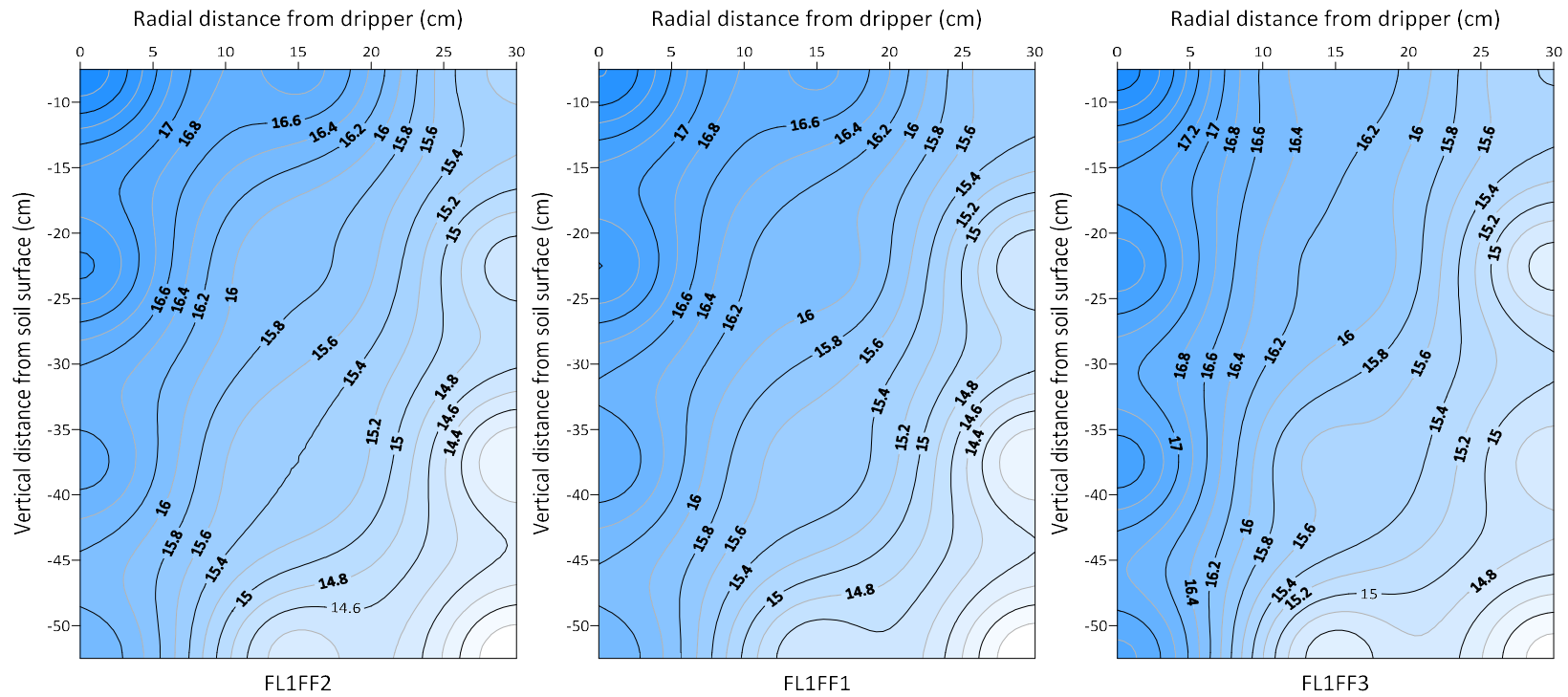
<b>Fertigation level</b>	<b>Fertigation frequency</b>	<b>Yield (q/ha)</b>	<b>Cost of cultivation (Rs./ha)</b>	<b>Gross return (Rs./ha)</b>	<b>Net return (Rs./ha)</b>	<b>B:C ratio*</b>
75%	<b>FF<sub>1</sub> (all time nutrition)</b>	164.82	156355	494460	338105	2.16
	<b>FF<sub>2</sub> (Weekly nutrition)</b>	157.29	156355	471870	315515	2.02
	<b>FF<sub>3</sub> (fortnightly nutrition)</b>	153.16	156355	459480	303125	1.94
100%	<b>FF<sub>1</sub> (all time nutrition)</b>	174.27	156573	522810	366237	2.34
	<b>FF<sub>2</sub> (Weekly nutrition)</b>	170.35	156573	511050	354477	2.26
	<b>FF<sub>3</sub> (fortnightly nutrition)</b>	158.73	156573	476190	319617	2.04
125%	<b>FF<sub>1</sub> (all time nutrition)</b>	178.40	156799	535200	378401	2.41
	<b>FF<sub>2</sub> (Weekly nutrition)</b>	172.92	156799	518760	361961	2.31
	<b>FF<sub>3</sub> (fortnightly nutrition)</b>	159.55	156799	478650	321851	2.05

The present investigation was carried out on “*Study of nitrogen fertigation through drip irrigation on Capsicum crop.*” The salient features of the present investigation, *i.e.*, effect of moisture content, fruit yield and its parameters, water and nitrogen use efficiency have been discussed in the successive paragraphs and supported with the findings of other researchers.

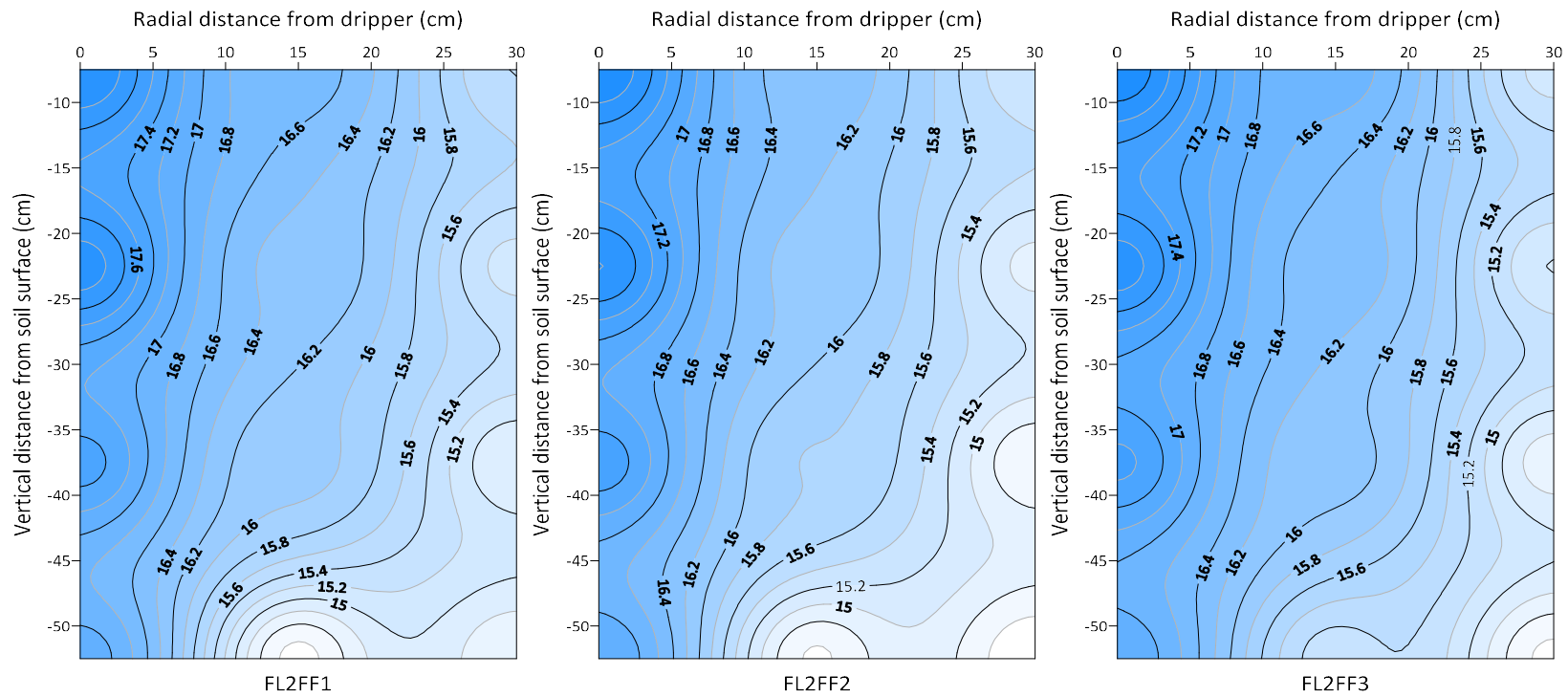
### **5.1 Soil moisture content**

The soil samples for moisture estimation at different radial distance (horizontally) and depth (vertically) were taken at a regular interval of 15 days after the transplanting of crop (Table 4.2). Average moisture content near the plant (below dripper) in 0-15 cm depth was more as compared to the moisture content at 15-30, 30-45 and 45-60 cm depth. The variation of moisture content with radial distance followed the same trend as mentioned above means it decreased as move away from the dripper. Soil moisture content was depleted with time in upper layer as well as in lower layers with the growth of the crop. Depletion in soil moisture content with increasing crop growth might be due to the utilization of water by the plant roots before reaching the lower parts of the root zone (Sharma *et al.*, 2013).

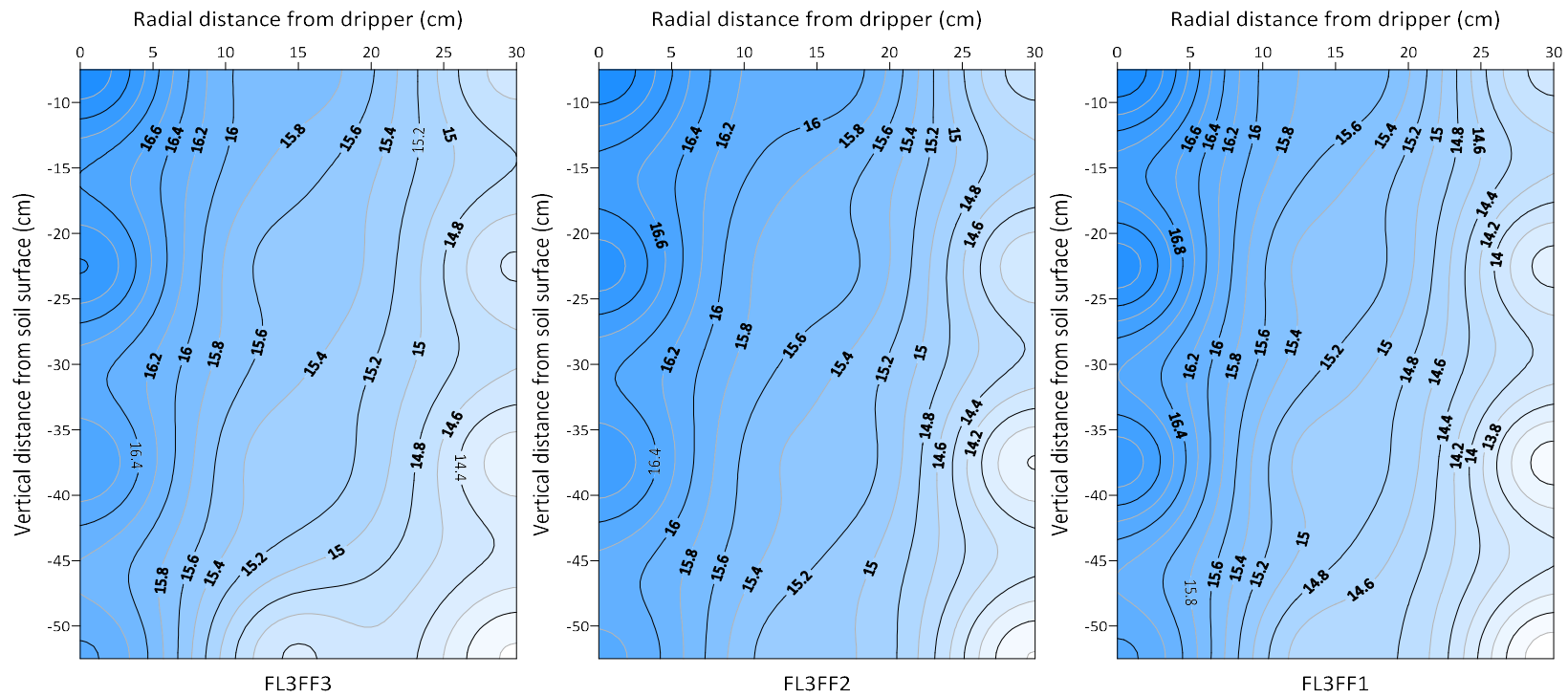
Contour maps of average moisture content during the cropping season of different treatments at different depth and radial distance are described in figure 5.1, 5.2 and 5.3. It was observed that the wetting pattern of moisture content in the root zone varied with fertigation level. The average moisture content near the plant was more (below dripper) than 15 and 30 cm radial distance. After 30 DAT in FL<sub>1</sub>FF<sub>1</sub> treatment near the plant, moisture content was 18.13% at a depth of 0-15 cm, while, at 45-60 cm depth it was 16.42%. Similarly, in FL<sub>3</sub>FF<sub>1</sub> treatment near the plant, moisture content was 18.26% at a depth of 0-15 cm and it was 13.07% at a depth of 45-60 cm at a radial distance of 30 cm away from the dripper. Average soil moisture content was maximum (below dripper) 18.28% in FL<sub>1</sub>FF<sub>3</sub> treatment at 0-15 cm, while, it was minimum at 12.66% in FL<sub>3</sub>FF<sub>1</sub> treatment at a depth of 45-60 cm with 30 cm away from the dripper (Table 4.2). Results shows that 125% of recommended dose of nitrogen with all time nutrition frequency utilized a little higher root zone water and has higher yield compared to other treatments.



**Figure 5.1:** Spatial and temporal movement of average moisture content in 75% RDN



**Figure 5.2:** Spatial and temporal movement of average moisture content in 100% RDN



**Figure 5.3:** Spatial and temporal movement of average moisture content in 125% RDN

## **5.2 Yield and yield parameters**

### **5.2.1 Plant height**

Plant height was measured at regular intervals during cropping season. It was found that the use of different nitrogen levels caused a significant variation of plant height. Out of various doses of fertigation, 125% of the recommended dose of nitrogen by drip fertigation increased plant growth characters, *viz.* plant height. The important reasons responsible for better growth at 125% than other application rates might be due to efficient root system of capsicum plants for the uptake of nutrients under higher fertigation levels, which attributed to build up favorable nutritional conditions in the root zone of capsicum plants, which helped the plants to grow more efficiently. The present study results are in agreement with the results of Brahma *et al.*(2010).

### **5.2.2 Number of branches**

The study for number of branches is illustrated in the Table 4.7. The maximum numbers of branches per plant were recorded for the application of 125% of recommended dose of nitrogen level. It may be reasoned that, fertigation leads to increase photosynthesis, protein metabolism that also assimilates translocation, resulted with desirable environmental condition to increase enzyme activities and hence resulted with increased branches per plant (Singandhupe *et al.*, 2005).

### **5.2.3 Fruit width, length, weight, number of fruits per plant**

Average recorded values of fruit width, length, and number of fruits per plant and weight of capsicum have been summarized in Tables from 4.8 to 4.11 respectively. All the parameters were higher in all time nutrition fertigation as compared to weekly and fortnightly fertigation frequency. Among the different fertigation level, all of the fruit parameters showed higher with 125% of recommended dose of nitrogen as compared to other fertigation levels. Earlier reports with drip irrigation in chilli crop reported highest average fruit weight, length and diameter at 125% recommended dose of NPK as compared with 75 and 100% of recommended dose of nitrogen levels (Ramachandrappa *et al.*, 2010). Application of nitrogen fertigation might have increased the endogenous auxin content and metabolic activities, which accelerated the photosynthetic rate and in turn might have increased the delivery of carbohydrates in plants, which finally resulted in increased fruit size, weight, number of fruits per plant, fruit yield per plant and yield per hectare (Everaarts and Boou, 2000).

#### 5.2.4 Yield

Application of sufficient nitrogen levels and fertigation frequency might have maintained an optimum level of nutrients within the root zone. Under all time nutrition fruit yield (178.40 q/ha) was maximum at 125% of RDN, which was at par with 100% RDN having (174.27 q/ha) yield but significantly higher in capsicum to 75% of RDN. Days to flowering was hastened, fruit length, fruit weight, and total fruit yield were also maximum under FL<sub>3</sub>FF<sub>1</sub>. The possible reasons for better formation of fruit yield with 100 and 125% of RDN under all time nutrition might be of better utilization of nitrogen content as compared with 75% RDN, which credited to support of good supplement water connection in the root zone and assisted the plant with using supplements more efficiently and frequently (Everaarts and Boou, 2000).

The results of the present investigation are in agreement with the findings of Kumar *et al.* (2017) in tomato with similar soil conditions, who reported the maximum fruit yield under 125% of recommended dose of nitrogen which was at par with 100% of RDN but significantly higher in comparison to 75% of RDN with drip irrigation. Spehia *et al.* (2020) obtained maximum fruit yield (8.9 kg per plant) in capsicum with 120% of RDN which was at par with 100% of RDN (8.4 kg per plant) but significantly higher than other fertigation treatments. Singh *et al.* (2020) found that irrigation and fertigation scheduled at 100 and 120% recommended dose of fertigation enhanced nutrients uptake, crop growth and maximum fruit yield (101.6 t/ha) in capsicum. A similar response was observed in green chilli, which showed maximum fruit yield (19.10 t/ha) at 125% recommended dose of NPK fertigation, but it was statistically at par with 100% of recommended dose of fertigation (Ramachandrappa *et al.*, 2010). Pramanik (2016) recorded that fruit yield per plant increased progressively with increasing the levels of fertigation through drip system. Similar observations were also recorded by Kumar (2010) in maize, Nalawade (2010) and Vasu (2011) in cabbage.

Findings of the present study are in accordance with (Badr *et al.*, 2011) who reported that the simultaneous varying effect of nitrogen rate and fertigation frequency had significant effect on all the parameters of potato yield and yield components, which indicated the most efficient utilization of nitrogen for potato plants with most frequent fertigation rate. Papadopoulos and Ristimäki (2000) reported that use of N along with irrigation water lead to 50% higher yield of potato crop as compared with direct irrigation. Significant increase in fruit yield and fruit size was recorded under all time nutrition with daily surface drip irrigation as compared to biweekly and monthly fertigation studied under loamy sand soil conditions in tomato (Cook and Sanders,

1991). Patel and Rajput, (2005) found that daily, alternate day and weekly fertigation did not significantly affect the bulb yields of onion but lower yield was obtained for monthly fertigation.

### 5.3 Water use efficiency

In drip irrigation, water use efficiency in a treatment is directly proportional to yield obtained under that treatment. Variation of water use efficiency with the change of fertigation level and fertigation frequency was remained in the range of 3.19 to 3.72 kg m<sup>-3</sup>. Among the different treatments, FL<sub>3</sub>FF<sub>1</sub> resulted in maximum water use efficiency (3.72 kg m<sup>-3</sup>) followed by FL<sub>2</sub>FF<sub>1</sub> treatment (3.65 kg m<sup>-3</sup>), while, its minimum value (3.19 kg m<sup>-3</sup>) was observed under FL<sub>1</sub>FF<sub>3</sub> treatment. On comparing fertigation levels, a significant reduction in WUE was noticed when nitrogen fertigation was decreased from 100 to 75% RDN. Under 125% RDN, WUE under all time nutrition is at par with weekly fertigation but it is significantly higher with fortnightly fertigation. These results were supported by Ashwani *et al.* (2020), who found maximum WUE (4.17 kg m<sup>-3</sup>) for 125% of recommended dose in chilli. Kumar *et al.*, (2020) also noticed maximum water use efficiency (26 kg m<sup>-3</sup>) under good quality of water with 125% RDF followed by 100% RDF (25.1 kg m<sup>-3</sup>) through drip irrigation in tomato. Ramachandrappa *et al.*, (2010) observed that water use efficiency was maximum for 125% RDF (31.0 kg/ha mm) in chilli under all time nutrition fertigation frequency.

### 5.4 Nitrogen use efficiency

Among the different treatments, FL<sub>1</sub>FF<sub>1</sub> resulted in maximum NUE (134.80 kg of capsicum per kg of Nitrogen) was obtained under all time nutrition fertigation frequency with 75% RDN and its minimum value (76.05 kg of capsicum per kg of Nitrogen) was observed under FL<sub>3</sub>FF<sub>3</sub> treatment (Table 4.13). These results have been earlier supported by Vijaykumar *et al.*, (2010) for hot chilli and by Kumar (2010) in maize crop. Previous studies showed that nitrogen use efficiency decreased with the increase in application of nitrogen. Lesser NUE at higher level of nitrogen dose indicates that excessive nitrogen application might shift the balance (C: N Ratio) between vegetative and reproductive growth toward excessive vegetative development. Drip irrigation provides the nitrogen in the root zone of the plant and increases the nitrogen use efficiency. A decrease in nitrogen use efficiency was also noticed by Stark *et al.* (1983) with higher rates of applied nitrogen in tomato.

Decrease in NUE with the increase in fertigation level was supported by various scientists. Gupta *et al.* (2010) found maximum fertilizer use efficiency (NUE-4.89 q/kg N, PUE-6.53 q/kg P and KUE-9.79 q/kg K) in capsicum crop with the treatment combination of 80% ET though drip with combination of 60% recommended NPK. The fertilizer use efficiency (FUE),

was higher at lower fertilizer level compared to higher level of fertilizer which showed an increase of 25% for 50% RDF and 9% for 75% RDF as compared to 100% RDF in chilli (Shashidhara, 2006). Simultaneous effect of drip irrigation and fertigation was found superior than their individual effects. Ramachandrappa *et al.*, (2010) observed significantly higher fertilizer use efficiency for 75% recommended NPK fertigation. Vijayakumar *et al.* (2010) reported highest fertilizer use efficiency with complete drip irrigation under 75% of pan evaporation and 75% of recommended dose of nitrogen and potash fertigation in hot chilli. Similarly, Vasu (2011) observed highest fertilizer use efficiency with daily fertigation of 75% of recommended dose of N and K in cabbage. Gupta *et al.* (2010) observed highest fertilizer use efficiency (4.89 q/kg N) for treatment combination of 80% ET and fertigation with 60% recommended dose of NPK in tomato.

### **5.5 Effect of nitrogen levels and its frequency on economics**

A critical examination of data showed that net returns and benefit cost ratio of capsicum significantly increased with nitrogen level at 125% of RDN with all time nutrition fertigation frequency. This might be due to the fact that under these treatments the cost of cultivation was high as compared to other treatment as well, therefore, higher fruit yields resulted in higher net returns and benefit cost ratio. These findings are in agreement with (Brahma, *et al.* 2014) it concluded that to achieve maximum fertigation with 100% of recommended dose of nitrogen produced the maximum benefit cost ratio (1:6.86) as compared to 50 and 75% of fertigation level in capsicum crop.

## CHAPTER-VI

### SUMMARY AND CONCLUSION

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Capsicum is nutrition rich vegetable crop grown throughout India and is suitable for drip system of irrigation being a wide-spacing crop. The research work entitled “*Study of nitrogen fertigation through drip irrigation on Capsicum crop*” was conducted at Research Farm of the Department of Vegetable Science, CCS Haryana Agricultural University, Hisar (Haryana) to find out the effect of fertigation levels and fertigation frequency on fruit yield and its attributes during spring-summer season of the 2019-20. Experiment was conducted to achieve the following objectives:

- i) To study the effect of nitrogen fertigation dose on capsicum crop
- ii) To study the effect of nitrogen fertigation frequency on capsicum crop

The treatments were comprised of three levels of fertigation (75, 100 and 125%) and three fertigation frequency (All time nutrition, weekly and fortnightly) at 0.6×0.3m row to row and plant to plant spacing. Capsicum plants were transplanted on February 23, 2020 and experiment was overed with final fruit harvesting on June 21, 2020. The data on fruit yield and its attributes was subjected to statistical analysis with split plot design. Based on the outcomes mentioned in previous chapters of this thesis, following important measurements were noted:

- The soil texture of the studied field was sandy loam with an average bulk density of 1.54 g cm<sup>-3</sup>. The average value of initial soil nutrients such as nitrogen (N), phosphorus (P), potassium (K), pH, electrical conductivity (EC) and infiltration rate were 115.9 kg ha<sup>-1</sup>, 15.2 kg ha<sup>-1</sup>, 227.5 kg ha<sup>-1</sup>, 8.3, 0.24 dS m<sup>-1</sup> and 2.89 cm h<sup>-1</sup>, respectively.
- Maximum average nitrogen content (140.1 kg ha<sup>-1</sup>) was observed in soil after harvest in all time nutrition fertigation with 125% of recommended dose of nitrogen.
- Soil moisture content was studied at different radial distance of 0, 15 and 30 cm and depth variation of 0-15, 15-30, 30-45 and 45-60 cm after 30, 45, 60, 75, 90, 105 and 120 days of transplanting. Minimum average moisture content recorded for 30 to 120 days of transplanting at varying depth and radial distance was 12.66% for the treatments with 125% of recommended dose of nitrogen with all time nutrition fertigation (FL<sub>3</sub>FF<sub>1</sub>), and maximum average soil moisture (18.28%) was recorded under FL<sub>1</sub>FF<sub>3</sub> treatment with fortnightly fertigation of 75% of recommended dose of nitrogen.

- Plant height increased with increase in nitrogen levels and decreased fertigation frequency. Among the various treatments, maximum plant height for 30, 60, 90 and 120 days after transplanting was recorded at 125% of recommended dose of nitrogen with all time nutrition fertigation.
- The treatment with 125% of recommended dose of nitrogen with all time nutrition fertigation took minimum number of days to flowering after transplanting.
- Average fruit width, length, weight and number of fruit per plant were maximum under 125% of recommended dose of nitrogen with various fertigation frequency in comparison to 100 and 75% of RDN.
- Maximum fruit yield (178.40 q/ha) was observed under all time nutrition fertigation with 125% of RDN which was at par with 100% of RDN but significantly higher in comparison to 75% of RDN.
- Minimum fruit yield (153.16 q/ha) was observed under fortnightly fertigation with 75% of RDN which was at par with 100% of RDN but significantly lower in comparison to 125% of RDN.
- All time nutrition fertigation with 125% of RDN (FL<sub>3</sub>FF<sub>1</sub>) showed maximum water use efficiency (3.72 kg m<sup>-3</sup>), followed by 100% RDN (3.63kg m<sup>-3</sup>) and the minimum value (3.19 kg m<sup>-3</sup>) was observed under fortnightly fertigation at 75% recommended dose of nitrogen (FL<sub>1</sub>FF<sub>3</sub>).
- Nitrogen use efficiency was estimated maximum (134.80 kg of capsicum per kg of Nitrogen) under all time nutrition fertigation with 75% recommended dose of nitrogen, while, it was minimum (76.05 kg of capsicum per kg of Nitrogen) for 125% of recommended dose of nitrogen at fortnightly fertigation.
- The highest net returns (Rs. 3,78,401) with benefit cost ratio (2.41) for capsicum crop were obtained at 125% of fertigation level with all time nutrition frequency, followed by 100% of fertigation level (Rs. 3.66,237) with benefit cost ratio (2.34) in all time nutrition frequency.

## CONCLUSION

Based on the study conducted on effect of nitrogen fertigation level and frequency, it may be concluded that fertigation level with 100% and 125% of recommended dose of nitrogen with all time nutrition frequency was highly responsive to obtain improved vegetative growth, fruit quality character and the maximum fruit yield of capsicum.

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## APPENDICES

### Appendix I

Date	DAT	Pan Evaporation (Ep) mm	Rainfall (mm)	Pan coeff. (Kp)	Crop coeff. (Kc)	Shaded area (%)	Water (ml/plant)	Irrigation time (hr/plant)	Timing (minutes)
23-Feb-20	1	1.6	0.0	0.85	0.6	15.00	28.80	0.01	0.75
24-Feb-20	2	2.0	0.0	0.85	0.6	15.00	36.00	0.02	0.94
25-Feb-20	3	2.3	0.0	0.85	0.6	15.00	41.40	0.02	1.08
26-Feb-20	4	1.6	0.0	0.85	0.6	15.00	28.80	0.01	0.75
27-Feb-20	5	1.7	0.0	0.85	0.6	15.00	30.60	0.01	0.80
28-Feb-20	6	2.9	0.0	0.85	0.6	15.00	52.20	0.02	1.36
29-Feb-20	7	3.4	0.0	0.85	0.6	15.00	61.20	0.03	1.60
1-Mar-20	8	2.6	0.2	0.85	0.6	15.00	46.80	0.02	1.22
2-Mar-20	9	2.0	0.0	0.85	0.6	15.00	36.00	0.02	0.94
3-Mar-20	10	2.1	0.0	0.85	0.6	15.00	37.80	0.02	0.99
4-Mar-20	11	2.2	0.0	0.85	0.6	15.00	39.60	0.02	1.03
5-Mar-20	12	7.5	20.5	0.85	0.6	15.00	0.00	0.00	0.00
6-Mar-20	13	3.0	5.6	0.85	0.6	15.00	54.00	0.02	1.41
7-Mar-20	14	0.0	35.7	0.85	0.6	15.00	0.00	0.00	0.00
8-Mar-20	15	1.4	0.0	0.85	0.6	15.00	25.20	0.01	0.66
9-Mar-20	16	2.1	0.0	0.85	0.6	18.09	45.59	0.02	1.19
10-Mar-20	17	3.1	0.0	0.85	0.6	18.09	67.29	0.03	1.76
11-Mar-20	18	2.6	0.0	0.85	0.6	18.09	56.44	0.02	1.47
12-Mar-20	19	2.7	11.6	0.85	0.6	18.09	58.61	0.03	1.53
13-Mar-20	20	4.2	0.0	0.85	0.6	18.09	91.17	0.04	2.38
14-Mar-20	21	1.7	0.0	0.85	0.6	18.09	36.90	0.02	0.96
15-Mar-20	22	2.8	0.0	0.85	0.6	18.09	60.78	0.03	1.59
16-Mar-20	23	2.2	0.0	0.85	0.6	18.09	47.76	0.02	1.25
17-Mar-20	24	1.7	0.0	0.85	0.6	28.26	57.65	0.03	1.50
18-Mar-20	25	3.0	0.0	0.85	0.6	28.26	101.74	0.04	2.65
19-Mar-20	26	3.1	0.0	0.85	0.6	28.26	105.13	0.05	2.74
20-Mar-20	27	3.2	0.0	0.85	0.6	28.26	108.52	0.05	2.83
21-Mar-20	28	3.5	0.0	0.85	0.6	28.26	118.69	0.05	3.10
22-Mar-20	29	3.2	0.0	0.85	0.6	28.26	108.52	0.05	2.83
23-Mar-20	30	3.5	0.0	0.85	0.6	28.26	118.69	0.05	3.10
24-Mar-20	31	3.5	0.0	0.85	0.6	28.26	118.69	0.05	3.10
25-Mar-20	32	5.7	1.5	0.85	1.05	28.26	338.27	0.15	8.82

26-Mar-20	33	3.4	0.0	0.85	1.05	28.26	201.78	0.09	5.26
27-Mar-20	34	3.8	2.3	0.85	1.05	28.26	225.51	0.10	5.88
28-Mar-20	35	4.3	17.8	0.85	1.05	28.26	255.19	0.11	6.66
29-Mar-20	36	3.1	0.0	0.85	1.05	28.26	183.97	0.08	4.80
30-Mar-20	37	3.6	0.0	0.85	1.05	28.26	213.65	0.09	5.57
31-Mar-20	38	3.9	0.0	0.85	1.05	28.26	231.45	0.10	6.04
1-Apr-20	39	2.8	0.5	0.85	1.05	28.26	166.17	0.07	4.33
2-Apr-20	40	4.0	0.0	0.85	1.05	32.15	270.06	0.12	7.05
3-Apr-20	41	4.0	0.0	0.85	1.05	32.15	270.06	0.12	7.05
4-Apr-20	42	5.1	0.0	0.85	1.05	32.15	344.33	0.15	8.98
5-Apr-20	43	3.5	0.0	0.85	1.05	32.15	236.30	0.10	6.16
6-Apr-20	44	3.7	0.0	0.85	1.05	32.15	249.81	0.11	6.52
7-Apr-20	45	5.0	0.0	0.85	1.05	40.69	427.25	0.19	11.15
8-Apr-20	46	5.3	0.0	0.85	1.05	40.69	452.88	0.20	11.81
9-Apr-20	47	5.1	0.0	0.85	1.05	40.69	435.79	0.19	11.37
10-Apr-20	48	4.1	0.0	0.85	1.05	40.69	350.34	0.15	9.14
11-Apr-20	49	4.6	0.0	0.85	1.05	45.34	437.98	0.19	11.43
12-Apr-20	50	4.5	0.0	0.85	1.05	45.34	428.46	0.19	11.18
13-Apr-20	51	4.8	0.0	0.85	1.05	45.34	457.03	0.20	11.92
14-Apr-20	52	5.3	0.0	0.85	1.05	45.34	504.63	0.22	13.16
15-Apr-20	53	5.7	0.0	0.85	1.05	45.34	542.72	0.24	14.16
16-Apr-20	54	6.5	0.0	0.85	1.05	45.34	618.89	0.27	16.14
17-Apr-20	55	7.3	0.0	0.85	1.05	50.24	770.18	0.33	20.09
18-Apr-20	56	7.7	0.0	0.85	1.05	50.24	812.38	0.35	21.19
19-Apr-20	57	7.2	0.0	0.85	1.05	50.24	759.63	0.33	19.82
20-Apr-20	58	6.1	0.0	0.85	1.05	50.24	643.57	0.28	16.79
21-Apr-20	59	3.9	0.8	0.85	1.05	50.24	411.47	0.18	10.73
22-Apr-20	60	4.8	0.0	0.85	1.05	50.24	506.42	0.22	13.21
23-Apr-20	61	5.6	0.0	0.85	1.05	50.24	590.82	0.26	15.41
24-Apr-20	62	2.0	2.1	0.85	1.05	50.24	211.01	0.09	5.50
25-Apr-20	63	5.4	0.0	0.85	1.05	61.79	700.70	0.30	18.28
26-Apr-20	64	6.6	0.0	0.85	1.05	61.79	856.41	0.37	22.34
27-Apr-20	65	6.3	1.9	0.85	1.05	61.79	817.48	0.36	21.33
28-Apr-20	66	6.3	0.0	0.85	1.05	61.79	817.48	0.36	21.33
29-Apr-20	67	5.1	0.0	0.85	1.05	61.79	661.77	0.29	17.26
30-Apr-20	68	4.1	0.0	0.85	1.05	61.79	532.01	0.23	13.88
1-May-20	69	8.1	0.0	0.85	1.05	72.35	1230.67	0.54	32.10
2-May-20	70	8.3	0.0	0.85	1.05	72.35	1261.06	0.55	32.90
3-May-20	71	9.7	0.0	0.85	1.05	72.35	1473.77	0.64	38.45
4-May-20	72	10.1	18.2	0.85	1.05	72.35	1534.54	0.67	40.03

5-May-20	73	3.6	0.0	0.85	1.05	72.35	546.97	0.24	14.27
6-May-20	74	6.9	0.0	0.85	1.05	72.35	1048.35	0.46	27.35
7-May-20	75	6.3	0.0	0.85	1.05	72.35	957.19	0.42	24.97
8-May-20	76	6.3	0.0	0.85	1.05	72.35	957.19	0.42	24.97
9-May-20	77	7.9	0.0	0.85	1.05	72.35	1200.29	0.52	31.31
10-May-20	78	8.2	0.0	0.85	1.05	72.35	1245.87	0.54	32.50
11-May-20	79	6.2	1.1	0.85	1.05	72.35	942.00	0.41	24.57
12-May-20	80	7.4	0.0	0.85	1.05	78.50	1219.89	0.53	31.82
13-May-20	81	7.6	0.0	0.85	1.05	78.50	1252.86	0.54	32.68
14-May-20	82	4.2	0.0	0.85	1.05	78.50	692.37	0.30	18.06
15-May-20	83	6.7	6.6	0.85	1.05	78.50	1104.50	0.48	28.81
16-May-20	84	6.6	0.0	0.85	1.05	78.50	1088.01	0.47	28.38
17-May-20	85	7.5	0.0	0.85	1.05	78.50	1236.38	0.54	32.25
18-May-20	86	7.0	0.0	0.85	1.05	78.50	1153.95	0.50	30.10
19-May-20	87	7.6	0.0	0.85	1.05	78.50	1252.86	0.54	32.68
20-May-20	88	9.1	0.0	0.85	1.05	78.50	1500.14	0.65	39.13
21-May-20	89	9.1	0.0	0.85	1.05	78.50	1500.14	0.65	39.13
22-May-20	90	8.8	0.0	0.85	1.05	78.50	1450.68	0.63	37.84
23-May-20	91	9.0	0.0	0.85	1.05	91.58	1730.86	0.75	45.15
24-May-20	92	13.3	0.0	0.85	0.9	91.58	2192.43	0.95	57.19
25-May-20	93	14.3	0.0	0.85	0.9	91.58	2357.27	1.02	61.49
26-May-20	94	9.3	0.0	0.85	0.9	91.58	1533.05	0.67	39.99
27-May-20	95	11.2	0.0	0.85	0.9	91.58	1846.25	0.80	48.16
28-May-20	96	13.9	0.0	0.85	0.9	91.58	2291.33	1.00	59.77
29-May-20	97	9.5	2.3	0.85	0.9	91.58	1566.02	0.68	40.85
30-May-20	98	8.5	5.2	0.85	0.9	91.58	1401.17	0.61	36.55
31-May-20	99	4.9	2.8	0.85	0.9	91.58	807.74	0.35	21.07
1-Jun-20	100	5.7	0.0	0.85	0.9	91.58	939.61	0.41	24.51
2-Jun-20	101	5.2	3.4	0.85	0.9	91.58	857.19	0.37	22.36
3-Jun-20	102	4.6	0.0	0.85	0.9	98.47	815.33	0.35	21.27
4-Jun-20	103	4.7	1.0	0.85	0.9	98.47	833.06	0.36	21.73
5-Jun-20	104	5.7	0.0	0.85	0.9	98.47	1010.30	0.44	26.36
6-Jun-20	105	5.9	0.0	0.85	0.9	98.47	1045.75	0.45	27.28
7-Jun-20	106	6.6	1.2	0.85	0.9	98.47	1169.82	0.51	30.52
8-Jun-20	107	4.8	0.0	0.85	0.9	98.47	850.78	0.37	22.19
9-Jun-20	108	6.9	0.0	0.85	0.9	98.47	1223.00	0.53	31.90
10-Jun-20	109	7.0	0.0	0.85	0.9	98.47	1240.72	0.54	32.37
11-Jun-20	110	8.7	0.0	0.85	0.9	98.47	1542.04	0.67	40.23
12-Jun-20	111	7.2	0.0	0.85	0.9	98.47	1276.17	0.55	33.29
13-Jun-20	112	7.9	0.0	0.85	0.9	98.47	1400.24	0.61	36.53

14-Jun-20	113	7.9	0.0	0.85	0.9	98.47	1400.24	0.61	36.53
15-Jun-20	114	6.5	0.0	0.85	0.9	98.47	1152.10	0.50	30.05
16-Jun-20	115	9.3	0.0	0.85	0.9	98.47	1648.39	0.72	43.00
17-Jun-20	116	9.4	0.0	0.85	0.9	98.47	1666.11	0.72	43.46
18-Jun-20	117	9.8	0.0	0.85	0.9	98.47	1737.01	0.76	45.31
19-Jun-20	118	6.1	0.0	0.85	0.9	98.47	1081.20	0.47	28.21
20-Jun-20	119	10.4	3.4	0.85	0.9	98.47	1843.36	0.80	48.09
21-Jun-20	120	6.7	3.8	0.85	0.9	98.47	1187.55	0.52	30.98
							<b>86250.181</b>	<b>37.50</b>	<b>2250.00</b>

## Appendix II

Average fruit width (cm) per harvesting									
Treatments		1st	2nd	3rd	4th	5th	6th	7th	8th
<b>FL<sub>1</sub>FF<sub>1</sub></b>	R1	6.0	6.5	6.4	6.0	6.4	6.8	6.3	6.0
	R2	5.8	6.4	5.9	5.9	6.3	6.4	5.7	6.1
	R3	5.9	6.3	6.2	6.3	6.7	6.3	6.5	5.8
<b>FL<sub>1</sub>FF<sub>2</sub></b>	R1	5.6	6.2	5.8	6.3	6.1	6.6	6.1	5.9
	R2	5.7	5.9	6.3	6.4	6.5	6.1	6.5	6.0
	R3	5.9	6.3	6.0	6.6	6.3	6.4	6.3	5.8
<b>FL<sub>1</sub>FF<sub>3</sub></b>	R1	5.8	6.4	6.3	6.1	6.1	5.9	5.7	6.1
	R2	6.0	6.3	6.2	5.9	6.0	6.4	5.9	6.3
	R3	6.1	6.2	6.6	5.8	6.2	5.7	5.8	5.5
<b>FL<sub>2</sub>FF<sub>1</sub></b>	R1	5.9	6.2	6.3	6.2	6.5	7.1	6.9	6.2
	R2	6.1	6.5	6.7	6.6	6.4	6.5	6.3	5.8
	R3	6.3	6.6	6.4	6.7	6.9	6.6	6.6	5.8
<b>FL<sub>2</sub>FF<sub>2</sub></b>	R1	5.8	6.2	6.8	6.6	6.6	6.7	6.3	6.3
	R2	5.7	6.1	6.4	6.5	6.4	6.4	6.4	5.9
	R3	5.8	6.3	6.5	7.1	6.8	6.4	6.1	6.4
<b>FL<sub>2</sub>FF<sub>3</sub></b>	R1	5.9	6.4	6.1	6.6	6.7	6.8	5.8	6.3
	R2	5.8	6.3	5.9	6.1	5.7	6.9	6.2	6.6
	R3	6.0	6.0	6.3	6.4	6.6	6.2	6.6	6.1
<b>FL<sub>3</sub>FF<sub>1</sub></b>	R1	6.2	6.7	6.6	6.7	6.8	7.4	7.2	5.8
	R2	6.4	6.9	6.9	7.0	6.8	7.3	6.6	6.3
	R3	6.2	6.8	7.1	6.8	7.1	7.4	7.0	6.6
<b>FL<sub>3</sub>FF<sub>2</sub></b>	R1	6.1	6.8	6.8	6.6	7.2	6.7	6.3	6.2
	R2	6.3	6.5	6.8	6.4	7.3	7.2	6.9	6.2
	R3	5.9	6.2	6.5	6.6	6.8	6.9	7.2	5.9
<b>FL<sub>3</sub>FF<sub>3</sub></b>	R1	6.0	5.8	6.3	7.2	6.6	7.0	6.5	6.6
	R2	5.9	6.1	6.4	6.8	6.8	7.1	6.8	6.2
	R3	6.2	6.0	6.3	6.3	7.1	6.6	6.7	6.0

### Appendix III

Average fruit length (cm) per harvesting									
Treatments		1st	2nd	3rd	4th	5th	6th	7th	8th
<b>FL<sub>1</sub>FF<sub>1</sub></b>	R1	6.2	7.1	7.1	7.7	7.7	7.3	7.1	7.4
	R2	6.6	6.9	7.3	8.0	7.3	7.1	7.2	7.1
	R3	7.0	6.9	7.2	8.1	6.9	6.9	7.1	6.9
<b>FL<sub>1</sub>FF<sub>2</sub></b>	R1	7.1	6.8	7.4	6.9	7.3	7.7	6.9	6.9
	R2	6.0	6.5	6.9	6.6	7.3	7.5	6.6	6.6
	R3	6.5	7.5	7.9	8.0	6.9	7.5	6.4	7.3
<b>FL<sub>1</sub>FF<sub>3</sub></b>	R1	6.6	6.8	6.8	6.6	7.5	7.4	6.7	6.8
	R2	6.8	6.2	6.9	8.1	6.5	6.9	7.4	6.6
	R3	6.9	6.6	6.9	6.9	6.3	6.9	7.1	6.5
<b>FL<sub>2</sub>FF<sub>1</sub></b>	R1	7.3	6.9	7.4	8.0	7.4	7.4	7.1	7.3
	R2	7.5	7.9	7.4	8.2	7.9	7.7	7.2	7.5
	R3	7.8	7.5	7.2	7.7	7.6	7.3	6.9	6.9
<b>FL<sub>2</sub>FF<sub>2</sub></b>	R1	7.3	7.1	6.9	7.3	7.6	7.7	7.1	7.7
	R2	6.9	6.9	7.0	7.9	8.2	7.0	7.2	7.3
	R3	7.4	6.9	7.3	7.7	6.9	7.3	6.9	7.0
<b>FL<sub>2</sub>FF<sub>3</sub></b>	R1	6.6	7.3	7.7	7.3	8.1	7.7	7.1	7.1
	R2	6.8	7.4	7.1	7.1	6.7	6.9	7.7	6.9
	R3	7.2	6.1	6.8	7.1	7.3	7.1	7.2	7.1
<b>FL<sub>3</sub>FF<sub>1</sub></b>	R1	7.3	7.5	7.9	8.8	7.9	8.2	7.2	6.6
	R2	7.1	7.9	8.2	9.0	7.6	8.2	7.5	7.7
	R3	7.3	7.1	8.5	9.1	8.0	7.7	7.1	6.9
<b>FL<sub>3</sub>FF<sub>2</sub></b>	R1	7.3	7.4	8.3	8.8	7.8	7.4	7.7	6.6
	R2	7.7	7.1	7.9	8.2	7.4	7.4	7.4	6.5
	R3	7.4	7.2	8.0	7.9	8.5	7.8	7.5	7.1
<b>FL<sub>3</sub>FF<sub>3</sub></b>	R1	7.4	7.0	8.1	7.9	8.2	7.4	6.9	6.8
	R2	6.9	7.2	7.9	6.9	8.3	7.5	6.9	7.0
	R3	7.3	7.8	7.5	8.5	7.9	7.9	7.1	7.1

## Appendix IV

Treatments		Average number of fruits per plant							
		1st	2nd	3rd	4th	5th	6th	7th	8th
<b>FL<sub>1</sub>FF<sub>1</sub></b>	R1	18	23	22	28	24	22	26	25
	R2	16	22	27	24	27	26	23	26
	R3	19	17	26	27	24	27	27	24
<b>FL<sub>1</sub>FF<sub>2</sub></b>	R1	23	22	21	22	27	18	27	23
	R2	16	20	27	26	23	19	24	19
	R3	19	25	25	26	29	22	21	25
<b>FL<sub>1</sub>FF<sub>3</sub></b>	R1	17	23	23	25	27	25	22	21
	R2	18	25	23	21	21	20	24	17
	R3	15	19	21	19	27	24	24	16
<b>FL<sub>2</sub>FF<sub>1</sub></b>	R1	22	29	25	25	30	31	29	23
	R2	21	23	29	28	29	25	29	26
	R3	29	29	28	29	27	30	33	25
<b>FL<sub>2</sub>FF<sub>2</sub></b>	R1	25	25	28	26	32	27	27	29
	R2	26	23	28	27	26	29	29	23
	R3	27	25	26	26	28	26	27	27
<b>FL<sub>2</sub>FF<sub>3</sub></b>	R1	28	27	27	29	21	27	28	22
	R2	23	29	25	27	26	25	26	28
	R3	25	22	22	28	21	26	29	24
<b>FL<sub>3</sub>FF<sub>1</sub></b>	R1	27	28	31	36	29	28	26	23
	R2	29	32	32	27	31	31	37	33
	R3	24	30	39	35	34	33	34	31
<b>FL<sub>3</sub>FF<sub>2</sub></b>	R1	19	31	29	35	29	25	26	28
	R2	17	33	31	37	30	27	25	27
	R3	15	32	27	33	35	29	26	22
<b>FL<sub>3</sub>FF<sub>3</sub></b>	R1	23	29	33	26	28	29	28	31
	R2	28	24	31	27	29	28	22	25
	R3	24	30	29	25	25	27	24	27

## Appendix V

Average fruit weight (g) per harvesting									
Treatments		1st	2nd	3rd	4th	5th	6th	7th	8th
<b>FL<sub>1</sub>FF<sub>1</sub></b>	R1	26.13	34.28	62.33	62.42	63.77	41.32	42.83	44.23
	R2	28.87	39.98	54.90	59.21	52.94	46.23	48.13	42.94
	R3	26.29	32.18	57.07	66.74	54.76	51.32	42.64	40.33
<b>FL<sub>1</sub>FF<sub>2</sub></b>	R1	29.32	33.29	52.89	51.29	50.56	45.12	46.12	39.73
	R2	28.43	47.78	41.83	52.87	48.65	49.23	44.23	40.72
	R3	27.55	37.44	59.72	49.43	44.92	40.76	48.38	38.23
<b>FL<sub>1</sub>FF<sub>3</sub></b>	R1	32.28	38.13	44.23	48.21	42.23	42.46	40.24	39.23
	R2	29.57	31.26	53.54	47.87	51.54	43.43	39.93	38.12
	R3	30.20	36.41	51.67	50.08	42.47	47.76	42.13	41.34
<b>FL<sub>2</sub>FF<sub>1</sub></b>	R1	28.17	40.17	61.21	62.18	60.49	55.34	43.24	38.76
	R2	37.53	48.76	61.50	55.74	58.45	51.94	50.93	45.48
	R3	31.57	54.23	63.87	64.25	64.76	55.22	46.29	41.45
<b>FL<sub>2</sub>FF<sub>2</sub></b>	R1	35.76	42.56	59.44	66.29	61.87	48.35	39.54	39.71
	R2	31.57	40.45	56.60	63.72	59.56	51.32	51.45	49.36
	R3	39.53	43.21	62.29	61.56	58.71	55.78	42.83	40.61
<b>FL<sub>2</sub>FF<sub>3</sub></b>	R1	35.97	42.76	57.43	54.17	58.45	48.23	49.56	42.12
	R2	42.78	45.34	55.82	62.92	56.93	44.23	40.04	39.71
	R3	38.62	41.23	60.89	59.66	61.65	49.42	41.73	45.84
<b>FL<sub>3</sub>FF<sub>1</sub></b>	R1	37.31	50.36	72.58	72.19	66.32	55.05	42.82	44.82
	R2	35.26	55.32	69.24	71.72	69.24	49.34	44.92	41.23
	R3	33.43	53.33	64.58	74.97	60.64	51.52	50.72	40.84
<b>FL<sub>3</sub>FF<sub>2</sub></b>	R1	29.64	46.76	65.47	68.45	64.12	58.34	49.54	38.31
	R2	31.45	42.42	61.29	69.26	65.96	55.93	44.82	42.39
	R3	29.88	49.34	59.94	62.61	70.22	59.33	50.72	38.13
<b>FL<sub>3</sub>FF<sub>3</sub></b>	R1	31.29	45.87	56.23	66.73	59.53	54.34	49.91	42.24
	R2	28.18	48.13	62.51	70.52	61.11	49.26	50.52	41.32
	R3	30.24	46.19	58.66	64.12	67.29	53.30	45.97	43.92

## Appendix VI

<b>Cost of cultivation of capsicum crop (Rs./ha)</b>				
<b>Sr.No.</b>	<b>Operations</b>	<b>Man days/Quantity</b>	<b>Rate</b>	<b>Total</b>
1.	Ploughing, leveling, planking	3	1250	3750
2.	FYM and fertilizers			
	i)    FYM	25 t	500/t	12500
	ii)   DAP	30 kg	23.5/kg	705
	iii)  MOP	30 kg	11/kg	330
3.	Layout	10 man days	321	3210
4.	Cost of seed	500 g	800	40000
5.	Cost of Sowing seed	8 man days	321	2568
6.	Irrigation charges	10 man days	321	3210
7.	Intercultural Opeations	20 man days	321	6420
8.	Plant Protection charges			1000
9.	Harvesting charges	50 man days	321	16050
10.	Transporting charges			8000
11.	Miscellaneous			2000
12.	Variable cost			99743
	Risk factor (10%)			9974
	Interest (7%)			6982
	Rental value	6 months	50000/year	25000
	<b>Total cost of cultivation</b>			<b>141699</b>

<b>Fertigation level -1 (75% RDN)</b>				
<b>Sr.No.</b>	<b>Operations</b>	<b>Man days/Quantity</b>	<b>Rate</b>	<b>Total</b>
1	Cost of cultivation			141699
2	Fertilizer	122.28 kg	5.35/kg	656
3	Drip cost (15%)			5585
4	Labour	15 man days	321	4815
5	Electricity cost	120 days	30/day	3600
	<b>Total cost</b>			<b>156355</b>
<b>Fertigation level -2 (100% RDN)</b>				
1	Cost of cultivation			141699
2	Fertilizer	163.04 kg	5.35/kg	874
3	Drip cost (15%)			5585
4	Labour	15 man days	321	4815
5	Electricity cost	120 days	30/day	3600
	<b>Total cost</b>			<b>156573</b>
<b>Fertigation level -3 (125% RDN)</b>				
1	Cost of cultivation			141699
2	Fertilizer	203.8 kg	5.35/kg	1100
3	Drip cost (15%)			5585
4	Labour	15 man days	321	4815
5	Electricity cost	120 days	30/day	3600
	<b>Total cost</b>			<b>156799</b>

## ABSTRACT

Title of Thesis : **Study of nitrogen fertigation through drip irrigation on capsicum crop**

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Admission Number : 2018AE08M

Title of the Degree : **Master of Technology**

Name of Discipline : Soil and Water Engineering

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Major Subject : Soil and Water Engineering

Total Number of Pages in Thesis : 48 +VII + X

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Key words : Capsicum, nitrogen fertigation, fertigation level, fertigation frequency, drip irrigation

(An abstract of the thesis submitted to CCS Haryana Agricultural University, Hisar, in partial fulfillment of the requirements for the degree of Master of Technology in Soil and Water Engineering)

Capsicum is a nutrition vegetable crop grown throughout India. Considering the water shortage and high demands of ground water, drip system of irrigation is best suited for capsicum crop. Nitrogen is an essential element for the plant growth and the major source of nitrogen is urea, which is readily available to the farmers. Nitrogen fertigation with drip irrigation saves the nitrogen losses and reduces its leaching. A study was conducted to examine the effect of nitrogen fertigation levels and fertigaion frequency on yield and yield parameters of drip irrigated capsicum crop. Experiment was carried out in 27 micro plots (nine treatments with three replications) constructed in the Research Farm of Department of Vegetable Science, CCSHAU, Hisar, (Haryana), India. The treatments comprises of three fertigation levels (75, 100 and 125% of RDN) and three fertigation frequencies (all time nutrition, weekly and fortnightly). Maximum fruit yield (178.40 q/ha) was obtained under all time nutrition fertigation with 125% RDN (FL<sub>3</sub>FF<sub>1</sub>), followed by 100% RDN (FL<sub>2</sub>FF<sub>1</sub>) having 174.27 q/ha fruit yield. In all time nutrition fertigation, 33.7% and 34.5% more yield was obtained in FL<sub>2</sub>FF<sub>1</sub> and FL<sub>3</sub>FF<sub>1</sub> treatment in comparison to FL<sub>1</sub>FF<sub>1</sub> treatments. Maximum plant height was recorded for all time nutrition fertigation with 125% of RDN and the number of branches, average fruit width and length were recorded maximum at 125% of RDN with all time nutrition fertigation. Fruit weight and number of fruits per plant maximum at 125% RDN followed by 100% RDN under all time nutrition fertigation. Outcomes of study showed that the treatment FL<sub>3</sub>FF<sub>1</sub> recorded maximum water use efficiency (3.72 kg m<sup>-3</sup>) followed by 100% RDN (3.63 kg m<sup>-3</sup>), while, minimum value (3.19 kg m<sup>-3</sup>) was recorded in FL<sub>1</sub>FF<sub>3</sub> treatment. Maximum NUE (134.80kg of capsicum per kg of Nitrogen) was recorded under all time nutrition fertigation with 75% RDN in FL<sub>1</sub>FF<sub>1</sub> treatment and minimum NUE (76.05 kg of capsicum per kg of Nitrogen) was recorded at 125% RDN with fortnightly fertigation. The highest net returns (Rs. 3,78,401) with benefit cost ratio (2.41) for capsicum crop were obtained at 125% of fertigation level with all time nutrition frequency followed by 100% of fertigaition level.

**MAJOR ADVISOR**

**SIGNATURE OF THE STUDENT**

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## CURRICULUM VITAE



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