CHAPTER-II
REVIEW OF LITERATURE

This chapter presents the up to date review on drip irrigation system, irrigation scheduling under drip irrigation, fertigation, the optimum water and fertilizer requirement under drip irrigation and economics of drip/fertigation.

1. Agronomical practices of wheat crop.
2. Irrigation scheduling and water use efficiency under drip irrigation.
3. Effect of fertigation and nitrogen use efficiency under drip irrigation.
4. Economy under drip fertigation.

2.1 AGRONOMICAL PRACTICES OF WHEAT CROP

Lomas (1974) studied the optimum temperature ranges for germination of wheat crop. The results indicated that 20 to 25 °C atmospheric temperature is optimum for germination of wheat seeds.

Pandey et al. (1991) carried out a field experiment on response of wheat varieties to sowing date and seed rate. Results revealed that the sowing of wheat during second fortnight of November gives best results with seed rate of 100 kg per hectare.

Deshmukh et al. (1992) conducted a field experiment on clay soils to find out the initial stages of irrigation to wheat (Triticum aestivum L.). They observed that most critical stages were crown root initiation (CRI) and flowering (F) stages in respect of moisture stress. Significant reduction in productivity was noticed due to delaying irrigation at the CRI (33%) and flowering (25%) stages.

FAO Water (2013) recommended that for Indian conditions, in addition to pre-irrigation, one irrigation during early vegetative period (1a); two irrigations - one during early vegetative period (1a) and one just prior to head emergence through flowering period (2); three irrigations - during early vegetative period (1a), just prior to head development through flowering period (2) and early yield formation period (early 3); four irrigations - during early vegetative (1a), late vegetative (1c), flowering (2) and early yield formation (early 3) periods.

Suleiman et al. (2014) conducted a field experiments to assess the performance of different wheat cultivars under different sowing dates. The experiment was laid out in split plot design with four replicates and comprised of four dates of sowing, namely
1st November, 15th November, 1st December and 15th December. The sowing dates shown significant effect on yield and yield components that decreased with delay in sowing date and the highest values were obtained when cultivars sown on 1st November and 15th November. This indicated that late sowing shortened the development phases of wheat and adversely affected the grain development and thus the grain yield.

2.2 IRRIGATION SCHEDULING AND WATER USE EFFICIENCY UNDER DRIP IRRIGATION

Patil and Bathkal (1975) conducted a field experiment to find out response of irrigation on wheat yield. They selected four critical stages (tillering, booting, flowering and grain formation stage) and subjected them with four IW/CPE ratios (0.4, 0.6, 0.8, and 1.0) and found that irrigation at 0.6 and 0.8 IW/CPE ratios produced significantly more yield than irrigation at 0.4. Yields under treatment of 0.6, 0.8, and 1.0 water use factors were at par.

Bhaliya et al. (1983) revealed that grain yield of wheat obtained at IW: CPE ratio of 1.0 (32.2 q ha⁻¹) and 1.2 (33.9 q ha⁻¹) were statistically at par but significantly higher over lower ratios of 0.6 and 0.8 in clayey soil of Junagadh.

Parihar and Tripathi (1989) showed that wheat sown during the second fortnight of November with irrigation at 0.8 IW/CPE ratio gave higher grain yield. (Grain yields were higher when irrigation was scheduled at 1.0 IW/CPE ratio with 150 kg N ha⁻¹ produced excessive vegetative growth without any benefit to grain yield). The reduction in grain yield due to late sowing could be compensated to some extent by higher level of nitrogen application.

Mahdi et al. (1997) carried out a field experiment on effective irrigation scheduling to manage water for spring wheat (Triticum aestivum L.) in south western Colorado under variable water applications. The study was conducted to determine the effect of varying rates of water replacement (0 ET, 0.33 ET, 0.67 ET, 1.0 ET and 1.33 ET) on spring wheat. Both grain yield and dry matter increased significantly with the increase in water application rates, up to 1.0 ET application rate.

Parihar and Tiwari (2003) conducted a field experiment on effect of irrigation and nitrogen level on yield, nutrient uptake and water use of late sown wheat. Irrigation applied at 1.2 IW: CPE ratio gave significantly higher grain yield than 0.6 and 0.9 ratios. Application of 120 kg N/ha gave higher yield and yield attributes than 80 kg N/ha. Total
nutrient uptake was positively influenced by irrigation and N levels. Total water use was lowest (29.60 cm), while water use efficiency was highest with 0.6 IW: CPE ratio. The WUE decreased with increase in frequency of irrigation.

Clinton et al. (2005) concluded on wheat that there was an increase in water productivity with the reduction in ETc replaced from 100% to 60%. The highest water productivity was recorded in 60% ETc which was at par with 80% ETc. Drip irrigation experiment on wheat with 4 Lph discharge capacity drippers on one line (S1), two lines (S3) and 8 Lph drippers on one line (S2), two lines (S4) in Cairo, Egypt and revealed that the highest water productivity (WP = 1.20 kg m⁻³) was obtained from the amount rate added by S3= 4 Lph drippers on two lines.

Shock et al. (2005) conducted an experiment at Malheur experiment station, Ontario, Oregon on wheat. They recorded the highest grain yield of wheat with drip irrigation scheduled at 100% ETc which was at par with 80% ETc and 60% ETc.

Hong et al. (2006) conducted a field experiment to study effect of irrigation on water balance, yield and WUE of winter wheat in the North China Plain. Results showed that with increasing ET, the irrigation requirements of winter wheat increases. Excessive amount of irrigation can decrease grain yield, WUE, and IWUE. These results indicate that excessive irrigation might not produce greater yield or optimal economic benefit, thus suitable irrigation schedules must be established.

Abd El-Rahman (2009) conducted a field experiment during 2004-2005 season in El-maghara research station, Egypt to study water use efficiency of three wheat variety (i.e. Sakha 8, Giza 7 and Giza 69) as effected by four irrigation applied rates by means of adding 4 lph - 8 lph on one line and on two lines. Statistically splits-splits plot design was used. The results revealed that grain and straw yields of wheat were increased by irrigation with drip irrigation on the two lines of laterals with 4 lph application rate. Seasonal amount of water applied for wheat was about 2087 m³ per fed, as calculated by Penman-Montieth meteorological equation. More ever, the highest grain yields were 2145, 2120 and 2085 kg per fed for Giza 7, Sakha 8 and Giza 69 respectively with the two lines of 4 lph application rate. Water use efficiency was also increased using 4 lph on two lines.

Kharrou et al. (2011) conducted the experiment during 2004-2005 season in Haouz irrigated area in Morocco with objectives (1) to evaluate the effect of the surface
irrigation scheduling method (existing rule) adopted by the irrigation agency on winter wheat production compared to a full irrigation methods and (II) to evaluate the effects of the drip irrigation versus surface irrigation impacts on water saving and yield of winter wheat. The methodology was based on the FAO-56 dual approach for the surface irrigation scheduling and simple FAO-56 approach was used for drip irrigation scheduling. For surface irrigation, the existing rule approach resulted in yield and WUE reductions of 22% and 15% respectively, compared with the optimized irrigation scheduling proposed by the FAO-56 for full irrigation treatment. It was demonstrated that drip irrigation applied to wheat was more efficient with 20% of water saving in comparison with surface irrigation (full irrigation treatment). Drip irrigation also gives higher wheat yield compared to surface irrigation (+28% and +52% for full irrigation and existing rule treatment respectively). The same improvement was observed for water use efficiency (+24% and +59% respectively).

Rathod and Trivedi (2011) conducted a field experiments to assess the crop performance and economics of drip system for groundnut (GG-2) during summer season (Feb. to May) for consecutive three years. Total Six treatments having different water application levels based on IW/CPE like 0.6, 0.7, 0.8, 0.9, 1.0 and 1.2 were selected. The lowest pod yield of 1917 kg/ha and highest pod yield of 2927 kg/ha could be obtained at the IW/CPE of 0.6 and 0.9 respectively requiring 502 and 757 ha.mm/ha of irrigation water respectively. The treatment of IW/CPE of 0.8 was found statistically better one having the highest water use efficiency of 4.148 kg/ha/mm. The IW/CPE of 0.8 was found most economical water application level. Also, in case of excess water supply (IW/CPE=1.2) and deficit water conditions (IW/CPE=0.6), the drip was not that profitable.

Ibrahim et al. (2012) conducted two field experiments in Egypt to study the effect of fertigation regimes on wheat grown in sandy soil was tested in Eight fertigation treatments, in addition to farmer irrigation were tested. The results showed that the highest yield and the highest water use efficiency (WUE) was obtained under irrigation application using 1.2 and 0.8 of ETc, respectively, with fertigation application in 80% of application time in both growing seasons.

Wang et al. (2013) selected different wheat genotypes and setting up different drip irrigation amount, the data about water consumption characteristics and yield
attributes of spring wheat in southern Xinjiang arid area were obtained and analyzed, the results showed that: (1) Water consumption amount in drip irrigation observed that spring wheat mainly focused at the middle-late growth stage and water consumption strength reached the maximum value of 5.18 to 7.52 mm/day during booting and flowering period; (2) The amount of drip irrigation mainly affected grains per spike and grain weight. WUE was the highest, reaching 13.75 to 15.21 kg/ha-mm. (3) with the maximum values of yield of 6388.7 kg/ha and WUE of 15.21 kg/ha-mm in appropriate water treatment.

Bhunia et al. (2014) conducted a field experiment to study the effect of crop geometry, drip irrigation and bio-regulator on growth, water use efficiency and yield of wheat (Triticum aestivum L.). The experiment was conducted in Randomized Block Design with three irrigation schedules viz.,60, 80 and 100 per cent ETc, two crop geometry levels viz.,22 cm paired row spacing-4 rows (120 cm lateral spacing) and 22 cm normal spacing sowing (60 cm lateral spacing). The study indicated that there was increase in dry matter accumulation, plant height, grain yield and biological yield with increase in irrigation level from 60 per cent ETc to 100 per cent ETc. The study also indicated that the interaction effect of irrigation and geometry gave maximum grain yield, biological yield and WUE at 100 per cent ETc + 60 cm drip line spacing, maximum harvest index at 60 per cent ETc + 60 cm drip line spacing whereas maximum WUE at 80 per cent ETc + 60 cm drip line spacing.

Chen et al. (2015) conducted a field experiment to determine the effects of lateral spacing and irrigation amount on wheat yield and water use efficiency. The irrigation treatments consisted of three lateral spacing (0.30 m, 0.60 m, and 0.90 m) and four water amounts (3000 m³/ha, 4500 m³/ha, 6000 m³/ha and 7500 m³/ha). The results showed that plant growth and grain yield both decreased as lateral spacing increased. They concluded that 0.60 m lateral spacing and 6000 m³/ha irrigation water resulted in the most water savings, the highest yield, and the greatest economic benefit.

Chouhan et al. (2015) conducted a field experiment to study 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.
Ibrahim et al. (2015) conducted a field experiment to determine the best irrigation scheduling and the proper period for injecting fertilizers through drip irrigation water in a sandy soil to optimize maize yield and water productivity. Four irrigation levels (0.6, 0.8, 1.0 and 1.2) of the crop evapotranspiration and two fertigation periods (applying the recommended fertilizer dose in 60 and 80% of the irrigation time) were applied in a split-plot design, the results showed that increasing the irrigation water amount and the fertilizer application period increased vegetative growth and yield. The highest grain yield and the lowest one were obtained under the treatment at 1.2 and of 0.6 crop evapotranspiration, respectively. The treatment at 0.8 crop evapotranspiration with fertilizer application in 80% of the irrigation time gave the highest water productivity (1.631 kg m\(^{-3}\)) and saved 27% of the irrigation water compared to the control treatment.

Deshmukh et al. (2016) conducted a field experiment to study the effect of moisture regime and levels of fertilizer on response of tomato (*Lycopersicon esculentum* L.) under drip irrigation. The experiment was laid out during October 2012 to March 2013 under drip irrigated condition. I1-Drip irrigation with IW/ETc (Irrigation water/Crop evapotranspiration) ratio of 0.60. I2-Drip irrigation with IW/ETc (Irrigation water/Crop evapotranspiration) ratio of 0.80. I3-Drip irrigation with IW/ETc (Irrigation water/Crop evapotranspiration) ratio of 1.00. The yield recorded that was 100.40 t/ha, 107.57 t/ha and 116.98 t/ha with treatment I1, I2 and I3 respectively, the yield recorded in control was 78.84 t/ha.

Suryavanshi and Buttar (2016) conducted a field study during rabi seasons of 2013-14 and 2014-15 to evaluate the impact of two micro irrigation methods viz. drip irrigation and sprinkler irrigation and four irrigation schedules IW/CPE ratio 0.6, 0.8, 1 and 1.2 on yield and economics of wheat cultivation. The effect of drip irrigation with 0.6 IW/CPE appeared to be most favorable compared to all other treatments and recommended surface irrigation in terms of both yield and economics of wheat. The results also suggest that drip irrigation was the optimum and sustainable strategy to achieve higher yield and income and also to improve water saving on sandy clay soil.

Taha and Ouda (2016) conducted two field experiments for wheat and maize. The irrigation treatments applied to either wheat or maize was three groups: farmer irrigation, which represents a 'typical' wheat or maize irrigation regime (high applied irrigation amount and low fertilizer use efficiency). The second group was required
irrigation, which consist of application of two irrigations water amount of 1.20 ETc with fertilizer application 80% or 60% of irrigation time, respectively. The third group was deficit irrigation amounts, which consisted of application of 1.00, 0.80 and 0.60 ETc with fertilizer application in 80% or 60% of irrigation time, respectively. The results indicated that wheat productivity was increased by 44% and 27% when 28 % and 25% of the applied water was saved, compared to farmer irrigation. Furthermore, deficit irrigation for wheat reduced yield by 2% and saved 11% of the applied water, compared to required irrigation. Farmer irrigation reduced water productivity compared to required irrigation and deficit irrigation for both wheat and maize. Thus, in case of water scarcity occurrence in Egypt, deficit irrigation can safely practice for wheat in sandy soil, where yield losses were only 2%.

Bhowmik et al. (2018) conducted a field experiment during Rabi season of 2016-17 in G.B. Pant University of Agriculture and Technology, Pantnagar to study the effect of drip irrigation on grain yield and their attributing characters, water use efficiency and monetary benefits of wheat crop. The treatments consisted of drip irrigation with 50, 75 and 100% CPE on each 2 days and 4 days interval period. Apart from drip irrigation treatments, two conventional irrigation methods were also included i.e. as absolute control and farmers’ practice. These eight treatments were designed in Randomized Block Design with four replications. Results revealed that water use efficiency and water savings in all drip irrigated treatments recorded significantly higher than the farmers’ method of irrigation. Wheat with drip irrigation at 100% CPE on two days’ interval resulted in higher grain yield (5825 kg ha\(^{-1}\)) with less water requirement (207.90 mm) compared to conventionally irrigated wheat with less grain yield (4485 kg ha\(^{-1}\)) and high water requirement (300 mm). So, it is clear that drip irrigation treatments based on CPE performed better than conventionally irrigated wheat. On the basis of above results, it can be concluded that Drip irrigation at 75 or 100% CPE on two days’ interval can be a better alternative over conventionally irrigated wheat.

2.3 EFFECT OF FERTIGATION AND NITROGEN USE EFFICIENCY UNDER DRIP IRRIGATION.

Pandey et al. (2001) conducted a field experiment on tropical wheat response to irrigation and nitrogen in a Sahelian environment. A two-year field study was conducted to determine wheat response to different seasonal irrigation regimes ranging
from 300 to 690 mm applied water and five nitrogen levels of 0, 40, 80, 120 and 160 kg N ha\(^{-1}\). Grain yield and all primary yield components increased linearly in response to irrigation in both seasons. Spikes per m\(^2\) were reduced with water deficit. Water deficient over both years reduced kernel weight by 12 and 19.4 % at the lowest and highest N rates.

Madan and Munjal (2009) conducted an experiment to study the effect of seed rate and nitrogen application (in split doses) on protein, protein fractions and yield of wheat. The results showed that splitting of recommended dose of nitrogen recorded higher total protein content (12.68%) as compared to control (10.23%). Similarly, more true protein content was observed with split dose of N application (10.8%) as compared to control (7.8%). The grain yield increased with increase in split doses of nitrogen and seed rate. Grain yield was significantly higher at 125 kg/ha and 112.5 kg/ha as compared to 100 kg/ha seed rate. Splitting of recommended dose of nitrogen increased the grain yield by 4.1%.

Kharub et al. (2010) conducted a field experiments during 2004-07 to study the effect of nitrogen scheduling on growth, yield and quality on bread wheat on sandy clay loam soil having low to medium soil fertility. A total of 9 nitrogen scheduling treatments including absolute control, full basal, 2, 3 and 4 splits at different stages were undertaken with recommended dose of nitrogen. Nitrogen splitting at 2 or 3 or 4 times resulted in almost similar plant height, tillers/m\(^2\) and 1000 grain weight but greater than the single dose application either at basal or tillering. The grain and straw yield were higher under 3 splits of nitrogen scheduling either 1/3 basal+1/3 at tillering+1/3 at floral formation or 1/4 basal+1/2 at tillering+1/4 at floral formation and 2 splits 1/3 basal+2/3 at first node compared to the other treatments. Full N as basal or full at tillering significantly reduced grain yield as compared to other treatments. It was also observed that three and four splits of nitrogen were significantly better in total protein yield as compared to two splits or single N application.

Rossella et al. (2010) conducted an experiment on durum wheat and barley, under different water regimes and nitrogen levels. Wheat and barley responses was assessed under three water supply regimes (i.e. full irrigation, 50% of full irrigation and rainfed condition) coupled with two N fertilizer levels (high N:120 kg ha\(^{-1}\) and low N:not fertilized). It was observed that the response of both crops to N fertilization in
terms of N uptake and grain N concentration was higher in the year characterized by greater water availability during the most sensitive stages to drought stress.

Abedi et al. (2011) carried out an experiment to study the effect of nitrogen rate application (0, 120, 240 and 360 kg Nitrogen ha\(^{-1}\)) and nitrogen timing on grain yield, yield components, grain quality and protein banding pattern in different growth stages of wheat (Shiraz cultivar) which was grown at research station of the School of Agriculture, Shiraz University at Bajgah in the 2008-2009. Results indicate that the highest value for grain yield was obtained at 240 kg N ha\(^{-1}\) when it was applied through vegetative growth stages (8230 kg ha\(^{-1}\)). Yield components were significantly increased with enhancing the level of nitrogen with no significant difference between 240 and 360 kg N ha\(^{-1}\).

Ali et al. (2011) conducted a field experiment to study the effects of different levels of nitrogen on growth and yield of wheat crop. The wheat variety, Sehar-2006 was tested at four different nitrogen rates i.e. 0, 80, 130 and 180 kg ha\(^{-1}\). The results showed that number of tillers per unit\(^{-1}\), plant height, spike's length, number of grain spike\(^{-1}\), 1000-grain weight and grain yield were significantly increased by increasing the nitrogen levels over control. Among nitrogen levels, highest grain yield (3.848 tons ha\(^{-1}\)) was obtained by an application of 180 kg N ha\(^{-1}\).

Rahman et al. (2011) conducted a field experiment at the central research farm of Bangladesh Agricultural Research Institute, Gazipur for two consecutive years to verify the yield response of wheat variety Prodip to different doses and split applications of N fertilizer to determine appropriate N dose and application method for increasing NUE and grain yield of wheat. The treatments comprised 12 combinations of three doses of nitrogen (80, 100, and 120 kg ha\(^{-1}\)) from urea, which were assigned in the main plots and four methods of N splitting viz. application of all N as basal; 2/3\(^{rd}\) basal plus 1/3\(^{rd}\) as top dress at crown root initiation (CR1) stage; 1/2 basal plus 1/2 as top dress at CR1 stage; and 1/3\(^{rd}\) basal with 1/3rd as top dress at CR1 plus 1/3\(^{rd}\) as top dress at 1\(^{st}\) node stage which were tested in the sub plots. Higher yield was achieved from N rate of 120 kg ha\(^{-1}\) applied as three equal splits of one third as basal during final land preparation, one-third as top dressing during CR1 and the rest one-third top dressing at first node stage. Whereas plant N uptake was significantly influenced by N rate and N split and also due to the interaction of N rate and N splitting. Split
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applications of sub-optimal dose of N (80 kg ha\(^{-1}\)) resulted in negative gain in apparent NUE.

Shirazi et al. (2011) conducted a field experiment to find out the response on yield and yield contributing parameters of maize (cv. Bornali) to water stress and nitrogenous fertilizer. The experiment included two factors such as five irrigation regimes and four nitrogen levels. Texturally, the soil was silty loam. Yield and yield contributing characters were significantly affected due to the application of irrigation and nitrogen. The highest grain yield of 6.77 t/ha was obtained with IW/CPE ratio of 0.5 and 5.61 t/ha by the application of 70 kg N/ha. Interaction between IW/CPE ratio of 0.5 and 70 kg N/ha were the best combination for yield and yield contributing characters of maize.

Abdelraouf et al. (2013) conducted two field experiments at the Agricultural Production and Research Station, National Research Centre (NRC), El Nubaria Province, Egypt, during the two successive winter seasons 2010-11 and 2011-12 to investigate the effects of fertigation levels and irrigation requirements (IR) on growth, yield and water use efficiency in wheat (Sakha 93 cv). The results showed that decreasing of fertigation levels from 100% to 50% NPK of the recommended fertilizer doses significantly decreased most studied growth characters, yield and yield attributes, protein and carbohydrate contents while, water use efficiency increased. Decreasing the IR from 100% to 50% significantly decreased most of growth characters, yield and yield attributes, protein while, water use efficiency significantly increased. The treatment 100% NPK of the recommended fertilizer + 100% IR records the highest values of the studied growth characters, spike length, seed index and biological yield/faddan (one faddan=0.42 ha), while, 75% NPK recommended fertilizers + 100% IR surpassed in number of spikelets/spike, number of spikes /m, grain and biological yield/ faddan.

Pradhan et al. (2013) conducted a field experiment during 2009-11 on a sandy loam soil of IARI, New Delhi on wheat with four levels of irrigation (rainfed, irrigations to replenish 30, 60 and 100% moisture deficit from field capacity) as main plot factors and four levels of nitrogen (0, 30, 60 and 120 kg N/ha) as subplot factors in a split plot design. The grain yield showed increasing trend with increase in irrigation and nitrogen levels. There was significant positive interaction between irrigation and nitrogen levels with respect to grain yield, water productivity and nitrogen use efficiency of wheat.
This study revealed that wheat may be grown with irrigation to replenish 60% SMD to field capacity and at 120 kg N/ha to achieve higher water productivity and nitrogen use efficiency without any significant reduction in crop yield and thus resulting in saving of irrigation water in sandy loam soils of semiarid region of North India.

Sharma et al. (2013) carried out a field experiment during 2009-10 to 2011-12 to assess four irrigation schedules (surface irrigation at IW/CPE 1.0, drip irrigation at 60%, 80% and 100% of crop evapotranspiration) and three nitrogen fertigation levels (80%, 100% and 120% of recommended dose of N) on the yield and water productivity of guava (cv. Psidium guajava L). The results showed that maximum fruit yield of 16.9 t/ha was registered at 100% of recommended dose of N. The interaction between irrigation schedules and N fertigation levels revealed that maximum fruit yield of 21.6 t/ha and water productivity of 17.8 kg/ha-mm was demonstrated under drip irrigation at 100% ETc with 120% of recommended dose of N.

Malve et al. (2014) conducted a field experiment at Jain Hi-Tech. Agri. Institute, Jain Irrigation Systems Ltd., Jalgaon, Maharashtra during 2012-13 to study the feasibility of drip irrigation and N-fertigation scheduling on growth and yield of winter wheat (Triticum aestivum L.) in sandy clay loam soil of western scarcity zone of Maharashtra. The results revealed that as the consumption of water increased, growth traits (plant height, leaf area index, number of tillers and dry matter production) and grain yield were increased significantly at each higher levels of drip irrigation up to 1.0 Epan. Further increased in irrigations level did not registered significant result. Similarly, each higher level of nitrogen significantly improved the growth traits and grain yield up to 120 kg N ha\(^{-1}\). However, application of higher N level of 160 kg N ha\(^{-1}\) did not prove to be advantageous over N\(_{120}\).

Shirazi et al. (2014) conducted a field experiment to evaluate the effect of irrigation regimes and nitrogen levels on the growth and yield of wheat (Triticum aestivum L.). The experiment includes two factors such as four irrigation regimes and four nitrogen levels. Three farmer’s fields were selected for experimentation as replication. Yield and yield contributing factors were significantly affected by irrigation regimes and different doses of nitrogen. Maximum grain yield of 2.27 t ha\(^{-1}\) by the application of 200 mm irrigation treatment. Interaction between 200 mm irrigation and 120 kg N ha\(^{-1}\) was the best combination treatment.
Hasan (2015) conducted an experiment to determine the effect of nitrogen and sulphur on growth and yield of sesame. The experiment consisted of two factors having 4 levels each of nitrogen (0, 75, 125, 175 kg N/ha) and sulphur (0, 50, 100 and 150 kg S/ha) laid out in Split Plot design with three replications. Plant height, number of leaves, capsule number, capsule length, seed per capsule, 1000 seed weight, seed yield and harvest index were varied significantly with increasing N level up to 75 kg N/ha (N1). The seed yield and harvest index were 1.38 t/ha and 29.43% respectively when applied 75 kg N/ha. But the highest Stover yield (3.81 t/ha) was recorded with 175 kg N/ha.

2.4 ECONOMICS OF DRIP IRRIGATION SYSTEM

Patel (1998) evaluated three systems of irrigation viz. flood, sprinkler and drip. The experiment was conducted on summer groundnut at JAU, Junagadh. The results revealed the superiority of the drip system of irrigation by recording higher mean yield of 2155 kg per ha and net profit 1538 Rs/ha over flood irrigation system.

Gurusamy et al. (2010) studied on the influence of irrigation regime and fertigation levels on sugarcane under subsurface drip fertigation system. Result indicated 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.

Sharda et al. (2012) conducted an experiment for maximizing production and profitability under drip irrigated and fertigated potato (Solanum tuberosum L.) in Punjab, India in 2009-10 and 2010-2011. The experiment comprised of three drip irrigation levels (1.0, 0.8 and 0.6 times potential evapotranspiration (PET)) in main plots and three levels of fertigation (100%, 80% and 60% of the recommended dose of N, P2O5 and K2O) in sub-plots of split plot design with three replications. The results indicate that the highest net returns of Rs. 156035/ha and Rs. 142385/ha during 2009-10 and 2010-11, respectively was registered under treatment I2F2 (I2 is 0.8 times PET and F2 is 80% of the recommended dose of fertilizer). Higher benefit cost ratio in the case of drip irrigation system as compared to conventional irrigation method suggests better returns from the drip irrigation system.
Pramanik et al. (2014) has assessed the economic viability of drip-fertigation system techniques in banana cultivation in West Bengal. The study was carried out in augmented factorial complete block design during 2008-10. The main factor was irrigation at 3 levels (I1= 50% CPE, I2= 60% CPE and I3= 70% CPE) and sub-factor was fertilizer at 3 levels (F1=50% RDF, F2=60% RDF and F3=80% RDF). The drip fertigation has been found economically-viable because of higher gross returns, net returns and return per rupee investment as compared to conventional method of irrigation. The high initial investment cost for the system is one of the major constraints, but considering the benefits in terms of water-saving, increased crop productivity and higher returns, the study has suggested its wider dissemination.

Kumbhar et al. (2015) conducted a field experiment to study the influence of irrigation scheduling (IW: CPE ratios) and sulphur on yield and quality of rabi pigeonpea (Cajanus cajan L.) Irrigation scheduling at 0.8 IW/CPE ratios (I3) resulted in significantly the highest grain yield (1677 kg ha\(^{-1}\)), protein content (20.85 %) and significantly higher Stover yield (4858 kg ha\(^{-1}\)) and gave highest net monetary returns of Rs.37591 ha\(^{-1}\) with maximum B:C ratio of 2.34.

Sharma and Kaushal (2015) conducted a field experiment to study the economic viability of Okra crop grown under different drip fertigation levels and different drip irrigation. The Nine drip fertigation treatments consisted of T1- 60% fertilizer Nitrogen (N) with irrigation applied at 0.60 IW/CPE (irrigation water/cumulative pan evaporation) ratio, T2- 60% fertilizer (N) with 0.80 IW/CPE ratio, T3- 60% N with 1.00 IW/CPE ratio, T4- 80% N with 0.60 IW/CPE ratio, T5- 80% N with 0.80 IW/CPE ratio, T6- 80% N with 1.00 IW/CPE ratio, T7- 100% N with 0.60 IW/CPE ratio, T8- 100% N with 0.80 IW/CPE ratio and T9- 100% N with 1.00 IW/CPE ratio. Economic viability of drip fertigation was evaluated by computing Benefit-Cost ratio (B/C ratio) for each of drip fertigation treatment obtained by dividing gross returns by total seasonal cost. Economic analysis was done as per the cost involved in drip irrigation system components and requirement of fertilizer for one-hectare area. The seasonal cost of growing okra under drip fertigation was calculated by considering depreciation, life of components, interest, fertilizers, insecticide, labors and cost of cultivation of growing Okra. Maximum B/C ratio was obtained in T5 treatment (2.25), (2.82) and (3.01) respectively; while minimum B/C ratio was obtained in T1 treatment (1.52), (1.9) and (2.03), respectively. The statistical analysis revealed that combination of fertilizers and
irrigation levels had significant effect on B/C ratio of Okra production. Conclusion: It is economically viable to grow okra under drip fertigation with 80% fertilizer (N) along with irrigation applied at 0.80 IW/CPE ratio.

Tasal and Pawar (2015) conducted a field study on wheat at Irrigation Water Management Farm, Post Graduate Institute, M.P.K.V., Rahuri, Maharashtra, India during rabi season of 2013-2014. The experiment was laid out in randomize block design with nine treatments and three replications. The treatment consisted of five fertiliser application rates as 100 % recommended dose with foliar sprays, 100 %, 80%, 60% and 0% under drip fertigation and compared with conventional irrigation and fertilisation. The treatment of 100% drip fertigation with foliar sprays was found to be more beneficial than conventional method of irrigation and fertilization in respect of increase in yield (25.6%) with 44.5% water saving which brought 0.8 ha more area under irrigation. In terms of economics, the same treatment was found more profitable with net extra income of Rs. 61,933 ha\(^{-1}\) as compared to conventional method.

Kombali \textit{et al.} (2017) A field experiment was conducted during Kharif 2012 at Zonal Agricultural Research Station, Bengaluru in red sandy loam soil (pH-6.9; OC-0.6 %) with medium available nitrogen (348 kg ha\(^{-1}\)), phosphorous (36.13 kg ha\(^{-1}\)) and potassium (244 kg ha\(^{-1}\)) to know the crop performance and economic feasibility of aerobic rice under drip fertigation. The experiment was laid out in Randomized Complete Block Design (RCBD) with 15 treatments. The results revealed that drip fertigation at 1.5 PE up to maturity with 100 % RDF through normal fertilizers (NF) recorded higher net returns and B:C ratio (Rs.72621 ha\(^{-1}\) and 2.88, respectively) and hence found to be economic in rice production under aerobic condition.