CHAPTER-II

REVIEW OF LITERATURE

Efforts are made to present a brief summary of studies related to the investigation carried out in this field at various places under the subheads; crop response to mulch, effect of mulch on soil moisture and soil temperature, effect of mulch on crop growth, effect of mulch on maturity and yield, effect of mulch on weed, crop response to drip irrigation level, crop response to irrigation and mulching.

2.1 Crop Response to Mulch

2.1.1 Effect of mulch on soil moisture and soil temperature

Lal (1974) studied on luvisols and cambisols under a tropical climate and found the increase in yield of maize grain due to mulching with rice straw mulch and forest litter. Mulched plants had a higher growth rate and increased vigor. Mulching significantly decreased the maximum soil temperature at 5, 10 and 20 cm depths. Initially during growth, temperature differences of up to 8 °C were observed between mulched and unmulched plots at 5 cm depth. Mulched plots also had higher soil moisture content. Increases in grain yield due to mulching were attributable mainly to a decrease in soil temperature but partly to improved soil moisture regime.

Gupta (1980) studied the effect of mulches on moisture and thermal regime of Jodhpur loamy sand soil and the production of pearl millet. Mean maximum soil temperature was higher under polyethylene and lower under millet husk mulch in comparison to control (without mulch). Soil temperature at 5 cm depth was higher by 1 to 3 °C under polyethylene and lower by 2 to 4 °C under millet husk. Maximum grain yield of pearl millet was obtained from soil (29.0 q/ha) under polyethylene followed by (23.0 q/ha) millet husk and (17.4 q/ha) control with water use efficiency of 10.4, 8.5 and 6.0 kg/ha-mm respectively.

Gupta and Gupta (1987) reported that the light and frequent irrigation (30 mm water at cumulative pan evaporation) to a sandy loam soil, together with straw mulching (6 t/ha), reduced the soil temperature by 2 to 7°C and increased water and N availability, thereby increasing the yields of tomato and okra by 100, 400 % respectively.
Wang et al. (2003) studied the effects of plastic film mulching on soil temperature and moisture and on yield of spring wheat. The result showed that the plastic film mulching could increase soil temperature in the whole growth period of spring wheat. The promotion of soil temperature and soil water content under plastic film mulching was favourable to the development and water use of spring wheat in its earlier stage.

Chakravati et al. (2005) studied the efficacy of some bio resources as mulch for soil moisture conservation. A two-year field experiment was conducted to study the efficacy of some mulching materials for soil moisture conservation in summer groundnut under rain fed conditions. The mulches used were water hyacinth (WH), rice straw (RS), banana leaves covered with grass (BL), jute stick (JS) and white polythene sheet (PS). The WH mulch conserved more soil moisture than the other mulches. The soil moisture content with ridge planting method (8.4 %), was significantly higher than the flat planting method (7.3 %).

Ramakrishna et al. (2006) studied the effect of mulch on soil temperature, moisture, weed infestation and yield of groundnut in Northern Vietnam. Polythene and straw mulches were effective in suppressing the weed infestation. Polythene mulch increased soil temperature by about 6 °C at 5 cm depth and by 4 °C at 10 cm depth; groundnut plants in polythene and straw mulch were tall, vigorous and reached early flowering.

Digrase and Awari (2008) resulted that tomato on a clay soil during summer season involving 4 treatments, i.e. transparent plastic mulch (M1), black plastic mulch (M2), sugarcane straw mulch (M3), wheat straw mulch (M4), and control (M5). Under M3, the soil temperature was the lowest (25.2-30 °C). The highest soil moisture was recorded under M3 (27.67 %). The lowest moisture was recorded under the control treatment M5 (24.68 %). Therefore, the lowest water requirement was recorded under M3 (78.24 cm depth), which saved 39.01 of irrigation water over the control. The highest water use efficiency (3.36 q/ha cm) was recorded under M1, which was 57.73 % higher over the control. M3 recorded significantly higher yield (262.70 q/ha) of tomato over M2, M4 and M5 but at par with M1. Hence, M3 was found suitable for increasing the productivity and water saving in tomato crop.
Gong et al. (2014) studied the effects of irrigation threshold on soil temperature in blossom and fruit-set periods of muskmelon under mulching-drip irrigation in greenhouse. In this study, different treatments were taken T1 55 %, T2 65 %, T3 75 % and CK 85 % of the field capacity. Effects of the ratio of soil moisture to heat were observed in the plough layer (0-20 cm) on muskmelon growth and fruit setting. Results revealed that during the flowering and fruit bearing periods, the order of mean soil temperature in the plough layer for the different treatments was T1 > T2 > T3 > CK. The maximum one-day variations for soil temperature on sunny day, rainy day and after irrigation were observed in the soil surface under the plastic film mulch, while the minimum happened in the soil layer of 20 cm outside the mulch. The treatment 75 % I, with the fastest plant growth rate, the minimum duration of fruit bearing and the maximum fruit setting rate, could be selected as the optimal treatment, and the ratio of soil moisture to heat in T3 was 1.62 mm °C⁻¹.

2.1.2 Effect of mulch on crop growth, maturity and yield

Agele et al. (2000) studied the effect of tillage and mulching on the growth development yield of late-season tomato. Mulch ameliorated the hydrothermal regime of the soil, improved the vegetative and flowering performance and significantly increased the fruit yield of tomato over bare ground.

Ibarra et al. (2001) conducted field experiment to determine the effect of plastic mulch alone or in combination with row covers on plant biomass, growth analysis parameters and yield of muskmelon. The treatments were taken no mulch; no row cover (control); black plastic mulch; BPM plus row cover removed after 10 days of seeding; BPM plus row cover removed after 20 days of seedling; BPM plus row cover removed 32 days. Early and total yield were both higher in BPM plants relative to the control.

Pawar (2004) studied the effect of different mulches (sugarcane trash mulch, wheat straw mulch, black plastic mulch, transparent mulch) on soil-moisture conservation and crop yield of groundnut. Percent increase in soil-moisture conservation over control was maximum in sugarcane trash mulch (13.56 %) followed by black plastic mulch (12.34 %), transparent plastic mulch (10.74 %) and wheat straw mulch (7.04 %). Maximum crop yield was observed in transparent plastic mulch.
(24.87 q/ha) followed by black plastic mulch (22.73 q/ha), sugarcane trash mulch (21.42 q/ha), wheat straw mulch (18.92 q/ha) and control (10.78 q/ha).

Mark and David (2007) conduct experiment to evaluate effects of reflective mulch, white inter-row mulch, and density on yields of pepper in Maine. They found mulch treatment significantly influenced total marketable yield and yield of cull bell peppers grown in Maine. The plot receiving the reflective silver mulch treatment produced significantly higher yield and number of fruits per acre than standard black plastic mulch treatment.

Seyfi and Rashidi (2007) carried out field experiments to study the influence of three irrigation methods corresponding to conventional (surface), drip and drip in combination with plastic mulch on cantaloupe (Cucumis melo L.). Result revealed that irrigation method significantly (P ≤ 0.01) affects the fruit weight and fruit thickness, but not the number of fruits per plant. The highest fruit weight and fruit thickness was obtained for the DI + PM treatment and lowest for the CI treatment. The results of the study also indicated that irrigation method significantly affects cantaloupe yield in the order of DI+ PM > DI > CI owing to differences in fruit weight and fruit thickness in the same order. The highest yield (27.07 t/ha) and WUE (0.91 t/ha cm) were found in DI + PM treatment. The DI+ PM treatment was found to be more effective irrigation method in improving WUE and increasing cantaloupe yield.

Subrahmaniyan et al. (2008) conducted a field investigation at Vridhachalam in Tamil Nadu during post-rainy seasons of 2001–02 and 2002–03 to study the microclimatic variation in relation to different types of polyethylene-film mulch and its effect on the growth and yield of groundnut. Results revealed that, irrespective of the colour plastic-film mulch significantly increased the soil temperature (1.0–1.9°C) at different phenophases of crop growth from sowing to harvest. The soil temperature was higher under black-film mulch, followed by transparent and white polyethylene film mulches among the different mulches evaluated. The soil temperature under ridges-and-furrows land configuration was 0.3°C lesser than flat-bed and broad-bed furrow methods. The dry-matter production and yield attributes were significantly higher under black polyethylene-film mulch which gave the highest pod yield of 2.87 t/ha compared with 2.21 t/ha by the non-mulched control. Hence black polyethylene film mulch in groundnut with adoption of flat-bed system of land configuration could
be an important agricultural practice to augment groundnut productivity besides improving microclimatic conditions.

Choudhary *et al.* (2012) studied the effect of different growth parameters in pepper (*Capsicum annuum* L.). All recorded vegetative parameters were higher with drip irrigation at 1.0 pan evaporation (Epan) and black polythene mulch. Physiological parameters such as photosynthesis rate (18.01 and 17.45 μmol m$^{-2}$ s$^{-1}$), transpiration rate (6.19 and 5.86 mmol H$_2$O m$^{-2}$ s$^{-1}$) and chlorophyll content (27.34 and 28.39; 39.22 and 41.27 SPAD, respectively at 50 and 100 days after planting) were maximal in crops with drip irrigation at 1.0 Epan and mulched with black polythene. Soil temperature was higher with the black polythene mulch. A higher level of drip irrigation and black polythene mulch resulted in early picking with higher yields compared with flood irrigation and no mulch.

Tyagi and Sharma (2013) defined the influence of mulching on growth and yield of watermelon under Nimar plains conditions of Madhya Pradesh. It was noticed that plastic mulch had significant response on vegetative growth, yield and net profit. Plants in plastic mulch treatment had higher yields ascribed to higher length of vine, number of branches, number of fruits per plant and average fruit weight. The study revealed that silver-on-black plastic film could be conducive and beneficial in enhancing the yield which lead to 75.29 % and 82.10 % increase over farmers’ practice during 2011 and 2012, respectively with a mean value of 78.70 % increase over farmers’ practice and net profit of watermelon found suitable for an early spring sowing under the Nimar Zone conditions of Madhya Pradesh.

An experiment was carried out to determine the effect of different irrigation level (0.8 ETc, 0.6 ETc, 0.4 ETc) and plastic mulch (Silver black - 20 μm, Black - 20 μm and No mulch) on watermelon crop during the year 2013 and 2014 at Instructional Farm, College of Agricultural Engineering and Technology, Junagadh Agricultural University, Junagadh. Result revealed that maximum crop yield (40.45 t/ha) was found in silver black plastic mulch whereas it was minimum (1.07 t/ha) for control (Anon., 2014).

Atif (2014) conducted a field experiment to study the effect of polyethylene black plastic mulch on growth and yield of okra and summer squash under rain-fed
conditions of Jordan. Two field experiments were conducted during summer growing season at Al Rabbah Agricultural Research Station, Mu’tah University, Jordan. Soil cover treatments were polyethylene black plastic mulch and no mulch (bare soil). The results indicated that the mulched plots had higher soil moisture content than bare soil plots, which has positively reflected on vegetative and yield parameters. Early, middle, late and total yield of both vegetable crops were significantly increased in plots covered with plastic mulch. In addition, fruit number and weight had also an increasing trend as fruit yield. Plots covered with black plastic mulch were produced higher fresh and dry weights of both vegetable crops.

Alenazi et al. (2015) studied the effect of White-on-black plastic mulch in combination with four irrigation levels (40, 60, 80 and 100 % based on crop evapotranspiration (ETc)) was applied to assess growth and yield of muskmelon under greenhouse conditions. Higher plant height, leaf area, fruit number, early fruit yield, total yield and crop water productivity were found in plastic mulch than non-mulch treatment. High and medium irrigation levels (100 and 80 % ETc) enhanced plant height and leaf area and increased fruit number, early and total yield. A higher crop production was observed with mulch and 100 % ETc treatment and WUE & IWUE values were found under mulch with the lowest irrigation level (40 % ETc). Plastic mulch with 80 % ETc water treatment was considered more suitable for optimizing WUE with no major yield reduction.

2.1.3 Effect of mulch on weeds

Prasad (1996) studied the effect of different type of mulches on growth, yield and weed intensities in opium poppy. Mulching significantly reduced the weed population with maximum reduction obtained in black polythene mulching. Maximum latex was obtained with black polythene mulching. Mulching with black polythene also reduced the cost of irrigation, chemical fertilizer, herbicides and weeding.

Raina et al. (1999) conducted an experiment to analyse the effect of drip irrigation and polyethylene mulch on yield, quality and water-use efficiency of tomato. Polyethylene mulch plus drip irrigation raised the yield. Water-use efficiency under drip irrigation plus polyethylene mulch was 0.48 tons/ha-m.
Rifai et al. (2002) studied the effect of different thermal units and three types of mulches on weeds in apple orchards. Mulches after chemical herbicide application were effective for controlling weeds. The effectiveness of depends on the weed species and on whether the same herbicide was used in preceding years. Compared to using herbicides with mulching, herbicide alone was less effective in controlling weeds and more costly in terms of cost per hectare and the environment.

Shirgure et al. (2003) studied the effect of different mulches on soil moisture conservation, weed reduction, growth and yield of drip irrigated Nagpur mandarin. Soil moisture conservation was higher in black polyethylene followed by grass mulching. The highest fruit yield was recorded with black polyethylene mulch followed by mulching with local grass compared to no mulch.

Hamid et al. (2010) conducted field experiment to evaluate the effect of coloured plastic mulches on weed and crop yield of tomato. Black and silver/black plastic mulches suppressed weeds. Mulching increased marketable yield relative to bare soil as the plants grown on silver/black plastic mulch indicated a 65 % increasing in marketable mulch compared to control treatment. The plastic mulches resulted in an 84-98% reduction in weed biomass.

Laurie et al. (2015) studied the effects of mulching, plant spacing and other control measures on effectiveness of weed control, canopy cover and sweet potato yield. Field trials were established at the Agricultural Research Council - Roodeplaat Vegetable and Ornamental Plant Institute in Pretoria, South Africa during 2006 and 2007. Seven treatments were applied in a randomized complete block design: 1) HW = Hand weeding, 2) NS = Narrow plant spacing (0.5 m between the rows and 15 cm between plants), 3) CO = Organic mulch (compost), 4) PL = Inorganic mulch (black plastic), 5) E*F = Eptam (EPTC; Thiocarbamate) followed by Fusilate (fluazifop-p-butyll), 6) L*F = Afalon (Linuron) followed by Fusilate (fluazifop-p-butyll), and 7) CN = Control (untreated plot). Organic mulch (compost) was omitted in the second trial as it will be beneficial for both weeds and the crop making it difficult to control the weeds. Instead, grass straws (ST) and newspaper (NP) mulches were added. Narrow row spacing, hand weeding, plastic mulch, and newspaper mulch outperformed the other treatments and obtained more than 90% canopy cover by 5 weeks after planting. Effective reductions in weeds were detected with plastic and newspaper mulched plots and was similar to the hand-weeded treatment, followed by narrow spacing.
Plots with newspaper mulch and narrow spacing produced marketable yields similar to the hand-weeded treatment. Inorganic mulching and narrow plant spacing were the most effective weed management treatments. Newspaper mulch seems to be a viable option for small holder farmers to control weeds in sweet potato plantings, eliminating the cost of labour to conduct hand weeding. Compost and grass mulch should not be adopted for weed control since these did not control weeds effectively.

Singh and Ghosal (2015) was conducted an experiment during 2010-2013 to assess the effect of different mulching materials viz., black polythene, transparent polythene, grass mulch, soil mulch, lac mud and unmulched (control) on soil moisture, soil temperature, weed suppression and summer season (rangeeni) lac yield of palas (Butea monosperma) under rainfed conditions in the Research farm of ICAR-Indian Institute of Natural Resins and Gums, Ranchi. Results showed the highest soil moisture conservation in black polyethylene by 22.3, 14 and 27.5 % over control for the year 2011, 2012 and 2013, respectively. The maximum mean temperature (22.4 °C) was recorded under transparent mulch, while, the lowest (20.2 °C) was recorded under grass mulch. Mean soil temperature under grass mulch was lower by 1.3, 2.5 and 2.8 °C compared to transparent polyethylene mulch for three years, respectively. Black polyethylene suppressed the maximum amount of weed (492.33 g/m²), whereas minimum (132.54 g/m²) was recorded in transparent mulch. Lac yield showed no definite trend in any of the treatments during the study period.

2.2 Crop Response to Drip Irrigation Scheduling

Water management in drip irrigated crop production requires information about the water needs of the crop as well as the water holding characteristics of the soil. Excessive irrigation can leach crop nutrients from the root zone while soil moisture deficit can result in crop stress. These reviews briefly present effect of drip irrigated conditions for crops production.

Verma et al. (2007) conducted a field experiment on the effect of drip irrigation and polyethylene mulch on yield, quality and water-use efficiency of peach (cv. July Elberta). They found that drip system with polyethylene mulch was very effective and an efficient method of irrigation for raising peaches especially on light textured soils. Drip irrigation at volume of water (100 % crop evapotranspiration) with polyethylene mulch resulted in significantly higher fruit yield and better quality
characteristics of peach. The drip system, besides giving a saving of 59.1 % of irrigation water, resulted in 30.4 % higher fruit yield of peach as compared to surface irrigation.

Cabello et al. (2009) conducted field experiment to investigate the effects of different nitrogen (N) and irrigation (I) levels on fruit yield, fruit quality, irrigation water use efficiency (IWUE) and nitrogen applied efficiency (NAE). Irrigation treatments consisted of 75 % of ETc, 100 % ETc control and an excess irrigation of 125 % ETc. The higher yield was obtained with 100 % ETc at N93. These results suggest that it is possible to apply moderate deficit irrigation, around 90 % ETc without lessening quality and yields.

Chun Zhi et al. (2009) conducted experiment to determine the optimum irrigation water amounts for muskmelon in plastic greenhouse. There were four different irrigation water levels 100 % (T100), 90 % (T90), 80 % (T80) and 70 % (T70) as the four different treatments. The results showed that plant growth, fruit production and quality were significantly affected under different irrigation water amounts. Plant height and stem diameter decreased as well as fruit yield from treatment T100 to T70. Fruit quality was the best in the T90 treatment. Hence, based on the quality and quantity of muskmelon yield, the regime for 90 % of field water capacity is the suitable soil irrigation treatment (T90) which can save irrigation water and improve the quality of fruit.

Yildirim et al. (2009) studied in Ankara, a semi-arid region of Central Anatolia, Turkey. Experiment carried out with three treatments; 50 % (P50), 75 % (P75), and 100 % (P100) of full irrigation water. Result revealed that fruit yields in the P75 and P100 applications were found similar, but they were found to be higher than the P50 application. From the experimental study, it was suggested that irrigation be kept on going until the beginning of fruit setting, not during the ripening period, and the application of 75 % of full irrigation water amount is the most convenient irrigation program with respect to high yield and fruit quality.

Zeng et al. (2009) carried field experiment to determine the optimum irrigation water amounts for muskmelon (Cucumis melo L.) in plastic greenhouse. The four irrigation levels were taken, 100 % (T100), 90 % (T90), 80 % (T80) and 70 % (T70) of the irrigation water requirement. The results revealed that plant growth,
fruit production and quality were significantly affected under different irrigation water amounts. Plant height and stem diameter decreased as well as fruit yield from treatment T100 to T70. Fruit quality was the best in the T90 treatment. The higher irrigation water use efficiency (IWUE) values found in the lower the amount of irrigation water applied. Hence, based on the quality and quantity of muskmelon yield, the regime for 90% of field water capacity is the suitable soil irrigation treatment (T90) which can save irrigation water and improve the quality of fruit.

Li et al. (2012) conducted experiment to determine the soil water content criteria at which growth and yield production of muskmelon would be optimal based on soil water measured by Time Domain Reflectometry (TDR) inside a plastic greenhouse using drip irrigation. Experiment included with four treatments of irrigation levels of 45% - I45, 55% - I55, 65% - I65, 75% - I75. The results showed that muskmelon plant development, fruit production and quality were significantly affected under different irrigation water amounts. The highest fruit yield and irrigation water use efficiency (IWUE) were obtained from the treatment employing the greatest irrigation thresholds and quantity of irrigation I75. Therefore, treatment I75 was the optimum irrigation schedule for muskmelon.

Yi et al. (2012) carried out experiment to determine the soil water content criteria at which growth and yield production of muskmelon would be optimal based on soil water inside a plastic greenhouse when using drip irrigation. Four soil water content lest thresholds (relative to the percentage of field water capacity) for starting the irrigation (45% - I45, 55% - I55, 65% - I65, 75% - I75) were compared inside plastic greenhouse. The results showed that muskmelon plant development, fruit production and quality were significantly affected under different irrigation water amounts. The highest fruit yield and irrigation water use efficiency (IWUE) were obtained from the treatment employing the greatest irrigation thresholds and quantity of irrigation I75. When the thresholds of soil water content were below 65% field water capacity during the whole growth period, the mean fruit weight and yield decreased significantly. Irrigation water amount significantly affected the flesh thickness and fruit total soluble solids (TTS), soluble sugar (SS), vitamin C (Vc), soluble protein (SP) and free amino acid (FAA) content. In conclusion, treatment I75 was the optimum irrigation schedule for muskmelon grown inside plastic greenhouse.
Mirabad et al. (2013) studied the impact of water-deficit stress levels on growth parameters, yield and sugar content of cantaloupe (Cucumis melo L.). In this experiment, three deficit-irrigation (DI) treatments were taken, 60, 80 and 100 %. Based on the results, DI levels had a significant effect on height, number leaves per plant, leaf area and dry weight, sugar content and yield. Increasing irrigation levels increased height, number of leaves per plant, leaf area and dry weight and yield. It was found that no significant difference between 80 and 100 % ETc in terms of yield. The highest height (194.7 cm), number of leaves per plant (243.3), leaf area (24375 cm²) and dry weight (111.6 g), obtained at 100 % ETc. While, sugar content increased under water deficit stress. So that highest value of sugar content (9.3 %) obtained in irrigation based on 60 % ETc.

Mirabad et al. (2014) conducted field experiment on growth, yield, yield components and water-use efficiency in irrigated Cantaloupes under full and deficit irrigation. In this experiment, three irrigation treatments consisted of 60 (I60), 80 (I80), and 100 % (I100) were applied during growing season. The result revealed that highest total crop yield (30.3 t/ha), mean number of fruits per plant (4.9), mean fruit weight (1.508 g), plant main stem length (194.6 cm) and total leaf area (24.375 cm²) were found in I100, but no significantly effect of I80 on cantaloupe yield but led to increase WUE and total soluble solids (TSS). Under I60 treatment, the yield was reduced by 35.3 % mainly due to decrease of fruit weight, while value of WUE (0.89 t ha⁻¹ cm⁻¹) in this treatment was 45.9 % greater than I100. Based on the total fruit yield, the preferable level of DI for cantaloupe production is I80.

From the reviews cited above, it can be concluded that drip irrigation with different level is effective to decrease crop water consumptions and increase the water use efficiency. Drip irrigation proved its mattel as a techno economically feasible and environmental compatible micro irrigation for saving water and boosting yield.

2.3 Crop Response to Drip Irrigation and Mulching

Khera et al. (1976) studied the effect of mulch, nitrogen and irrigation on growth, yield and nutrient uptake of forage corn. Mulching increased the dry forage yield by 11.8 q/ha or 26 % and showed a significant interaction with nitrogen rates. 50 kg N/ha and 100 kg N/ha with mulch yielded as much as 100 kg N/ha and 150 kg N/ha without mulch, respectively.
Sandhu et al. (1992) reported that mung beans were irrigated at (IW/CPE) ratios of 0.4, 0.6 and 0.8 and given 6 tone rice straw mulch/ha. Mulching increased soil water content at all the depths studied up to 180 cm. Rooting density increased from with increase in irrigation frequency. The nodule index increased with irrigation frequency and was higher with mulching. Seed yield increased with irrigation frequency up to an IW/CPE ratio of 0.6 and was 38 % higher with mulch than no mulch. Water use efficiency was highest with an IW/CPE ratio of 0.6 and mulching.

Munguia et al. (1996) carried out field experiment to evaluate the effect of plastic mulch on the spatial distribution of solute and soil moisture on the top soil profile and its relations with the growth and yield of muskmelon. The measurements were taken at 0.15 m and 0.30 m to both side of the irrigation line, before and after irrigation were applied. Result revealed that total solute and soil moisture were higher in first 0.15 m of soil depth under the plastic mulch as compare to no mulch. Also leaf area index, total dry matter and fruit yield were higher in the plots with plastic mulch.

Warner and Zandstra (2004) conducted field experiment on biodegradable polymer mulches in bell paper production and reported that average soil temperature at 5 cm depth was increased by the soil covers compared to bare soil. Ecofilm increased average soil temperature the most by 3.9 ºC, whereas green plastic increased soil temperature the least by 0.7 ºC, compared to bare soil but none of the mulches increased early yield compared to bare soil and the performance of biodegradable mulches was similar to black polythene except that field removal of the biodegradable film was not required at the end of the season.

Spehia et al. (2007) investigated the effect of different levels of drip irrigation with and without plastic mulch on the yield and irrigation water requirement of capsicum. The treatments employ were: T1 drip irrigation with 1.0 V volume of water, T2 drip irrigation with 0.8V volume of water, T3 drip irrigation with 0.6V volume of water; T4 surface irrigation, T5 (T1+ plastic mulch0, T6 (T2+ plastic mulch), T7 (T3+ plastic mulch) and T8 (T4+ plastic mulch). Drip irrigation at 0.8V volume of water recorded a significantly higher yield compared with surface irrigation. Drip irrigation with polyethylene mulch increased crop yield. Water use efficiency with sole drip irrigation, drip irrigation with polyethylene mulch and surface irrigation was 3.73, 3.88 and 2.35, respectively. Drip irrigation with polyethylene mulch besides the 55.6 % water saving has also resulted to 37 % higher
yield compared with surface irrigation only. The benefit cost ratio of capsicum cultivation under drip irrigation, drip irrigation with polyethylene mulch and surface irrigation was 2.66, 2.77 and 2.27, respectively.

Rodrigo et al. (2008) studied influence of subsurface drip irrigation and mulching over melon yield and quality characteristics. Mulching using double-sided silver/black film increased fruit average mass, plant production, yield, daily growth rate for plant height and crown diameter, fruit distal diameter, and pulp thickness.

Rajbir et al. (2009) conducted two year field study on sandy loam soil to investigate the effect of drip irrigation and black polyethylene mulch compared with surface irrigation, on growth, yield, water-use efficiency and economics of tomato. Drip irrigation at 80% evapo-transpiration (ET) crop based on pan evaporation applied gave significantly higher fruit yield (45.57 t/ha) compared with the surface irrigation (29.43 t/ha). Use of black polyethylene mulch plus drip irrigation further raised the fruit yield to 57.87 t/ha. Plant height, leaf area index, dry matter production, fruit weight and yield increased significantly with the use of drip irrigation alone and in conjunction with polyethylene mulch compared to surface irrigation alone or with mulch. Drip irrigation besides giving a saving of 38% water resulted into 55% higher fruit yield compared to surface irrigation.

Akbari et al. (2011) conducted field experiment at Esfahan in central of Iran to evaluate the yield of muskmelon under mulched, irrigation level and irrigation system treatments. The experiment carried out with three treatments: two kind of irrigation systems (surface and drip irrigation), two level of irrigation amount (75 and 100 percent of irrigation water requirement) and three level of mulches (black and transparent plastic mulches and without mulch as a control). Result revealed that water use efficiency in drip irrigation (11.2 kg/m³) system was 2.5 times higher than surface irrigation (4.8 kg/m³). Higher yield, better crop growth, available soil moisture and greatly weed controlled were observed in the mulched (BPM) plots with drip irrigation (100% of irrigation water requirement) which might be due to conservation of soil moisture. Result shows that, application of the drip irrigation system and plastic mulches can optimize the water consumption.

Majid et al. (2011) Field experiments were conducted to study the effect of different irrigation methods on crop yield and yield components of cantaloupe. Three
irrigation methods, i.e. surface irrigation (SI), drip irrigation (DI) and drip irrigation in combination with plastic mulch (DI+PM) were applied to cantaloupe. The maximum values of CY, FW, FT and NFPP were obtained in case of DI+PM treatment.

Mohammadi et al. (2012) carried out field experiments to study the response of crop yield and yield components of cantaloupe to different irrigation methods in the arid lands of Iran. Work carried out on three irrigation methods, i.e. surface irrigation (SI), drip irrigation (DI) and drip irrigation in combination with plastic mulch (DI+PM) were applied to cantaloupe. Result revealed that irrigation method significantly (P ≤ 0.01) affected CY, NPPH, FW and FT, but there was no significant difference in NFPP. The maximum values of CY (27.1 t /ha), FW (1383 g) and FT (4.1 cm) were obtained in case of DI+PM treatment. Conversely, the maximum value of NPPH (4756) was obtained in case of SI treatment and the minimum value of NPPH (4082) was recorded in case of DI+PM treatment. Although there was no significant difference in NFPP, the maximum value of NFPP (4.8) was also obtained in case of DI+PM treatment.

An experiment was carried out to determine the effect of different irrigation level (0.8 ETc, 0.6 ETc, 0.4 ETc) and plastic mulch (Silver black - 20 µm, Black - 20 µm and No mulch) on watermelon crop during the year 2013 and 2014 at instructional farm, College of Agricultural Engineering and Technology, Junagadh Agricultural University, Junagadh. Result revealed that maximum crop yield (40.45 t/ha) was found in silver black plastic mulch whereas it was minimum (1.07 t/ha) for control (Anon., 2014).

Ravisankar et al. (2014) conducted a field experiment during dry season of 2008-10 at Andaman and Nicobar Islands to study the influence of irrigation at critical stages and mulching on yield and water productivity of table purpose groundnut under humid tropical conditions. Experiment was laid out in split plot design with three replications by assigning irrigation at critical stages (‘No irrigation’, one irrigation at pegging’, ‘two irrigation at life and pegging’, ‘three irrigation at life, flowering and pegging’ and ‘four irrigation at life, flowering, pegging and pod development’) to main plot and crop residue mulching (‘Paddy straw’, ‘banana leaf’, and ‘Gliricidia leaf’ and ‘No mulch’) to subplots. Growth and yield attributes were significantly influenced by irrigation and mulching. Application of two irrigations at life (3 DAS) and pegging (55-60 DAS) resulted in higher pod yield (3549 kg/ha)
compared to three and four irrigations which registered 2.6 and 7.7 % yield reduction. Higher net returns ( ₹41,599/ha), B:C ratio (1:8), energy ratio (15.3) and lower specific energy (4.0 MJ/kg) was recorded with two irrigations. However, one irrigation at pegging registered higher water productivity of ₹ 66/ m³. Among the crop residue mulches, paddy straw mulch registered higher pod yield (3425 kg/ha), water productivity ( ₹33/m³), net returns ( ₹39,280/ha), B:C ratio (1:6) and energy ratio (15.0).

2.4 Economics of Drip/Mulch

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 and saving of 42% over flood irrigation system.

Tiwari et al. (1998) conducted a field experiment to evaluate the economic feasibility of drip irrigation in combination with different types of mulches for an okra crop. Field experiment were conducted on the lateritic sandy loam soils of Kharagpur, West Bengal, India during spring–summer (February to May) seasons for 3 years (1995 to 1997). Effect of two organic mulches (rice husk and rice straw) was also studied with drip irrigation. The study indicated that 100 % irrigation requirement met through drip irrigation along with black plastic mulch gave the highest yield (14.51 t/ha) with 72 % increase in yield as compared to furrow irrigation. The net seasonal income, benefit-cost ratio and the yield per unit depth of water used, were found highest for drip irrigation with black plastic mulch.

Agrawal and Agrawal (2005) founded that drip irrigation increases banana yield and conserves more water than surface irrigation. The maximum yield of 498.68 q/ha was recorded under 60 % water through drip with plastic mulch which found significantly better than basin irrigation.

Aujla et al. (2005) revealed that when the same quantity of irrigation water and N were applied through drip irrigation system, it increased the cotton yield to 2144 from 1624 kg ha⁻¹(an increase of 32 per cent) compared to check basin irrigation. When the quantity of water through drip was reduced to 75 %, the increase in cotton yield was 12 %.
Kumar et al. (2005) carried out a field experiment at Nauni, Solan (Himachal Pradesh, India) in a sandy loam inceptisol to study the comparative effects of drip and surface irrigation, with and without mulch on irrigation requirement, yield, quality and water use efficiency of ‘Chandlar’ strawberry (Fragariaananassa). He reported that drip irrigation, besides saving 51 % irrigation water, resulted in about 19 % higher fruit yield compared with the surface irrigation.

Singh (2007) conducted an experiment to determine the yield response and economic feasibility of tomato under drip irrigation at different levels of irrigation. Highest yield of 34.3 t/ha was recorded in case of treatment VD+PM (100 % irrigation requirement supplied with drip plus plastic mulch) followed by VD. The yield per mm of water used and B:C Ratio in case of 0.8 VD (100 % irrigation requirement supplied with drip) were observed as 53 and 1.13 which is the best among all the treatments in terms of B:C Ratio, yield obtained and yield per mm of water used. The income from produce was estimated using prevailing average market price @ ₹2000/t.

Panigrahi et al. (2010) conducted an experiment on sandy loam soil at the Regional Research and Technology Transfer Station, Chiplima, Orissa, to study the effects of furrow irrigation and variable water supply by drip irrigation on yield and water use of tomato crop. As a result, the yield of crop was found to be maximal (180.97 q/ha) for the treatment T1 (drip irrigation at 100 % ETc) whereas those for treatments T2 (drip irrigation at 80 % ETc), T3 (drip irrigation at 60 % ETc) and T4 (drip irrigation at 40 % ETc) were 162.77, 145.12 and 156.86 q/ha, respectively. The study reveals that drip irrigation at 100 % ETc in tomato can increase the yield by 15.4%, besides saving 17.9 % more costly irrigation water than the conventional furrow irrigation practiced by most of the farmers.

Parmar et al. (2013) conducted field experiment on watermelon (Citrulluslanatus Thunb) cv. Kiran at Fruit Research Station, “Lalbaugh”, Department of Horticulture, College of Agriculture, JAU., Junagadh during summer season of 2010 to study the effect of different mulching material on growth, yield and quality of water melon cv. Kiran. All the plant growth, yield and quality characters were superior with silver on black polyethylene mulch while, plants without mulch (control) resulted poor growth and yield. With economic point of view, silver on
black mulch resulted in the highest net return and found to be more economical with highest cost: benefit ratio.

Paul et al. (2013) conducted an experiment to evaluate the yield, water-use efficiency and economic feasibility of capsicum grown under drip and surface irrigation with non-mulch and black Linear Low Density Poly Ethylene (LLDPE) plastic mulch. The study indicated better plant growth, more number of fruits per plant and enhancement in the yield under drip irrigation system with LLDPE mulch. The highest yield (28.7 t/ha) was recorded under 100 % ne irrigation volume with drip irrigation and plastic mulching as compared to other treatments. Drip irrigation system could increase the yield by 28 % over surface irrigation even in the absence of mulch.

Biswas et al. (2015) investigated the combined effects of drip irrigation and mulches on yield, water-use efficiency and economic return of tomato. The treatments of the study comprised different combinations of three drip irrigation levels (100, 75 and 50 % of crop water requirement, ETc) and two mulches (black polyethylene sheet and paddy straw). The yield and yield-contributing characters in the mulched treatments for all levels of irrigation were significantly higher compared to those in the unmulched treatments. The yield of tomato increased with the increasing amount of irrigation water in unmulched treatment. The trend was reversed when drip irrigation was coupled with mulches. The highest yield for each mulch (81.12 t/ha for polyethylene and 79.49 t/ha for straw) was obtained when 50 % of water requirement was applied. With 100 % water application, polyethylene-mulched treatment produced lower yield than the straw-mulched treatment. The highest water use efficiency of 592 kg/ha-mm was obtained with 50 % water application under polyethylene mulch. The highest net return (US$ 7098/ha), incremental net return (US$ 1556/ha), and incremental benefit-cost ratio (7.03) were found for 50 % water application with straw mulch.

From the reviews cited above, it can be concluded that drip irrigation with mulching gave higher water use efficiency, yield, productivity and profitability under scarce water availability.