CHAPTER-II

REVIEW OF LITERATURE

This chapter deals with up-to-date reviews of literature related to “Irrigation scheduling of fennel (Foeniculum vulgare Mill.) under trickle irrigation” by various researchers for fennel crop at different places. Since information on fennel crop is meagre, therefore, pertinent literature on other crops has also been incorporated in this text. The relevant review of literature is categorized under the following subheads.

- Agronomic practices for the crop
- Effect of irrigation levels and frequencies on crop growth and yield
- Effect of irrigation levels and frequencies on consumptive use and water use efficiency
- Economics of the drip system

2.1 AGRONOMIC PRACTICES FOR THE CROP

Agronomic management plays an important role for realizing higher productivity of improved crop variety. An agronomical practices right from plant variety, crop spacing, time of sowing, fertilizer (Nitrogen, phosphorous and potash), crop husbandry and irrigation are the important parameters for crop production. Efforts here are made to study and review brief summary of research related to agronomical practices of fennel crop.

Bianco et al. (1994) carried out two experiments to study the effect of sowing dates, plant density and crown cutting on yield and quality of Florence fennel seed. In the first year no differences were registered with 'crown' cutting compared to the control while in the second year the seed yield was higher in the control and during the third year, when the cutting took place 7 and 14 days after the harvest date, the seed production was lower. In the second experiment (sowing dates, plant density and plant- cutting), the crop sown on September flowered 14 days after the crop sown on August, and crown cutting postponed flowering by 9 days. Seed yield decreased with second sowing date and with 'crown' cutting. Differences were noted among density in the following characters: plant height at flowering of primary umbel, number of stem and umbel per plant, yield per plant and per hectare. 'Crown' cutting reduced germination percentage and on the first sowing date increased the time to reach 25, 50, 75 and 95 % of the final germination.
Damato et al. (1994) studied the effect of temperatures, incubation periods, osmotic potentials and rate of germination of Florence fennel "seeds" at optimal and critical temperatures. They observed that "Seeds" of Florence fennel (*Foeniculum vulgare* Mill.) were osmotically primed in 0, -9, -12 or -15 MPa polyethylene glycol 8000 at 10, 15 or 20 °C for 6, 12 or 18 days before germination at 15, 25 or 35 °C. Priming had little effect on germination at 35°C (11 %). Increasing temperature during priming shortened of 1.2 days the time to achieve the final germination; osmotic potential and priming duration improved the speed of germination.

Hartz and Hochmuth (1996) concluded that the use of fertigation generally does not change the fertilizer requirements of a particular crop. Total fertilizer nutrient requirements vary with location, soil type, and crop. Most soils, except for organic soils, are deficient in N, which must be applied for most annual vegetables. Most mineral soils also lack P and K, which are applied to each crop. Needs for secondary and micro-nutrients vary widely according to the crop and the fertility of the soil.

Masood et al. (2004) conducted research to assess the effect of different sowing seasons and row spacing on seed production of fennel (*Foeniculum vulgare* Mill.) and carried out experiment in Peshawar during the year 2002-2003. They found that the row spacing 40 cm gave maximum plant height (114.7 cm) while minimum plant height (78.1 cm) was in 70 cm spacing.

Amin (2005) an experiment was conducted to observe the response of fennel (*foeniculum vulgare* mill) to irrigation and fertility levels under north Gujarat condition. A seed yield and consumptive use of water increased with increase in nitrogen levels, but significant increase was observed up to 90 kg N/ha. Maximum water use efficiency and water expense efficiency were obtained with application of 120 kg N/ha. Application of phosphorus was unable to produce any remarkable effect on yield and consumptive use of water.

Amin et al. (2005) studied the effect of various row spacing’s and nitrogen levels on drilled rabi fennel (*foeniculum vulgare* mill.). They recorded significantly higher seed and stover yields and its attributes of fennel in 45 cm row spacing. Whereas, growth attributes increased with increase in row spacing from 30 to 60 cm.

Sing and Sastry (2005) association studied for seed yield and its attributes in bi-parental progenies of fennel. 100 bl-parental progenies developed separately from two diverse populations of fennel were evaluated to determine correlations among seed
yield and its components. Seed yield per plant was found to be positively and significantly correlated with branches per plant, umbels per plant, biological yield per plant and harvest Index in both the populations. It is suggested that seed yield could be improved if selection is practiced for these characters.

Ayub et al. (2008) a field experiment was conducted to evaluate the effect of different sowing methods and times on the growth and yield of fennel (*foeniculum vulgare* Mill.). The crop sown in lines gave significantly higher seed yield due to higher number of umbels per plant and number of seeds per umbel. Plant height and biological yield were only influenced during the year 2004-05. The fennel sown on 14\textsuperscript{th} November produced significantly lowest seed yield than 14\textsuperscript{th} September and 14\textsuperscript{th} October mainly due to lower stand density, number of umbels per plant and number of seeds per umbel. The line sowing of fennel in mid-October seems to be the best combination for getting higher fennel seed yield.

Khorshidi et al. (2009) In order to study the effect of different densities of planting on yield and essential oil components of Fennel (*Foeniculum vulgare* Mill.). The higher essential oil percentage (3.53 \%) was obtained with the lowest densities of planting. The higher percentage of anethole (83.07 \%), estragol (3.47 \%), fenchone (8.04 \%), p-cymene (4.45 \%), \(\delta\)-terpinene (0.54 \%), sabinene (0.51 \%), and \(\delta\)-Pinene (0.48 \%) were obtained with space between plants 25, 10, 20, 20, 15, 20, and 25 cm, respectively.

Mollazade et al. (2009) A trial was conducted to study the Some Physical and Mechanical Properties of Fennel Seed (*Foeniculum vulgare*) Some physical and mechanical properties of fennel seed were determined as a function of moisture content in the range of 7.78–21.67\% d.b. The average length, width and thickness were 58.87, 18.96 and 15.64 mm, at a moisture content of 7.78 \% d.b., respectively. In the moisture range from 7.78\% to 21.67\% d.b., studies on rewetted fennel seed showed that the thousand seed weight increased from 5.5 to 9.2 g, the porosity from 55.91\% to 62.21\%, the static and dynamic angle of repose from 37.6 to 46.6 and 41 to 53.3, respectively, the coefficient of friction on glass, plywood, and galvanized iron sheet surfaces from 0.55 to 0.74, 0.45 to 0.63, and 0.43 to 0.66, respectively, and deformation on width section increased from 1.68 to 1.86 mm. The bulk density decreased from 413.51 to 352.39 kg m\(^{-3}\) and rupture force on both seed length and width sections decreased from 198.93 to 78.68 N, and 600.65 to 186.44 N, respectively, with moisture content in the
moisture range of 7.78 to 21.67% d.b. But there was not regular trend for sphericity, true density, and deformation on length section with increasing the moisture content.

Mehta et al. (2010) A field trial was conducted to study the effect of irrigation and weed management practices on nodulation and yield of fenugreek. Significantly more number of nodules per plant and their dry weight at 40 and 60 DAS and leaf chlorophyll content, higher seed yield, straw yield, biological yield and B:C ratio were recorded with PE application of Pendimethalin @ 0.75 kg / ha + IC at 40 DAS followed by HW at 20 and 40 DAS which were statistically at par with each other and with weed free treatments and significantly superior over rest of the treatments but weed control efficiency at maturity was recorded higher with two hand weeding at 20 and 40 DAS.

Mehta et al. (2011) Field experiment was conducted to study the Growth and yield of fennel (Foeniculum vulgare Mill.) as influenced by irrigation, nutrient levels and crop geometry. Growth parameters, yield attributes, yield and N, P and K uptake were significantly higher with application of 120 kg N and 50 kg P₂O₅ ha⁻¹. Crop geometry of 60 cm x 25 cm resulted in significantly higher seed yield.

Dewangan et al. (2012) The field experiment was conducted for evaluating the effect of planting geometry and stage of harvesting and their interaction on yield attributes and seed yield of rabi fennel (Foeniculum vulgare Mill.) under south Gujarat condition. Planting geometry 90 × 30 cm (G₄) and 60 × 30 cm (G₂) were equally effective in improving almost all the yield parameters studied. However, these treatments failed to touch the yield level recorded under closer planting geometry 60 × 15 cm (G₁). The seed weight plant⁻¹ and test weight were significantly higher under full length green seed stage of harvest (S₂). Growing crop at 60 × 15 cm (G₁) geometry found most remunerative with maximum net realization of Rs 55533 ha⁻¹ and higher (Benefit Cost Ratio) BCR of 3.12. Harvesting at full length green seed stage (S₂) found most remunerative with maximum net realization of Rs 42087 ha⁻¹ with BCR 2.40.

Mahmood et al. (2012) an experiment was conducted to find out the Fennel yield and yield components as influenced by sowing methods and planting geometry. According to the data, different geometry and sowing methods affected significantly the growth, yield and yield components. The ridge sowing method gave significantly higher yield than the other two methods mainly because of greater number of reproductive branches and umbels per plant, seeds per umbel and 1000-seeds weight. It was closely followed by bed sowing, whereas line sowing with 18.5 and 12.5 cm plant spacing treatments produced the lowest seed yield.
Mehta et al. (2013) conducted field experiment to study the Growth and yield of coriander (Coriandrum sativum L.) as influenced by irrigation and nutrient levels with varying crop geometry. The higher growth parameters, yield attributes, seed yield (12.48 q/ha), net return (Rs. 42,922/ha) and B: C (2.21) were obtained with application of 50 kg N and 25 kg P$_2$O$_5$/ha. Crop geometry 30 x 10 cm resulted 9 % higher seed yield over 20 x 10 cm.

Bhardwaj et al. (2014) conducted a field experiment to study the effect of irrigation and crop geometry on growth, yield, quality and profitability of transplanted fennel (Foeniculum vulgare Mill.) The trench method of irrigation exhibited significantly higher plant height, number of branches, number of roots plant$^{-1}$, root length, fresh weight of shoot and roots plant$^{-1}$, maximum number of umbels plant$^{-1}$, umbellate umbel$^{-1}$, number of seed umbel$^{-1}$, highest seed yield (26.52 q ha$^{-1}$) with maximum gross return (Rs. 305,714.15), net return (Rs. 266,314.15) and benefit cost ratio (6.75). Comparatively less time (26.25 h) was required for one hectare irrigation in the same treatment in both the years. The crop planted in paired row (210 cm/120 cm x 25 cm) significantly influenced crop growth, yield and profitability of fennel. In this treatment, highest plant height, number of branches plant$^{-1}$, number of roots plant$^{-1}$, root length, fresh weight of shoot and root, maximum number of umbel plant$^{-1}$, umbellate umbel$^{-1}$, number of seed umbel$^{-1}$, highest seed yield (28.55 q ha$^{-1}$) with maximum gross return (Rs. 336,940.80), net return (Rs. 294,670.80) and benefit: cost ratio (6.97) was observed in both the years. Lower growth, yield and profitability were found in border strip method of irrigation and single row (90 cm x 45 cm) method of planting.

Koyani et al. (2014) a field experiment was conducted to study the response of direct-seeded rabi fennel (Foeniculum vulgare Mill.) to varying levels of nitrogen and phosphorus. Significantly the highest seed yield (18.67 q/ha) was recorded under 120 kg N/ha (N$_3$) which was at par with 90 kg N/ha (N$_2$). Application of phosphorus at 60 kg P$_2$O$_5$/ha (P$_2$) registered significantly the highest seed yield and found at par with 30 kg P$_2$O$_5$/ha (P$_1$).

Bhunia et al. (2015) a field experiment was conducted to study the effect of crop geometry and drip irrigation levels on pearl millet (Pennisetum glaucum). Highest seed yield, straw yield, biological yield and water use efficiency were recorded with normal sown crop at 60 cm drip line spacing which was at par with paired row sown crop at 120 cm drip line spacing.
Ioana et al. (2015) conducted a field experiment to study fennel seed germination (*foeniculum vulgare* var.). Seed germination depends on both internal and external conditions. Germination is epigeal and fennel seed normally germinates in 10-14 days depending mainly on the weather following sowing. The experiences made that the preparation SM (produced by Research and Development Centre for Biostimulators "BIOS" Cluj-Napoca) in concentration of 0.05%, in case of treating seeds for 3 h, has a positive influence on seeds germination, compared to untreated water control.

Singh and Amin (2015) conducted an experiment to study the response of drilled rabi fennel (*Foeniculum vulgare* Mill.) to spacing under varying levels of nitrogen. Fennel crop sown at 45 cm row spacing reported significantly higher seed yield (1521 kg ha\(^{-1}\)) over 30 and 60 cm row spacing. Similarly, Stover yield (2270 kg ha\(^{-1}\)) and oil yield (21.92 kg ha\(^{-1}\)) was significantly superior over 30 and 60 cm row spacing.

Kunapara et al. (2016) undertook a field experiment to access the influence of drip irrigation regimes and lateral spacing on cumin productivity. A higher seed yield, plant height and dry matter of 1344.17 kg/ha, 36.42 cm and 2365 kg/ha respectively was observed at lateral spacing 0.6 m as compared to other treatments by maintaining proper agronomical practices of crop husbandry with nutrient and irrigation management one can obtain yield of crop and good remuneration.

### 2.2 EFFECT OF IRRIGATION LEVELS AND FREQUENCIES ON CROP GROWTH AND YIELD

Irrigation scheduling is a tool used by irrigation managers to program water supplies to the crop. Basic questions arise are when and how much to irrigate. Irrigation scheduling when coupled with micro-irrigation will not only prevent under or over irrigation but will also reduce soil hardness through frequent watering. Frequent irrigation ensures better environment for root extension and proliferations which in turn results in higher production and quality. Numerous studies have been carried out in the past on the development and evaluation of irrigation scheduling techniques under a wide range of irrigation system and management, soil, climate and crop conditions (Jensen et al. 1970, Imtiyaz and Singh 1990, Imtiyaz et al. 1992, Steel et al. 1997).

Malavia et al. (1988) Studied on irrigation, nitrogen and phosphorus level on growth and yield of mustard. They reported that the seed and stover yields of mustard
and yield attributes viz., seed weight and number of siliqua/plant increased with increasing level of irrigation (i.e. IW/CPE ratio of 0.4, 0.6 and 0.8).

Tank (1988) studied the response of mung to irrigation scheduling based on cumulative evaporation of 0.6 IW/CPE, 0.8 IW/CPE and 1.0 IW/CPE and found IW/CPE ratio of 1.0 remarkably increased growth characters viz., plant height, number pods per plant, 1000 seed weight. This ratio also yielded significantly higher grain (858 kg ha⁻¹) and fodder (1412 kg ha⁻¹) yield over rest of the lower IW/CPE ratios.

Sharma and Prasad (1990) conducted experiment on Nitrogen and irrigation requirement of Fennel and they observed that irrigating the fennel crop at IW/CPE ratio of 0.6 (two irrigations) resulted in higher yield than the yield obtained with one irrigation at IW/CPE ratio of 0.4.

Trivedi et al. (1994) studied the Effect of varying irrigation schedule, depth of ploughing and mulching on growth and yield of summer green gram (Phaseolus radiatus). They reported that summer green gram irrigated at IW/CPE ratio of 0.7 significantly improved plant height, dry matter production and primary branches/plant as compared to IW/CPE ratio of 0.5.

Patel (1998) evaluated three systems of irrigation viz. flood, sprinkler and drip. The experiment was conducted on summer groundnut at Junagadh Agricultural University, Junagadh. The results revealed that the superiority of the drip system of irrigation by recording higher mean yield of 2155 kg per ha over flood irrigation system.

Deshmukh and Lahatonde (1999) conducted a field experiment to study the water use of pre monsoon hybrid cotton as influence by water regimes (0.4, 0.6 and 0.8 ETC) under trickle irrigation in Akola, India. Irrigation scheduling at 0.8 ETC recorded the highest seed cotton yield (20.20 q/ha).

Patel et al. (2000) studied the Response of fennel (Foeniculum vulgare) to irrigation, nitrogen and phosphorus at Junagadh (Gujarat). They reported that irrigation at IW/CPE ratio of 1.0 recorded significantly higher plant height, number of branches/plant, number of umbels/plant, umbellate/umbel, seeds/umbellate and test weight over IW/CPE ratios of 0.6 and 0.8.

Kumar et al. (2002) studied the Influence of irrigation and fertilizer levels on growth, seed yield and water use efficiency by fennel (Foeniculum vulgare). They observed that irrigating fennel three times (branching, flowering and seed-filling stages), being at par with both of two irrigation levels at branching + flowering and
branching + seed filling stages recorded maximum plant height and branches per plant which were significantly more than one irrigation (branching).

Patel et al. (2004) carried out an experiment on feasibility of drip irrigation in castor at S.K. Nagar. They reported that irrigation scheduling for castor at 0.8 PEF through drip after cessation of monsoon increased 36% castor seed yield with 25% saving of irrigation water over surface irrigation (Farmers practice).

Amin (2005) studied the effect of various row spacing’s and nitrogen levels on drilled rabi fennel (*foeniculum vulgare* mill). They reported that fennel crop irrigated at IW/CPE ratio of 0.8 recorded significantly higher seed yield as compared to 0.6 IW/CPE ratio but remained at par with 1.0 IW/CPE ratio.

Bhunia et al. (2005) studied the Effect of nitrogen and irrigation on water use, moisture extraction pattern, nutrient uptake and yield of fennel (*Foeniculum vulgare*). They conducted a field experiment during the winter season 2001-03 at Sriganganagar (Rajasthan) and reported that the plant height, primary, secondary branches/plant, number of umbels/plant, umbellate/umbel, seeds/umbel, test weight, seed and Stover yields were significantly higher with irrigation at 0.8 IW/CPE ratio over lower levels.

Swarajyalakshmi et al. (2005) reported that the highest green chili yield of 21.56 t/ha in drip irrigation scheduled at 0.8 ET. This increase was accounted to 34 per cent over conventional method of irrigation.

Nalayani et al. (2006) studied evapotranspiration based scheduling of irrigation through drip irrigation for cotton at Coimbatore reported. They observed that scheduling of irrigation through drip at 0.8 ETc was at par with 1.0 ETc with respect to seed cotton yield in upland cotton. The yield enhancement due to drip system during summer was 28.9, 44.5 and 61.5 % at 0.6, 0.8 and 1.0 ETc over conventional method of irrigation, respectively.

Lakpale et al. (2007) conducted a field experiment to study the effect of irrigation schedules in coriander, black cumin, fenugreek and chickpea crops grown after medium duration rice. The treatments comprise irrigation schedule at 0.6 and 0.8 IW/CPE. The results revealed that the irrigation schedule at 0.8 IW/CPE gave significantly higher growth characters like plant height, number of branches, shoot and root.

Jonghan and Piccinni (2009) conducted an experiment to investigate grain yield responses of corn (*zea mays*) under irrigation management based on crop evapotranspiration (ETc) as well as a possibility to monitor plant water deficiencies
using some of psychological and environmental factors. The field was treated with irrigation regimes of 100 %, 75 % and 50 % ET_{C}. Grain yield was increased as irrigation increased.

Mehta et al. (2010) studied the influence of irrigation and weed management practices on nodulation and yield of fenugreek (*Trigonella Foenum-Graecum* L). They found significantly increased length of pod, number of pods/plant, number of seeds/pod and test weight of seeds as well as seed, straw and biological yields of fenugreek with irrigation at 1.0 IW/CPE ratio over 0.6 and 0.8 IW/CPE ratios.

Rao *et al.* (2010) conducted a field experiment to find out the Effect of microirrigation on productivity and water use of cumin (*Cuminum cyminum*) at varying fertility levels at Pali-Marwar. They observed that irrigating cumin at 0.8 IW/CPE ratio recorded significantly highest umbels/plant, seeds/umbel, seed and stover yields and harvest index over lower IW/CPE ratio (0.4 and 0.6).

Tayel *et al.* (2010) reported that drip irrigated garlic under clay loam soil condition achieved maximum yield when irrigated at 75% level of ET_{C} and 120 kg of nitrogen per feddan and a minimum yield when irrigated at 50% level of ET_{C} and 60 kg of nitrogen per feddan.

Mahmoud (2011) study the effect of irrigation intervals, nitrogen sources and nitrogen levels on some characters of parsley (*petroselinum crispum* Mill) at king Abdulaziz University, hada alsham, Saudi Arabia, during 2007 and 2008 seasons. Results indicated that Application of 2 days as irrigation interval produced the highest mean values of plant height (32.0 cm), number of branches/ plant (7.14), number of leaflets/ plant (18.41), fresh weight of plants/ m^2 (2.852 kg) and fresh weight of 5 plants (53.74 g).

Mehta *et al.* (2011) conducted an experiment during 2003-06 at Ajmer (Rajasthan) to study the growth, profitability and productivity of fennel (*Foeniculium vulgare*) as influenced by irrigation interval (12, 15 and 18 days interval), nutrients levels (N and P each at 60/30, 90/40 and 120/50 kg ha^{-1}) and crop geometry (40 cm x 25 cm, 50 cm x 25 cm and 60 cm x 25 cm). Thus, irrigation at 15 days interval with 120 kg N and 50 kg P_{2}O_{5} ha^{-1} at 60 cm x 25 cm was optimum for realizing higher yield, profitability and productivity of fennel.

Doro (2012) studied the effect of irrigation interval on the yield of garlic (*Allium Sativum* L.) at Ajiwa Irrigation Site of Katsina State – Nigeria. He obtained results indicating that 4 – day irrigation interval had significant and positive effect on
yield parameter over other treatments. Maximum yield of 4,110.2 kg/ha was recorded from the 4 day irrigation interval while, 1,835.4 kg/ha was recorded from the 8 – day irrigation interval.

Godara et al. (2013) conducted experiment to study the effect of different levels of drip irrigation along with fertigation levels in fennel (Foeniculum vulgare Mill.). The maximum plant height (141.56 cm), number of branches per plant at 50 percent flowering (39.22), diameter of main umbel (19.01 cm), dry matter of plant (34.46), biological yield (110.78) and test weight (8.58) were recorded under the treatment of 100 per cent ETc. The number of umbels per plant (21.40), number of umbellate per umbel (11.13), number of seeds per umbellate (10.63), and seed yield (18.45 q ha\(^{-1}\)) were recorded maximum under the treatment of 80 per cent ETc level.

Meena et al. (2014) conducted a field experiment to find out the effect of irrigation levels and mulching on performance of fennel. Results indicated that application of six irrigations significantly increased the plant height, number of branches plant\(^{-1}\), total chlorophyll content, dry matter accumulation per metre row length, number of umbels plant\(^{-1}\), umbellate umbel\(^{-1}\), seeds umbellet\(^{-1}\) as well as seed, Stover and biological yield compared to four and five irrigations. However, it remained at par with seven irrigations.

Bhunia et al. (2015) a field experiment was conducted during kharif 2012 at Niche Area Excellence Farm, S. K. Rajasthan Agricultural University, Bikaner to study the effect of crop geometry and drip irrigation levels on pearl millet (Pennisetum glaucum). The study indicated that there was increase in yield attributes, seed, straw and biological yield with increase in irrigation levels from 40 to 80 per cent ETc and 60 and 80 per cent ETc gave at par yield but superior to surface irrigation.

Jat et al. (2015) carried out the field experiment at S. K. N. College of Agriculture, Jobner (Rajasthan) during rabbi season 2012-13 to select appropriate drip irrigation schedule for maximizing productivity and profitability of fennel. The results showed that the drip irrigation at an IW/CPE ratio 0.8 with paired row planting, being at par with 0.8 IW/CPE ratio in normal row planting and drip irrigation at 1.0 IW/CPE ratio in normal and paired row planting, recorded significantly higher plant height and dry matter accumulation/metre row length at 35, 70, 105 DAS and at harvest.

Prajapati et al. (2015) conducted a field experiments to study the response of fenugreek (Trigonella foenum-graecum L.) to irrigation scheduling based on IW/CPE ratio and method of sowing. A field experiment was conducted at Instructional Farm,
College of Agriculture, JAU, Junagadh (Gujarat) during rabi season of 2011-12. Significantly higher plant height, dry matter accumulation, number of branches per plant, pods per plant, pod length and number of seeds per pod, were recorded at IW/CPE ratio of 1.0 than rest of the treatments but it remained at par with IW/CPE ratio of 0.8.

Solanki et al. (2015) conducted a field experiment during the rabi seasons from 2009-10 to 2011-12 at micro irrigation scheme, instructional farm, college of agriculture, Junagadh Agricultural University, Junagadh (Gujarat). They obtained on the basis of three years pooled data, significantly highest chickpea seed and stover yields of 1699 and 2531 kg/ha, respectively were recorded when crop was irrigated at 0.8 PEF through drip (I4).

Verma et al. (2015) conducted a field experiment to study the water use, nitrogen (N) uptake and economics of coriander (Coriandrum sativum L.). Under organic enrichment, foliar feeding of N and fertigation. Drip irrigation at 80% ETc+ foliar spray of 25% N (15 kg/ha) + fertigation (45 kg/ha) gave the highest plant height, umbel/plant, seed/umbel and test weight compared to irrigation at 80% ETc and at 60% ETc (upto flowering stage) + 80% ETc (reproductive stage) with or without foliar spray.

The micro-irrigation systems with ability to provide small but frequent water application have been found superior in terms of water savings yield and irrigation production efficiency (Theodore 1980, Pruitt et al. 1984., Sivanappan et al. 1987, Srivastav et al. 1994 Hanson et al.1997, Intiyaz et al. 2000). Better crop growth and higher yield can be attained at optimum level of irrigation at proper time or frequency. It is therefore, important to develop a proper and effective irrigation schedule under prevailing climatic condition to obtain maximum benefit from the available limited water resources.

2.3 EFFECT OF IRRIGATION LEVELS AND FREQUENCIES ON CONSUMPTIVE USE AND WATER USE EFFICIENCY

Water use efficiency (WUE) is a measure of a crop’s capacity to convert water into plant biomass or grain. It includes the use of water stored in the soil and rainfall during the growing season. Water use efficiency relies on the ability of soil to capture and store water, the ability of crop to access water stored in the soil and rainfall during the season, the ability of crop to convert water into biomass, and the ability of crop to convert biomass into grain (harvest index). Water use efficiency can be used to
calculate the potential yield of a crop given the available moisture. Growers can use this information to assess the costs and benefits of different management decisions, in order to improve their profitability and manage risk. Several past studies reviews regarding consumptive use and water-use-efficiency are presented here below.

Patel et al. (1989) studied on the response of chickpea to irrigation and fertilizers. They reported that the water use efficiency was maximum with irrigation at IW/CPE ratio of 0.3 but yield and consumptive use of water was at 0.5 IW/CPE ratio in chickpea.

Patel (1998) evaluated three systems of irrigation viz. flood, sprinkler and drip. The experiment was conducted on summer groundnut at Junagadh Agricultural University, Junagadh. The results revealed that the superiority of the drip system of irrigation saving of 42% water over flood irrigation system.

Deshmukh and Lahatonde (1999) conducted a field experiment to study the water use of pre monsoon hybrid cotton as influence by water regimes (0.4, 0.6 and 0.8 ETc) under trickle irrigation in Akola, India. The highest water use efficiency (2.02 kg/ha-mm) was observed with irrigation at 0.4 ETc and decreased with an increase in water regimes (0.6 and 0.8 ETc).

Kumar et al. (2002) studied the influence of irrigation and fertilizer levels on growth, seed yield and water use efficiency by fennel (Foeniculum vulgare). They observed that the maximum water-use-efficiency was recorded, when two irrigations to fennel were applied at branching/flowering and seed filling stages. Further increase in number of irrigations from 2 to 3 decreased the water use efficiency.

Das and Roy (2003) studied on the response of different irrigation schedules on consumptive use, water use efficiency and crop coefficient value of mustard crop. They reported that consumptive use of water increased with increasing irrigation frequency and highest consumptive use obtained with IW: CPE ratio of 1.0 followed by three irrigations at vegetative, maximum flowering and siliqua development stages and two irrigations applied at vegetative and flower development stages in mustard.

Patel et al. (2004) studied on the feasibility of drip irrigation in castor (Ricinus communis L.) under sandy loam soil of North Gujarat at S.K. Nagar and reported that irrigation scheduling for castor at 0.8 PEF through drip after cessation of monsoon recorded 25% saving of irrigation water over surface irrigation (Farmers practice).

Amin (2005) conducted an experiment in loamy sand soil to observe the effect of irrigations (0.6, 0.8 and 1.0 IW/CPE ratios) under varying levels of nitrogen (60, 90
and 120 kg N/ha) and phosphorus (30, 45 and 60 kg/ha) on yield, consumptive use of water and water use efficiency of fennel crop. The consumptive use of water increased significantly up to 1.0 IW/CPE ratio. Water use efficiency and water expense efficiency was maximum under 0.8 IW/CPE ratios.

Bhunia et al. (2005) studied on the effect of nitrogen and irrigation on water use, moisture extraction pattern, nutrient uptake and yield of fennel (*Foeniculum vulgare*). They conducted a field experiment during the winter season 2001-03 at Sriganganagar (Rajasthan). They observed that irrigating fennel at IW/CPE ratio of 0.8 recorded significantly higher consumptive use and water use efficiency over lower IW/CPE ratio.

Dutta and Chatterjee (2006) studied on the Effect of irrigation regimes on moisture extraction pattern, evapotranspiration and yield of fenugreek (*Trigonella foenum graecum* L.). They observed that consumptive use and water use efficiency of fenugreek was highest when irrigations were scheduled at IW/CPE ratio of 1.0 and reduced with decreasing the number of irrigations and it was highest in no irrigation treatment.

Bandyopadhyay et al. (2009) studied on the efficient utilization of limited available water in wheat through proper irrigation scheduling and integrated nutrient management under different cropping systems in a vertisol at Bhopal. They reported that application of irrigation to wheat at 0.8 IW/CPE resulted in significantly higher WUE of wheat (10.3 kg/ha-mm) than irrigation to wheat at 0.6 IW/CPE (9.1 kg/ha-mm).

Godara et al. (2013) conducted experiment to study the effect of different levels of drip irrigation along with fertigation levels in fennel (*Foeniculum vulgare* Mill.). The maximum WUE (0.542 q ha\(^{-1}\) cm\(^{-1}\)) were recorded maximum under the treatment of 80 per cent ET\(_c\) level.

Chouhan et al. (2015) studied the effect of drip irrigation on water productivity and yield attributes of wheat crop. Results revealed that water saving of about 28.42% higher in case of drip irrigation compared with the border irrigation system. Data also revealed that water productivity of drip irrigated wheat was 24.24% more than the border irrigated wheat.

Mehanna et al. (2015) conducted a field experiments to study the effect of phosphorus (P) fertilization (0, 12 and 24 kg·ha\(^{-2}\) P) on the seed yield, and volatile oil of Egyptian cultivar of coriander under water stress conditions. Coriander plants have
high water use efficiency (WUE) at 50% ET crop, and 24 kg·ha\(^{-2}\) P whilst irrigation at 100% ET crop without any phosphorus application gave the lowest WUE.

The studies discussed in this section indicated that, the water use efficiency and water productivity can be increased by using drip irrigation as compared to surface irrigation in the intensive crops by getting more crops per drop of water. By using this saved water, an additional area can be brought under irrigation and subsequently more production can be attained.

### 2.4 ECONOMICS OF DRIP IRRIGATION SYSTEM

The initial investment of micro-irrigation in general and drip irrigation system is in particular is higher as compared to surface irrigation. Economic considerations usually limit the use of drip irrigation system. Cost of drip irrigation system can be reduced by increasing the lateral and dripper spacing using high discharge drippers, as laterals and drippers contribute approximately 80% of total system cost. Some past studies related to economic present here below.

Tank (1988) studied the response of mung to irrigation scheduling based on cumulative evaporation of 0.6 IW/CPE, 0.8 IW/CPE and 1.0 IW/CPE. He found that the Maximum net profit of Rs 3896 ha\(^{-1}\) was also recorded with application of irrigation at IW/CPE ratio 1.0.

Patel (1998) evaluated three systems of irrigation viz. flood, sprinkler and drip. The experiment was conducted on summer groundnut at Junagadh Agricultural University, Junagadh. The results revealed that the superiority of the drip system of irrigation by recording higher mean net profit 1538 Rs/ha over flood irrigation system.

Patel et al. (2000) studied on the Response of fennel (\textit{Foeniculum vulgare}) to irrigation, nitrogen and phosphorus at Junagadh (Gujarat). They reported that the maximum net returns was realized in fennel by scheduling irrigation at an IW/CPE of 1.0.

Agarwal \textit{et al.} (2004) reported that the economic yield of 52.5 q/ha highest benefit cost ratio of 3.21 were recorded in pomegranate under 80 per cent of irrigation and fertigation with water soluble fertilizers.

Bhunia \textit{et al.} (2005) studied on the effect of nitrogen and irrigation on water use, moisture extraction pattern, nutrient uptake and yield of fennel (\textit{Foeniculum vulgare}). They reported that increasing irrigation levels increased gross return and benefit: cost ratio of fennel and all the values were the highest with IW/CPE ratio 0.8.
Datta et al. (2006) effect of Irrigation Level on Growth, Yield and Evapotranspiration in Coriander. They reported that the gross returns, net returns and benefit: cost ratio were increased with the level of irrigation increased from IW/CPE ratio 0.6 to 1.0.

Dutta and Chatarjee (2006) studied on the effect of irrigation regimes on moisture extraction pattern, evapotranspiration and yield of fenugreek (*Trigonella foenum graecum* L.). They reported that significantly higher net returns were recorded with 1.0 IW/CPE ratio but B: C ratio was higher with 0.8 IW/CPE ratio in fenugreek.

Lakpale et al. (2007) conducted a field experiment to study the effect of irrigation schedules in coriander, black cumin, fenugreek and chickpea crops grown after medium duration rice. The results revealed that the irrigation schedule at 0.8 IW/CPE gave significantly higher net return and B: C ratio.

Gurusamy et al. (2010) studied on the influence of irrigation regime and fertigation levels on sugarcane under subsurface drip fertigation system and resulted that, Higher net return was recorded in 125 percent ETc with 75 per cent RDF as water soluble fertilizers in plant crop however in ratoon crop, higher net return was observed in 125 percent ETc with 100 per cent RDF as WSF. Higher B:C ratio was associated with drip irrigation at 125 percent ETc in combination with 100 per cent RDF as commercial fertilizers followed by drip fertigation of 75 percent RDF as commercial fertilizers at 125 per cent ETc in both crops.

Rao et al. (2010) studied on the effect of micro irrigation on productivity and water use of cumin (*Cuminum cyminum*) at varying fertility levels at Pali, Marwar and they reported that the application of irrigation to cumin at 0.8 IW/CPE ratio recorded maximum net returns and benefit: cost ratio in comparison to 0.6 and 0.4 IW/CPE ratios.

Sharma et al. (2012) conducted an experiment on effect of drip irrigation and nitrogen fertigation on water use efficiency (WUE) and cost economics of guava. The cost of cultivation includes expenses incurred in field preparation, cost of seedlings, fertilizer, weeding, crop protection measures and irrigation water and harvesting with labor charges. The income from both the surface and drip irrigation was evaluated and then the benefit-cost ratio was calculated. The B: C ratio was found maximum (2.84) in drip irrigated treatment (along with nitrogen fertigation) than that of surface irrigated treatment.
Shinde et al. (2012) found that drippers of lower discharge rate of 1 and 2 lph clogged 15 to 30 days earlier as compared to drippers of higher discharge rate of 4 lph for irrigation with saline water. Economic considerations usually limit the use of drip irrigation system. Cost of drip irrigation system can be reduced by increasing the lateral and dripper spacing using high discharge drippers, as laterals and drippers contribute approximately 80% of total system cost.

Pandya and Rank (2015) conducted an experiment to find the techno-economic feasibility of high discharge drip irrigation and mulch for summer sesame. They found that the High discharge drip irrigation having dripper discharge 14 lph with 2.1 m lateral spacing resulted in Rs. 17085/- more net return per hectare than traditional method of border irrigation.

The past research works described above shows that the high economics values or B: C ratio found in more drip discharge and about 80-100 % irrigation water applied. In fact, the cost of piping (main and sub-main) will be increased but that will be less than the cost saving in lateral and emitters. It also increases the inconvenience in operation because of more number of sub-mains and lateral take off.