IMPACT OF FERTIGATION AND DRIP SYSTEM LAYOUT ON PERFORMANCE OF CHILLI (*Capsicum annum*)

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NADIYA NESTHAD

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DECLARATION

I hereby declare that this thesis entitled "**IMPACT OF FERTIGATION AND DRIP SYSTEM LAYOUT ON PERFORMANCE OF CHILLI (*Capsicum annum*)"** is a bonafide record of research done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title of any other University or Society.

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SYMBOLS AND ABBREVIATIONS

A	Ampere
B/C	Benefit/Cost
C_C	Canopy factor
CD	Critical difference
CPE	Cummulative pan evaporation
C_V	Coefficient of manufacturing variation
D_1	First drip sytem layout
D_2	Second drip system layout
Dept.	Department
E_P	Normal monthly pan evaporation
ET	Potential evapotranspiration
FPE	Fraction of pan evaporation rate
ha	hectare
hp	horse power
I_1	First irrigation level
I_2	Second irrigation level
I_3	Third irrigation level
IW	Irrigation water requirement
IW/CPE	Irrigation water requirement/Cummulative pan evaporation rate
K	potassium
KAU	Kerala Agricultural University
K_C	Crop Coefficient

KCAE T	Kelappaji College of Agricultural Engineering and Technology
kg(f)/cm^2	Kilogram force per centimeter square
K_P	Pan evaporation factor
L W R C E	Land and Water Resources Conservation Engineering
L/min	Litre per minute
LDPE	Low Density Poly Ethylene
mins	minutes
ml	milli litre
mm	millimeter
N	Nitrogen
N/ha	Nitrogen per hectare
NS	Non significant
PE	Potential evapotranspiration
PVC	Poly Venyl Chloride
rpm	revolution per minute
S	Significant difference
sec	second
T_1	Treatment 1
T_2	Treatment 2
T_3	Treatment 3
T_4	Treatment 4
T_5	Treatment 5
T_6	Treatment 6
TNAU	Tamil Nadu Agricultural University

INTRODUCTION

Water resources are found to be getting deteriorated in terms of quality as well as quantity. Mark *et al*. (2002) reported that by the year 2025, 33 per cent of India's population will live under absolute water scarcity condition. The per capita water availability in terms of average utilizable water resources in the country was 6008 m^3 in 1947and is expected to dwindle to 760 m^3 by 2025 (Kumar, 2003).

Water is a major input in agriculture. The water use efficiency of the crops has to be increased in order to reduce the water loss from the fields. The water loss in irrigated agriculture occurs through percolation and evaporation. The evaporation loss from land and water surfaces depend on the amount of water lost from the ground surface. Efficient water management practices are needed to bring most of the land in India under irrigation. The efficiency of irrigation has to be improved to save the water resources and to make water available to most of the land.

India has to increase use of land, conserve water and other natural resources to meet the demands in tune with the increasing population. Indian agriculture today faces the challenge of meeting demand for safe and quality food. All care has to be taken in protecting the natural resources and the environment in the race for food security. Agriculture intensification is commonly attained through irrigation and fertilizer application. Over irrigation may prove detrimental in terms of its demerits and fertilizer application at dozes higher than recommended lead to pollution of the environment. Suitable methods which are both eco and farmer friendly have to be developed.

Adoption of micro irrigation for crops is reported to be effective in increasing agricultural production. The benefits of micro irrigation which include water saving, precise application and water use efficiency make the system highly acceptable. Drip system is considered as the most effective micro irrigation method, as water is applied directly into soil at the crop root zone. The system delivers a constant rate of discharge, which do not change significantly in the field. Judicious application of fertilizers and plant nutrients will enhance the system efficiency and ultimately the yield.

Water saving is one of the important advantage of the drip irrigation system. This system of irrigation ensures uniform application of water over the field. This results in uniform plant growth and greater yield. Considerable interest has been shown by the government in popularizing micro irrigation and adoption of this method is high among farmers. Drip irrigation can be adopted as a better method to substitute traditional irrigation methods which accelerate soil erosion especially on sloppy terrains.

Scientific methods of cultivation and judicious use of all inputs, including water and fertilizers, should be cost effective for adoption. Higher efficiency can be achieved by introducing advanced methods of water and fertilizer application. Fertilizers applied under traditional methods of irrigation are not efficiently utilized by the crops. As an alternative, fertigation and drip system can be recommended.

Water and nutrients are the major inputs contributing towards production in irrigated agriculture. Improvement of the use efficiency of these inputs is of utmost importance. Acceptable reduction in the water application and an increased production can be achieved by the adoption of drip irrigation. The field experiments on vegetables and fruits crops grown under drip and fertigation system are reported to have shown improved quality, higher yields and saving of chemicals and fertilizers. The adoption of fertigation and drip system has shown favorable results in terms of fertilizer use efficiencies and quality of produce.

With drip fertigation, nutrient use efficiency is increased and the loss of nutrients to the ground water is reduced. Soluble chemicals and nutrients move with the wetting front. Hence a precise scheduling of irrigation and fertilizer applications is essential for sustainable crop production. Successful fertigation requires precise calculation of injection rates, motive flow rate, knowledge regarding solubility of different nutrients in water and know how on the different fertigation equipments.

Vegetables are cultivated commonly as summer fallow in India. Irrigation is an essential practice for vegetable cultivation. Irrigation is frequently interrupted due to the scarcity of water during the season. Fertigation and drip irrigation is an effective method that can be resorted to improve the vegetable production. During summer season, the available water has to be used effectively and the soil moisture has to be conserved. Mulching is a relevant practice for soil moisture conservation under this context. Fertigation along with mulching helps to achieve both the objectives of efficient utilization of available water and the conservation of soil moisture. Plastic mulch can reduce the loss of soil moisture. Effective control of weed growth is also attained under this system. Cost of cultivation can be reduced by selecting proper layout of drip system.

Vegetable production in Indian agriculture has wider scope for increasing the income of the marginal and small farmers. Vegetables have vast potential in gaining foreign exchange through the export. The vegetable growers are looking for new ways to achieve superior quality produce with higher yields. Among the vegetables grown, chilli is a spice cum vegetable crop of commercial importance. It is characterized by tempting colour and biting pungency. Chilli (*Capsicum annum*) is grown as an important spice crop in Andhra Pradesh, Maharashtra, Karnataka, Tamil Nadu, Kerala and Orissa. India is the largest producer of chilli in the world contributing 25 per cent of the total world production. India produces about six to nine lakh metric tonnes of dried chilli annually.

In Kerala, chilli is grown in almost all districts. The important districts growing chilli in terms of production are Palakkad, Kollam, Thrissur and Kannur. The total production of green chilli in the state is around 1553 metric tonnes from a cropped area of 1601 hectares (Anonymous, 2011). The export of chilli from India was 204 000 metric tonnes in the year 2009 -10. There is a high demand for value added products of chilli such as chilly powder, chilli paste and other sauces for the food industry. In the extraction industry, there is always demand for chilli with high capsaicin content.

Chilli forms an indispensible condiment in every house hold. Chillies are rich sources of vitamin A, C and E and it imparts pungency and red colour to the dishes. In addition to this it has medicinal properties also. India dominated in the international trade of chillies. During the last few years, there has been a change in the situation. The export from the country has come down considerably due to lesser cultivation of chilli. The total export of chillies from India is about four per cent of total production. As the demand for natural pigments is growing, the demand for chillies is also increasing day by day. Thus a reduction in exportable surplus is reported. This situation could be improved by increasing the production and improving productivity.

Fertigation was first started in the late 1960's in Israel with the development of drip irrigation. Fertigation is addition of fertilizers to irrigation water and application via drip or similar micro irrigation system. Fertigation is in its introductory stage in Kerala. The adoption of fertigation by farmers largely depends on the benefits derived from it. Its success in terms of improved production depends upon how efficiently plants take up the nutrients. Proper scheduling and intervals are also needed to provide nutrients at a time when plants require them. Fertigation provides nitrogen, phosphorous and potassium as well as essential nutrients directly to the active root zone. This minimizes the loss of nutrients and helps in improving productivity and quality of farm produce.

The important components of a fertigation system include drip irrigation system of suitable layout and fertigation equipment. Crops are raised under fertigation system with the application of suitable mulch materials in order to reduce the water loss and weed infestation. The performance of crop may vary with the application rates and schedule of irrigation. The cost of the system will vary with the layout of the drip irrigation system as the use of laterals in each system of layout may vary.

The impact of fertigation and drip system on the performance of the growth and yield of Chilli (*Capsicum annum*) need to be assessed under this context. The methodology for drip fertigation has to be standardized for field adoption. An efficient layout which can meet the water requirement for the crop under study is very essential for adoption in farm level. Keeping these points in view, the thesis work is undertaken with the general objective of studying ***"Impact of fertigation and drip system layout on performance of chilli*** **(*Capsicum annum*)",** Ujwala variety.

The specific objectives of the present study are

1. Performance evaluation of different fertigation equipments.
2. Standardization of the irrigation requirement and drip system layout of chilli under plastic mulching.
3. Work out the cost economics.

REVIEW OF LITERATURE

In India efforts were made to introduce micro irrigation system at farmer's level around 1980. Micro irrigation conserves irrigation water easily, doubling the command area of a water resource with yield increase up to 50 per cent. Judicious use of irrigation water for agriculture is equally important to increase the productivity. This can be achieved by introducing micro irrigation, coupled with other improved water management and fertilizer application methods. The productivity of crops is based on effective utilization of water and fertilizer, along with other agricultural inputs. Fertigation provides flexibility of fertilizer application, which enables three specific nutritional requirements of the crop to be met at different stages of its growth. In comparison with the conventional methods, it appears that fertigation gives higher crop yields with substantial saving in fertilizer usage.

2.1 Drip Irrigation and Fertigation Development

2.1.1 Drip Irrigation

Goldberg (1971) reported that drip irrigation is a multi disciplinary agricultural practice and has enormous potentials and possibilities. Kensworthy *et al.* (1972) reported that if the pressure distribution along a lateral line can be determined, uniform irrigation can be achieved by adjusting the length and size of microtubes used and by adjusting the size of emitters.

In 1860 an Israeli engineer Simcha Blass developed the first drip irrigation system using micro-tubes extending from a plastic main line. The growth of micro irrigation has really gained momentum in recent years. From a mere 1 500 ha in 1985, the area under micro irrigation has grown to 2, 59,500 ha at present. Area covered under drip irrigation in Kerala is 6000 hectares (Anwar *et al*., 1980).

Singh *et al.* (1998) reported the emerging scenario of micro Irrigation in India. Research on micro irrigation, which was confined to a single research centre, was enlarged through DRIPNET of the ICAR and 16 Plasticulture Development Centres were established in different parts of the country. More than 0.3 million ha land has been brought under micro irrigation till 1998-1999. Sugarcane, oil palm and cotton, which are known for its high consumption of water, are now being brought under drip irrigation. As a result, India has now emerged as a leading country in micro irrigation.

Singh (2001) conducted studies on the emerging scenario of micro irrigation in India and reported that drip system permits the use of fertilizers, pesticides and other soluble chemicals along with the irrigation water. It has a potential for use as a major component in adoption of precision farming.

The use of emitters or drippers for sub surface irrigation in Israel started during 1960. The first emitter or dripper were developed by Simcha Blass and was made of a tube 2 to 3m long with a diameter of 1.2 to 1.4mm. The tube was coiled up and water moving through the long spiral passage caused a reduction in pressure and a low rate of flow from the dripper or emitter (Natan *et al.,* 2005).

Several types of drippers or emitters are manufactured such as laminar flow, turbulent flow and orifice type. Pressure compensating drippers enable irrigation of undulated and sloping lands with uniform flow rate from the drippers. Pressure compensating drippers are self flushing and operate in the range of 0.7 to 3.0 kg/cm^2 (Natan *et al.,* 2005).

An Israeli firm “NAAN” manufactured another type of emitter which could deliver water as fine spray. The rate of flow, radius, wetted area and wetted sector in the spray irrigation system vary according to the structure of the spray. The spray jets are now widely used in citrus plantations of U. S. and have found good application in India for irrigating coconut, mango, guava, ber and citrus (Natan *et al.,* 2005).

To reduce the cost, some advanced technologies, such as computer-aided design (CAD), computational fluid dynamics (CFD), rapid prototyping (RP) and rapid tooling (RT) were used to establish a rapid method for emitter development. The emitter channel was designed using a three-dimensional parameterized CAD model. Then the flow within the channel was simulated using CFD, which provided visual results of pressure and velocity distributions. Moreover, the discharge and flow exponent of the emitter were also obtained from the CFD simulations. Verified by the simulation results, several types of emitters were fabricated using RP/RT without making an experimental steel mould or amplifying emitter models (Wei *et al.*, 2006).

Micro irrigation is the slow application of water on, or below the soil by surface drip, subsurface drip and bubbler and micro sprinkler systems. Water is applied as discrete or continuous drips, tiny streams, or miniature spray through emitters or applicators placed along a water delivery line adjacent to the plant row (James *et al*, 2007).

Schwankl *et al.,* (2007) defined drip irrigation as an irrigation method that transfers the water under a definite pressure, after filtering, through pipe network into the soil surrounding the root system of plants in drops slowly and uniformly. The emitters are to drip the pressured water in the pipeline to the root of the crops evenly and steadily, so as to guarantee the water demand for crop growth. The quality of the emitter has an important effect on the reliability, life span of the drip irrigation system and irrigation quality.

Yildrim *et al.,* (2010) made accurate evaluation of the pressure head distribution along a trickle irrigation lateral which can be operated under low pressure head. Simple mathematical expressions for computing three energy loss components-minor friction losses through the path of an inline emitter, the local pressure losses due to emitter connections and major friction losses which are quickly implemented in a simple excel spread sheet

Because of highly increasing demand for freshwater, optimal usage of water resources has been provided with greater extent by automation technology and its apparatus such as solar power, drip irrigation, sensors and remote control. Data acquisition is performed by using solar powered wireless acquisition stations for the purpose of control of valves for irrigation. The designed system has three units namely, base station unit (BSU), valve unit (VU) and sensor unit (SU). The obtained irrigation system prevents the moisture stress of trees and provides an efficient use of fresh water resource. In addition, the developed irrigation method removes the need for workmanship for flooding irrigation (Mahrin *et al*., 2011).

2.1.2 Fertigation Development

The major advantages of fertigation with drip irrigation are saving of water, labour, better timing, uniform distribution, less damage to crop and soil and ultimately higher yield. Also this method offers an opportunity for precise application of water soluble fertilizers and other nutrients to the soil at appropriate times with desired concentration (Kumar, 1992).

For efficient and uniform distribution of plant nutrients, the irrigation system must full fill certain requirements like it must be designed correctly to operate efficiently and should ensure complete solubility of the fertilizers without leaving any residues and should supply nutrient solution at constant rate and pressure from the main flow line (Nache, 1996).

Several factors such as plant species, media, its pH, solar radiation, temperature, humidity and water availability in the green house affect the absorption and utilization of nutrients. Hence care in proper management of the media and appropriate fertigation programme is essential for getting sustained productivity of crops under green house. Excessive or imbalanced application of nutrients would result in improper plant growth (Mortvedt, 1997).

Fertigation is one of the recent techniques of applying nutrients through micro irrigation system. The system permits application of various fertilizer formulations directly at the active root zone. Fertigation system is becoming more popular because of its advantages like, higher fertilizer use efficiency, increased availability of nutrient content to the plant, fertilizer saving to the range of 20 – 40 per cent, regular supply of crop nutrients as and when required, labor and energy savings and facility for application of chemicals other than fertilizers for specific purposes (Khan *et al*., 1999).

Loccasio (2000) reported that drip irrigation systems are generally costly and require good management. Water application rate was reduced and the nutrient use efficiencies are increased with fertigation system. Loss of nutrients from the root zone was reduced in the fertigation system.

Fertilizers supplied under traditional methods of irrigation are not effectively used by the crops. Through fertigation, water and fertilizers are efficiently used by the plant. Studies conducted in various commercial, horticultural and high value crops, revealed that adoption of this technology improves the yield and quality of crops. It is also highly beneficial to the farming community in reducing the cost of production. Further it helps in sustaining the soil health for better productivity and reducing environmental hazards (Manickasundaram, 2005).

A study was done to compare the effects of nitrogen fertigation and granular fertilizer application on growth and availability of soil nitrogen during establishment of high bush blueberry (*Vaccinium corymbosum* L. “Bluecrop”). Treatments included four methods of N application (weekly fertigation, split fertigation, and two non-fertigated controls) and four levels of nitrogen fertilizer (0, 50, 100, and 150 kg/ha). Fertigation treatments were irrigated by drip and injected with a liquid urea solution. Non-fertigated controls were fertilized with granular ammonium sulfate, also applied as a triple - split, and irrigated by drip or micro sprinklers. Results indicate that fertigation may be less efficient (i.e., less plant growth per unit of nitrogen applied) at lower N rates than granular fertilizer application but is also safer (i.e., less plant death) and promotes more growth when high amounts of nitrogen fertilizer is applied (David *et al*, 2011).

Usman *et al*. (2011) conducted studies on the speaking plant approach for automatic fertigation system in green house. In order to supply water and nutrition in the right amount and time, plants condition can be observed using a CCD camera attached to image processing facilities to develop a speaking plant approach. The plants development during their growing period are observed using image processing. The response of plant growth in the same condition was monitored, and the response was used as input for the fertigation system to turn electrical pump automatically on and off, so the fertigation system could maintain the growth of the plants.

2.2 Fertigation equipments

Jain Irrigation Company conducted experiments on the performance evaluation of ventury injector. The result revealed that for an inlet pressure of 1 kg/cm^2 and an outlet pressure of 0.2 kg/cm^2, the corresponding motive flow rate and suction rate of ventury injector of ¾ inch was 8.4 L/min and 70.8 Lph. (Anonymous, 1999)

Ashwani (2001) reported that the adoption of fertigation world wide has shown favourable results in terms of fertilizer use efficiency and quality of produce. The choice of water soluble fertilizers should be based on its properties in avoiding corrosion of pipe lines, softening of plastic pipe network and safety in field use.

Fertigation system makes use of three different types of fertilizer applicators. The three different fertilizer applicators are the ventury injector, fertilizer tank and dosmatic fertilizer injector commonly called as fertilizer pump.

In a ventury injector partial vacuum is created in the system which allows suction of the fertilizers into the irrigation system through ventury action. The vaccum is created by diverting a small percentage of water flow from the main and allowing it to pass through a constriction called ventury which increases the velocity of flow and thus creating a drop in pressure. When the pressure drops the fertilizer solution is sucked into the ventury through a suction pipe from the fertilizer tank and from there enters into the irrigation stream. The suction rate of ventury varies from 30 to 120 litres per hour (Anonymous, 2008).

Fertilizer tank containing fertilizer solution is connected to the irrigation pipe at the supply point. A part of irrigation water was delivered through the tank diluting the nutrient solution and returning to the main supply (Anonymous, 2008).

In the Dosmatic fertilizer injector, water in the main line, on its way through activates the dosmatic unit which takes up the required quantity of concentrate directly from the container. Inside it, the concentrate is mixed with water, and the water pressure forces the solution downstream to the main line (Anonymous, 2008).

The flow rate of the chemical from the pump however depends on the pressure in the irrigation main line. The higher the pressure differences in the irrigation main line, higher the flow rate in the pump (Boman *et al.*, 2004).

Fares *et al.* (2009) conducted studies on the injection rates and components of a fertigation system. Accurate chemical application and easy adaptation for automation are the major advantages of injection system.

Fig.1 Ventury Injector

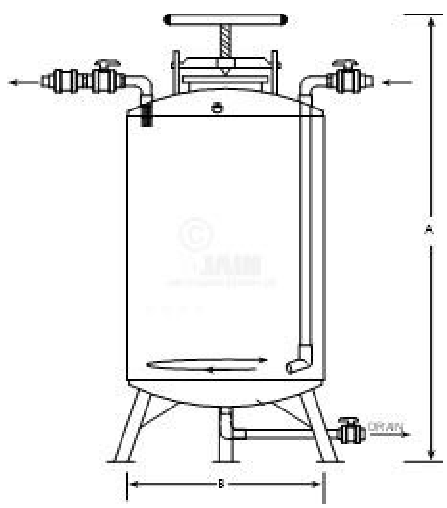

Fig.2 Fertilizer Tank

Fig.3 Fertilizer Injector Pump

2.3 Hydraulic performance of drip irrigation system

One of the basic measures of any irrigation system's performance is Christiansen's (1942) uniformity coefficient, CUC. Christiansen defined the uniformity coefficient as

$$CUC = 1 - (D/M)$$

Where, D is the average absolute deviation of irrigation amounts and M is the average irrigation amount. Christiansen was probably the first to point out the significance of distribution pattern in assessing the performance of drip irrigation system.

Solomon (1979) presented the manufacturing variation for various single and multiple orifice type emitters used for micro – irrigation. These emitter types had a Cv range of 0.02 – 0.07 for sprinklers and micro – spray emitter models used for irrigation of tree crops.

Bralts *et al*. (1981) and Solomon (1979) reported that in reality unit to unit emitter discharge is variable. The actual emitter flow rates along a line vary considerably depending on several factors. These factors affect the hydraulics of micro irrigation system and decrease its efficiency and uniformity and lower the system efficiency. Among all the factors that affect the micro irrigation, uniformity and the emitter manufacturer variation were the most important factors (Wu and Gitlin, 1981; Bralts *et al.*, 1982)

The emitter flow variation was determined by the equation suggested by Bralts *et al*. (1982)

$$\mathbf{Q_{var} = (q_{max} - q_{min}) / q_{max}}$$

The emission uniformity varied depending on the operating pressure and spacing. The emission uniformity values for micro jet at different operating pressures and stake height were observed in the range of 92.56 - 95.59 per cent. The average values of emission uniformity were found to be than 90 per cent (Keller and Karmeli, 1974). Brian (1989) reported that uniformity is an indicator of the equality of the application rates with in the pattern diameter of an emitter. Chen and Zhen (1995) determined the importance of irrigation uniformity in the design of micro irrigation system by analysis the relationship between crop yield and water consumption.

Hassan (1997) evaluated the emission uniformity for micro irrigation system. He found that the emission uniformity is a sound indicator of the efficiency of micro irrigation system. The study revealed that poor emission uniformity would lead to over irrigation, resulting in low efficiency and excessive energy consumption.

Shinde *et al.* (2001) conducted studies on efficient water management with micro irrigation systems for sugarcane. The result revealed that uniformity of water distribution in pressure compensating, non pressure compensating and inline drip irrigation system was 93.43, 86.89 and 93.53 per cent respectively. The pressure compensating and inline drip irrigation systems recorded more than 93 per cent uniformity of water distribution.

Kishor *et al.* (2005) tested the hydraulic performance of market available drippers. He used an automatic dripper testing set up for the study. The drippers were tested for pressure and discharge relation, pressure and coefficient of manufacturing variation. The pressure and discharge relations were developed for all drippers by fitting power equation to the data. The drippers had the C_V value less than 5 per cent indicating the good performance, 5 to 10 per cent indicating the average performance while C_v more than 10 per cent indicated the unacceptable range of performance. The uniformity coefficient of dripper was found to be more than 95 per cent at all operating pressures.

2.4 Effect of drip irrigation on growth and yield of crop

Bernear (1971) carried out experiments on tomato crop and reported that with drip irrigation system there was about 50 per cent water saving over furrow irrigation. There was a significant increase in yield under drip irrigation system

Sivanappan and Natarajan (1976) carried out field studies to see the performance of drip and surface irrigation on tomatoes. They found that there was only 78.4 per cent water saving and 26 per cent yield increase on tomato due to drip irrigation compared to surface irrigation.

Padmakumari and Sivanappan (1978) conducted experiments at for 2 seasons with brinjal grown by drip irrigation. The yield was 18,750 kg/ha for a total of 24 cm of water used. They observed that the plant height was not significantly high but the number of branches was more and the yield was above normal.

Sivanappan *et al.* (1979) indicated that irrigation requirement of chilli crop was 402 cm and 100 cm in Tamil Nadu under furrow and drip irrigation, respectively. Drip irrigation of chilli plants with small amount of water gave good yields of 2.65 to 4.0 metric tonnes per hectare with 150 to 180 m^3 of water. By increasing the amount of water to 250 m^3, a yield of 3.3 to 4.5 metric tonnes per hectare was achieved.

Optimization and minimization of water to be applied to the crops is essential in drip irrigation system. Yield of crops were adversely affected with the excess or inadequate water supply. Yield can be considerably increased by adopting proper irrigation management. For proper irrigation management scheduling of water is essential (Tan, 1980). Irrigation scheduling is the process by which an irrigator determines the timing and quantity of water to be applied in to the crops. According to Tan and Lanye (1981) for proper irrigation management the challenge is to estimate the crop water requirement in the context of growth stages and climate.

Yield response to irrigation was significant only if water stress was severe enough to affect normal plant growth. If the rainfall was inadequate, more frequent irrigation at lower soil moisture tension significantly increased marketable yield (Batal and Smittle, 1981). The effect of water quantities of 2, 4 or 6 mm/day and drip irrigation frequencies of every 1, 2 or 3 days on the fruit production in bell pepper was positively correlated with the amount of water and negatively with percentage of dry matter. Fruit mean weight and the incidence of injured fruit did not differ between treatments, but fruit wall thickness increased with decreasing with amount of water and greater irrigation frequency and decreased with raising water quality and reduced irrigation frequency (Caixeta *et al*., 1981).

Lin and Hubbles (1983) studied the effectiveness of different amounts of water applied through drip irrigation on yield and quality of tomato. Four levels of moisture maintaining above 25, 50, 65 and 80 per cent available water was used. Such treatments produced 20-40 per cent more marketable yield than the treatment with monthly furrow irrigation.

Russo (1983) observed that for a given amount of irrigation water, yield of chilli obtained under daily irrigation was greater than the yield obtained under irrigation once in three days. Pampatiwar *et al*. (1986) showed that drip method saved water by 29 per cent along with an increase in yield of brinjal by 16 per cent. Seasonal net irrigation requirement was estimated to be 34.1 cm for winter and 35.2 cm for summer pepper (Goyal *et al*., 1987).

According to Sivanappan *et al*. (1987) different methods of moisture controls provided yield of 11 000 to 14 000 kg/ha, whereas water requirement ranged from 20.6 cm to 69 cm. Similarly, different systems of drip required 13.5 cm of water besides 40 cm of rainfall, where as control plot required 60 cm of water along with a 40 cm of rainfall. Such a water application provided yields of 12 000 to 14 200 kg/ha as against the control plot 12 500 kg/ha.

Singh (1987) conducted field experiments to study the effect of irrigation on the growth and yield of okra. It was found that the irrigation increased vegetative growth and fruit yield in Okra in comparison to un irrigated control treatment. It was also reported that the irrigation level of 60 per cent pan evaporation produced maximum fruit yield.

Roshni *et al.* (1992) conducted experiments on influence of irrigation and conservation methods on chlorophyll content, yield and water use efficiency of chilli. The highest water use efficiency was obtained under drip irrigation, 80 per cent field capacity and coir pits mulching. Water use efficiency of 0.729 t/ha-cm and water saving of 51 per cent was higher under drip irrigation at 0.4 CPE compared to surface irrigation (Khistaria, 1993).

Locascio and Smajstria (1996) studied the effect of amount of water application and mulches for 3 years on irrigated tomatoes by applying water at 0.00, 0.25, 0.5, 0.75 and 1.00 times pan evaporation in one application per day. They found that fruit yield gets doubled with drip irrigation. The total yield was found highest with quantities of 0.75, 0.5 and 1.00 times pan evaporation and significantly lower with 0.25 and 0.5 times pan evaporation values.

In water melon, 25 per cent increase in yield and 40 per cent saving in water were observed with drip irrigation compared to furrow irrigation. Similarly in musk melon, 0-21 per cent increase in yield was recorded with a saving of 16 per cent water (Prabakar and Hebber, 1996).

Studies conducted at Bhavanisagar, Tamil Nadu, revealed that drip irrigation once in two days to sugarcane at 40 per cent of surface irrigation with 175 kg nitrogen per hectare recorded higher cane yield of 166 metric tonnes per hectare along with a water saving of 43.6 per cent compared to conventional furrow irrigation (Selvaraj *et al.*, 1997). At Bhavanisagar, results indicated that fresh rhizome yield of turmeric was increased up to 76.3 per cent with a water saving of 53.1 per cent besides 25 per cent saving in nitrogenous fertilizer saving up to 27.3 per cent (WMS, 1997).

Research work on micro irrigation in tomato clearly indicated that drip irrigation at 75 per cent of CPE has registered an increase in fruit yield up to 59 per cent along with a water saving up to 29 per cent compared to furrow irrigation at 0.8 IW/CPE ratio (Ashokaraja, 1998).

Gilsha *et al*. (1998) conducted field experiment on effect of use of synthetic mulch on moisture conservation and yield of drip irrigated brinjal at Tavanur. The results indicated that drip irrigation with black mulch gave better yield compared to transparent mulch. The yield was about 76 per cent higher than the control treatment. Optimum micro climate around the plant and higher moisture content in the root zone were the reasons for increased yield from black mulched treatments. Treatments with transparent mulch reduced yield due to higher soil temperature. In drip method 0.8V volume of irrigation level was the best.

Experiments at Bhavanisagar revealed that drip irrigation to tapioca at 50 per cent of surface level once in two days has registered higher tuber yield of 51.6 t/ha which was comparable with that of surface irrigation together with a water saving up to 50 per cent and nitrogen saving up to 33 per cent (Anonymous, 1998 a).

Dhanpal *et al.* (1998) reported that drip irrigation equal to 66 per cent of open pan evaporation (E_o) proved to be the best method of irrigation with a water saving of 34 per cent compared to 100 per cent of E_o of basin and drip method. Annual leaf production and nutrient content was not affected by reducing the quantity of water input.

Joby *et al.* (1998) conducted studies on drip irrigation and plastic mulching for horticultural crops in Tavanur. The results showed that the vegetative growth of plants with V volume of water and 0.8V volume of water was better than 0.6V and V flood. On mulched plants, about two weeks earlier flowering and emergence were noted than non mulched plants. The water use efficiency and benefit cost ratio were the highest in 0.6V together with black mulch.

Patel *et al.* (1998) conducted experiments on cotton and castor using drip irrigation based on fraction of pan evaporation (FPE). The results showed that drip irrigation operated at 0.5 FPE recorded significantly higher seed cotton yield of 2 995 kg/ha with 227 mm of water than surface irrigation yield of 2364 kg/ha with 480mm of water. Drip irrigation at 0.2 FPE level required 173 mm of water to harvest 2 122 kg/ha castor yield. Water saving amounted to 472 mm, under drip irrigation in comparison with surface irrigation.

Studies conducted in the farmer's field at Coimbatore during 1993-1996 indicated that drip irrigation at 112 litres /tree/day has recorded 63 per cent water saving with yield increase up to seven per cent compared to surface irrigation (Muthuchamy, 1998). Experiments at Bhavanisagar revealed that drip irrigation to tapioca at 50 per cent of surface level once in two days has registered higher tuber yield of 51.6 tonnes per ha which was comparable with that of surface irrigation together with a water saving upto 50 per cent and nitrogen saving up to 33 per cent (Anonymous, 1998 b).

Singh *et al.* (2000) made an attempt to study the effect of drip irrigation compared to conventional irrigation on growth and yield of Apricot, to work out its irrigation requirement. Drip irrigation at 80 per cent evapotranspiration of water gave significantly higher growth and fruit yield of 8.6 tonnes per hectare compared to that surface irrigation. Plastic mulch plus drip irrigation further raised the fruit yield to 10.9 tonnes per hectare. Drip irrigation besides giving a saving of 98 per cent irrigation resulted in 3.3 metric tonnes per hectare higher fruit yield.

Singh *et al*. (2000) studied the yield, water requirement and economics of drip irrigation in litchi orchard at farmer's field in Uttar Pradesh. It was found that good quality marketable yield of litchi varied from 12.5 to 16 to metric tonnes per hectare for drip system. The total volume of water applied was 282 mm for drip irrigation during four months of system operation. The benefit cost ratio was found to be 3.91 for drip irrigated litchi orchard compared to 3.05 for surface irrigated litchi.

Ashokaraja (2001) conducted studies on Micro irrigation revealed that drip irrigation is an effective tool for conserving water resources. The studies revealed significant water saving ranging between 40 to 70 per cent by drip irrigation compared with surface irrigation with yield increased as high as 100 per cent in some crops in specific location.

Dhanpal *et al.* (2001) conducted field experiments with 'Chowghat Orange Dwarf' ('COD') x 'West Coast Tall' (WCT) and 'West Coast Tall' coconut (*Cocos nucifera* L.) cultivars under laterite soil condition, to study the influence of drip irrigation on nut yield and nut characters at Kasaragod, Kerala. The treatments consisted of 3 levels of drip irrigation, 33, 66 and 100 per cent of open pan evaporation (E_o) daily along with basin irrigation of 100 per cent of E_o and rain fed control. Drip irrigation at 66 per cent of E_o (27 litres water/palm/day during December-January and 32 litres of water/palm per day during February-May) resulted in water saving and the nut yield was on par with 100 per cent through drip and 100 per cent of E_o through basin irrigation. Rain fed control and 33 per cent of E_o through drip treatments recorded significantly lower nut yield in both the cultivars. The nut characters like nut weight, copra thickness, and copra content were superior under irrigated treatments compared to rainfed control.

Jain *et al.* (2001) conducted experiments on the response of potato under drip irrigation and plastic mulching. The highest water use efficiency was found to be 3.24 t/ha- cm for the treatment irrigated with drip system at 80 per cent level with mulch as compared with to 2.17 t/ha-cm control treatment.

Narayana (2001) showed the benefits of micro-irrigation in terms of water saving and productivity gains were substantial in comparison to the same crops cultivated under flood method of irrigation. Apart from benefiting the farmers, irrigation development also helps to increase the employment opportunities and wage rate of the agricultural landless laborers, both of which are essential to reduce the poverty among the landless labor households.

Singh *et al.* (2001) carried out experiments to study the effect of different irrigation regimes of 100 per cent potential ET (V), 0.8V, 0.6V, 0.4V, 0.2V at four fertility levels on cauliflower yield with and without mulch under drip system and its comparison with the surface irrigation system. The highest curd yield was obtained under 100 per cent recommended dose of fertilizer with volume of water applied equal to 22cm through drip irrigation without mulch. The cost analysis indicated that higher net income over conventional practice and net profit per millimeter of water used were Rs 7 0741 per hectare and Rs 96.91 per hectare respectively under drip irrigation with mulch treatment and 18.8 cm (0.8V) irrigation application.

Singh *et al.* (2001) conducted studies on drip irrigation resulted in significant increase in production and water use efficiency of potato. At Udaipur it was reported that besides saving in water, the yield of potato tubers was high and weed growth was least in drip irrigation compared to surface irrigation.

The response to urea fertilizer with drip irrigation and compared with conventional furrow irrigation for two years. Application of nitrogen through the drip irrigation in ten equal splits at eight days interval saved 20 to 40 per cent nitrogen as compared to the furrow irrigation when nitrogen was applied in two equal split. Similarly, 3.7 to 12.5 per cent higher fruit yield with 31 to 37 per cent saving of water was obtained in the drip system. Water use efficiency in drip irrigation, on an average nitrogen level was 68 and 77 per cent higher over surface irrigation in 1995 and 1996, respectively. At a nitrogen application rate of 120 kg/ha, maximum tomato fruit yield of 27.4 and 35.2 tonnes per hectare in two years was recorded (Singhandhube *et al.,* 2003).

Sefer *et al.* (2009) was conducted study to investigate the effects of drip irrigation methods and different irrigation levels on yield, quality and water use characteristics of lettuce cultivated in solar green house. The result showed that the highest yield was obtained from subsurface drip irrigation at 10cm drip line depth and 100 per cent of Class A Pan Evaporation rate treatment. The water use efficiency and irrigation use efficiency increased as the irrigation was reduced.

2.5 Effect of fertigation on growth and yield of crop

The use of fertigation in drip irrigation system was reviewed by Haynes (1985). The advantages of the use of fertigation in a drip irrigation system included reduced labour, increased fertilizer efficiency and the increased flexibility of fertilizer application. Fertigation allows nutrient placement directly into the plant root zone during critical periods of nutrient demand (Mikkelsen, 1989).

Bachav (1995) conducted a field experiment on fertigation by comparing fertigation with NPK over farmer's fertilizer practice with conventional fertilizers in terms of yield, quality and monetary returns. Fertigation at weekly intervals was found more convenient and economically profitable for the farmers.

Siti *et al.* (1995) conducted a field experiment to study the influence of potassium fertilizer levels of 0, 66 and 132 kg/ha and different types of mulching using black plastic, reflective plastic or coconut fronds on growth and yield of chilli. Yield was increased by 89 per cent and 142 per cent with K levels of 66 and 132 kg/ha, respectively. Highest yield was obtained from plant grown under reflective plastic mulch.

Drip irrigation generates a restricted root system requiring frequent nutrient supply. Nutrient requirement may be satisfied by applying fertilizers in irrigation water. Maximization of crop yield and quality and minimization of leaching losses below the rooting volume may be achieved by managing fertilizer concentration in measured quantity of irrigation water according to crop requirement (Hagin and Lowengart, 1996).

Highest fruit yield of 45.7 t/ha was obtained for tomato with application of recommended dose of fertilizers comprising polyfeed (19:19:19), MAP (12:60:0) and urea through fertigation. The yield were nearly 22 -27 per cent higher compared to yields obtained in crop which was provided with normal fertilizers through soil application (Prabhakar and Hebber, 1996).

Pawar *et al.* (1997) took up studies to assess the effects of fertigation through drip on the growth, yield and quality of banana. The result revealed that, for banana the fruit yield was significantly higher in normal planting than paired row planting. The fruit yield increased significantly with water soluble complex fertilizers compared to Nitrogen alone and it also increased significantly with an increase in fertilizer levels.

Shinde *et al.* (1997) conducted field experiment to study the effect of water soluble fertilizers through drip on the growth and yield of cotton. The expression of growth and yield contributing characters of cotton due to normal planting was at higher magnitude compared to paired row resulting in higher seed cotton yield by 7.75 per cent. Maximum seed cotton yield of 3.4 t/ha was obtained due to 100 per cent of recommended fertilizer dose.

Neelam *et al.* (1998) conducted field experiments at IARI, New Delhi with four fertilizer levels of 100 per cent, 80 per cent, 60 per cent, 40 per cent. The yields of onion realized under different treatments of fertigation were compared with that achieved by conventional methods. Fertigation resulted in 60 per cent saving of fertilizer for achieving same level of production compared to conventional method of fertilizer application.

Fertigation studies carried out on chrysanthemum in a high cost green house at UAS, Banglore, revealed that fertigation with 80 per cent recommended level of fertilizers (10: 15: 10 g/m^2) resulted in maximum growth, early flowering and highest extent of marketable flowers of good quality as compared to soil application of recommended level of fertilizers (Gopal, 1999).

Application of soluble fertilizer like urea and muriate of potash through drip irrigation could bring about substantial savings of 20-25 per cent in fertilizer use, besides minimizing pollution of ground waters through nitrate – nitrogen leaching to a considerable extent. Fertigation also offers the possibilities of using nutrients matching the crop demand at different stages of crop growth (Srinivasa, 1999).

Anil *et al.* (2001) conducted field experiment in sandy loam soil to investigate the water and nutrient use efficiency of sprouting Broccoli grown on sandy loam soil using fertigation. Yields obtained showed that substantial saving in the fertilizer applied, to the extend of 20-40 per cent could be accomplished through fertigation.

Singh *et al*. (2001) conducted field experiments to investigate the water and nutrient use efficiency of sprouting broccoli growing on sandy loam soil using fertigation. The treatments included application of the recommended fertilizer dose as soil application and irrigation through drip irrigation as well as three levels of fertigation viz. 100, 80, 60 per cent of the recommended fertilizer doses. Flood irrigation with recommended doses was considered as control. Yield obtained indicated substantial saving in the fertilizer applied to the extend of 25 – 40 per cent.

The effects of irrigation water level and nitrogen fertilizer on total canopy and wetted area basis of chilli in respect of yield, water saving and water use efficiency was studied on loamy sand soil by Singh *et al*. (2001). The highest yield of 3.03 kg/ha was recorded with water applied on total area basis along with 180 kg N/ha. The study suggested that it is better to schedule irrigation at 0.8 of E pan evaporation and apply on canopy area basis combined with 180 kg nitrogen per hectare to maximize the production.

Singh *et al*. (2001) conducted experiment on the response of drip irrigation and black plastic mulching on young mango trees. The study indicated that the biometric growth of the treatments irrigated at 60 per cent level through drip system with plastic mulching performed better when compared to 80 per cent and 100 per cent levels of water use along with water saving of 20 – 40 per cent.

Veeranna *et al.* (2001) conducted field experiments to investigate the effects of broadcast application and fertigation of normal and water soluble fertilizers at three rates through drip and furrow irrigation methods on yield, water and fertilizer use efficiency in chilli (*Capsicum annum*). Fertigation with 80 per cent water soluble fertilizers was effective in producing about 31 and 24.7 per cent higher yield over soil application of normal fertilizers at 100 per cent recommended level in furrow and drip irrigation methods respectively, with 20 per cent saving of fertilizers and 36 per cent saving of irrigation water.

Subbi *et al*. (2005) was conducted a study to compare the effect of subsurface and surface drip irrigation on soil moisture distribution and growth of three years old pre-bearing mango in Agricultural Research Station, Andhra Pradesh. Soil moisture at the surface and near the dripper was the highest in the case of surface dripper and subsurface dripper placed at 30 cm depth.

Anitha *et al.* (2006) did experiments on nutrient management in chilli based cropping system in Kerala. Nutrient levels significantly influenced the yield of crops in chilli based cropping system. Better growth and yield performance of chilli, French bean and amaranthus was observed when both chilli and intercrops were given 100 per cent nutrient dose. The yield of intercropped chilli was 8917, 5598 and 4865 kg/ha at 100, 75 and 50 per cent nutrient doses respectively

Shatarpoora *et al.* (2005) conducted an experiment at the Assam Agricultural University to investigate the effect of drip irrigation and plastic mulch on yield of Broccoli as compared to that over furrow irrigation. The water use efficiency was highest at lower level of ET replenishment by drip and with mulch. Maximum yield was obtained under drip irrigation replenishing 120 per cent of ET depletion and under mulch.

Vijaya *et al.* (2007) conducted studies at Agricultural Research Station Bhavanisagar to maximize the water and fertilizer use efficiency of drip system in brinjal crop. The experiments were laid out in Factorial Randomised Block Design with nine treatments which included three irrigation levels 100, 75 and 50 per cent of pan evaporation along with three fertigation levels, viz. 125, 100 and 75 per cent of recommended Nitrogen and Pottasium application by fertigation and replicated thrice. In brinjal higher yields with maximum shoot length and number of branches per plant were recorded for the treatment with 75 per cent of PE with fertigation of 75 per cent of recommended Nitrogen and Pottasium.

Yasser (2009) reported the impact of fertigation scheduling on tomato yield under arid ecosystem conditions. Results revealed that tomato yields, water and fertilizer use efficiency had been enhanced by 25.6, 49.3 and 20.3 per cent respectively under surface drip in comparison with solid set sprinkler irrigation system. The cost of tomato production under fertigation was lower than that when using traditional method of fertilization.

2.6 Effect of mulch on plant growth and yield

Baskett (1960) reported that black polythene sheeting used for mulching young plum trees in New South Wales reduced the need for watering by one-third. Mulch materials are well known to improve conservation of soil moisture during during dry period in comparison to clean cultivation in apple (Baumeister, 1964 and Luchtov *et al.,* 1988).Mulching greatly increased the growth and vigor of fruit trees

(Haynes, 1980). The use of black polyethylene mulch, has been reported to control the weed incidence, reduce nutrient loss and improve the hydrothermal regime of soil (Ashworth and Harisson, 1983).

The advantages of mulching in vegetable crop production have been well documented. Various mulching materials are utilized and these include weed or grass clippings, paddy straw, bark, sawdust and plastic. Mulches can effectively minimize water loss as vapour, soil erosion, weed problems and nutrient loss (Clough *et al.*, 1990).

The advantages of drip irrigation coupled with black polyethylene mulch has been reported to improve the yield, quality and water use-efficiency of high value crop like tomato (Raina *et al*., 1999).

Rajbir *et al.* (2003) was conducted a field experiment on sandy loam soil to investigate the effect of drip irrigation and black polyethylene mulch compared with surface irrigation on growth, yield and water use efficiency and economics of tomato. Drip irrigation at 80 per cent pan evapo transpiration applied gave significantly higher fruit yield compared with the surface irrigation. Use of black polyethylene mulch plus the drip irrigation further raised the fruit yield to 57.89 t/ha.

Tiwari *et al.* (2005) conducted experiments on pineapple crop grown in the lateritic sandy loam soil to study yield response and to evaluate the economic feasibility of its cultivation with drip irrigation and plastic mulch. The yield of pineapple was highest and recorded 81 t/ha in case of 100 per cent irrigation requirement met by drip plus plastic mulch. The net income was highest for the 100 per cent irrigation requirement met with drip plastic mulch.

Singh *et al.* (2009) reported the effect of drip irrigation and polyethylene mulch influence on growth, yield and water use efficiency of tomato in India. Among different irrigation levels, drip irrigation at 80 per cent ET resulted in higher fruit yield of 45.57 t/ha compared with surface irrigation.

2.7 Water use efficiency and fertilizer use efficiency

The use of fertigation in drip irrigation system was reviewed by Haynes (1985). Ramesh (1986) noticed that higher level of irrigation with drip method produced significantly higher irrigation water use efficiency of 20.86 kg/ha/mm compared to furrow irrigation which produced an yield of 15.64 kg/ha/mm. Pairing the rows also increased irrigation water use efficiency over uniform row planting.

The advantage of the use of fertigation in a drip irrigation system included reduced labour, increased fertilizer efficiency and the increased flexibility of fertilizer application. Fujiyama and Nagal (1987) reported that the nutrient solution brought about a high nutrient recovery rate and appears to be a suitable method for supplying nutrients and water. Palled *et al.* (1988) found maximum dry chilli yield of 1968 kg/ha and water use efficiency with irrigation at 0.5 IW/CPE ratio. Fertigation allows nutrient placement directly into the plant root zone during critical periods of nutrient demand (Mikkelesen, 1989).

Balassubrahmanyam (1999) conducted studies on the evaluation of water requirement of mango. The results showed that mango plantation responds well to irrigation at 10 950 litres/tree/year, whereas the bearing trees require a minimum 20 080 litres/tree/year. The water use efficiency was maximum under drip system.

2.8 Soil moisture distribution pattern under drip irrigation system

Dhanpal *et al*. (1998) reported that vertical and horizontal movement of water and volume of active root zone in coconut basin wetted in laterite soils were directly related to the quantity of water applied. The percentage volume of active root zone wetted was 13.6 and 18.2 respectively under surface and subsurface placed emitters. The subsurface placement wetted 35 per cent more volume than surface placed emitter.

Jain *et al.* (2001) conducted studies on the response of potato under drip irrigation and plastic mulching. The results revealed that maximum water was required 1.0 V volume in irrigated treatments (11.23 cm), followed by 0.8 V level (9.39 cm) and 0.6 V level (7.56 cm). It also showed that maximum saving of water was obtained in drip irrigated at 0.6 V level (36.66 per cent), followed by trickle 0.8 V levels (16.32 per cent).

Through drip irrigation the soil water status was maintained at optimum level in the root zone of the crop (0-50cm) which extended up to 30 cm horizontally from the plant (Anil *et al*., 2001) In the surface layer the soil (< 20 cm) the soil water content was reduced to 15 per cent by volume approximately in the 0-5 cm layer before irrigation, but 20 per cent in the surface layer up to a distance of 45 cm from the emitting point.

Shirahatti *et al.* (2001) made comparison of drip and furrow irrigated cotton on a red soil. The soil moisture was measured in between two irrigation intervals. In vertical distribution, maximum soil moisture content increased along the depth but in lateral distribution, maximum soil moisture was found just below the drip source (0-10cm) and decreased as the distance from the water source increased.

Reddy *et al.* (2001) conducted experiment on water, nutrient and root distribution of sweet orange as by drip irrigation and micro nutrient management was studied. When soil moisture was taken three days after basin irrigation, soil moisture was 13.28 per cent in surface layer while it was 9.79 per cent with drip irrigation. Similar trend was observed at lower depths of soil. From profile taken 1 m away from drip line to a depth of 1 m, it was found that soil moisture was 10.5 per cent.

MATERIALS AND METHODS

The present study, ***"Impact of fertigation and drip system on performance of chilli"*** was carried out in KCAET Instructional Farm, Tavanur during October 2011 to April 2012. A laboratory study was also conducted to evaluate the performance of different fertilizer application equipments i.e. ventury injector, dosmatic fertigation unit and fertilizer tank. The materials used and methodology adopted during the study are described in this chapter.

3.1 Components of the experimental set up

3.1.1 Pumping unit

An electric motor of 12 hp, volt 380/415V, cycle 50, phases 3 and current 12A connected with a pump of 4 hp, size of 60 × 65mm, 2900 rpm and capacity of 23.5 lire per second was used for the present study. A portion of water was by passed to the tank by means of a ball valve arrangement to control the inlet pressure. The water source for drip system was a well located near the experimental site.

3.1.2 Ball valve assembly

Ball valves, each having diameter of 40 mm were used on the sub mains to control the flow into each block. The time of operation of these ball valves can be controlled according to the requirement of the irrigation to the individual field.

3.1.3 Screen filter

Screen filter is fitted to remove the solid impurities like fine sand and dust from the irrigation water. The parts of the screen filter consist of body, one or two filtration elements, gaskets, cover, inlet, outlet and drainage valves. Screen filters are characterized by the size, filtration area and size of the openings. Screen filter model *Jain Super Clean Filter* of nominal size of 2 inch, mesh size of 100 micron, nominal pressure of 1.5 kg(f)/cm^2 and nominal flow rate of 25m^3/hr was used for the experiment.

3.1.4 Pressure gauges

Two pressure gauges with pressure range of 0-7 kg(f)/cm^2 were located before and after the fertigation unit for indicating the pressure in the system.

3.1.5 Mainline and Laterals

Rigid PVC pipes of 50 mm diameter with pressure rating of 6 kg(f)/cm^2 were used as the main and sub main pipes. The key component of the drip irrigation system is the lateral which delivers the water to the crop root zone. Low density polyethylene pipe of 12 mm diameter was used as the laterals. End caps were provided at the end of laterals. The lateral constituted of inline drippers of discharge 4 liters per hour in spacing of 50 cm for a length of 5 m.

3.2 Fertigation and equipments

Fertigation is a recent technology in fertilizer application. Ventury injector, dosmatic fertigation unit and fertilizer tank were the different fertigation equipments used for the study.

3. 2. 1 Ventury Injector

A ventury fertigation unit of ¾ inch manufactured by *Jain Irrigation Systems* was used for the study. Ventury injector was connected directly to the main line. A suction pipe with an end filter is connected from the centre of unit and its filter was inserted into the fertilizer tank. A partial vacuum is created in the system which allows suction of the fertilizers into the irrigation system through ventury action. The vacuum is created by diverting a portion of water flowing through the main to the ventury. When the flow passes through the ventury, the velocity of flow increases creating a drop in pressure. When the pressure drops, the fertilizer solution is sucked into the ventury through a suction pipe from the tank and from there into irrigation stream. The experimental set up for ventury fertigation unit is shown in Plate 1.

3. 2. 2. Dosmatic fertigation unit

These are piston or diaphragm pumps which are driven by the water pressure of the irrigation system. The injection rate is proportional to the flow of water in the system. A high degree of control of the fertilizer injection rate is possible. Dosmatic fertigation unit was a self priming unit and operated on hydraulic pressure. Operating pressure for this fertigation unit is 0.3 – 5 kg(f)/cm^2. The experimental set up for dosmatic fertigation unit is shown in Plate 2.

The water in the main line on its way through, activates the dosmatic which in turn takes up the required quantity of concentrate directly from the container. Inside it, the concentrate is mixed with water, and the water pressure forces the solution down stream to main line. Dosmatic fertigation unit was connected as directly to the main line. A suction pipe with an end filter is connected from the centre of unit and its filter was inserted into the fertilizer tank. Suction was created by the piston arrangement maintaining a pressure difference.

3. 2. 1. 3 Fertilizer Tank

A part of the irrigation water is diverted from the main line of flow through a tank containing the fertilizer soluble solid form. Before returning to the main line, the pressure in the tank and the main line is the same but a slight drop in pressure is created between the take off and return pipes for the tanks by means of a pressure reducing valve. This causes water from main line to flow through the tank causing dilution and flow of the diluted fertilizer into the irrigation stream. Fertilizer tanks are available in the market in the range of 90, 120, 160 litres. A locally manufactured fertilizer tank of capacity 25 litres was also used for the study.

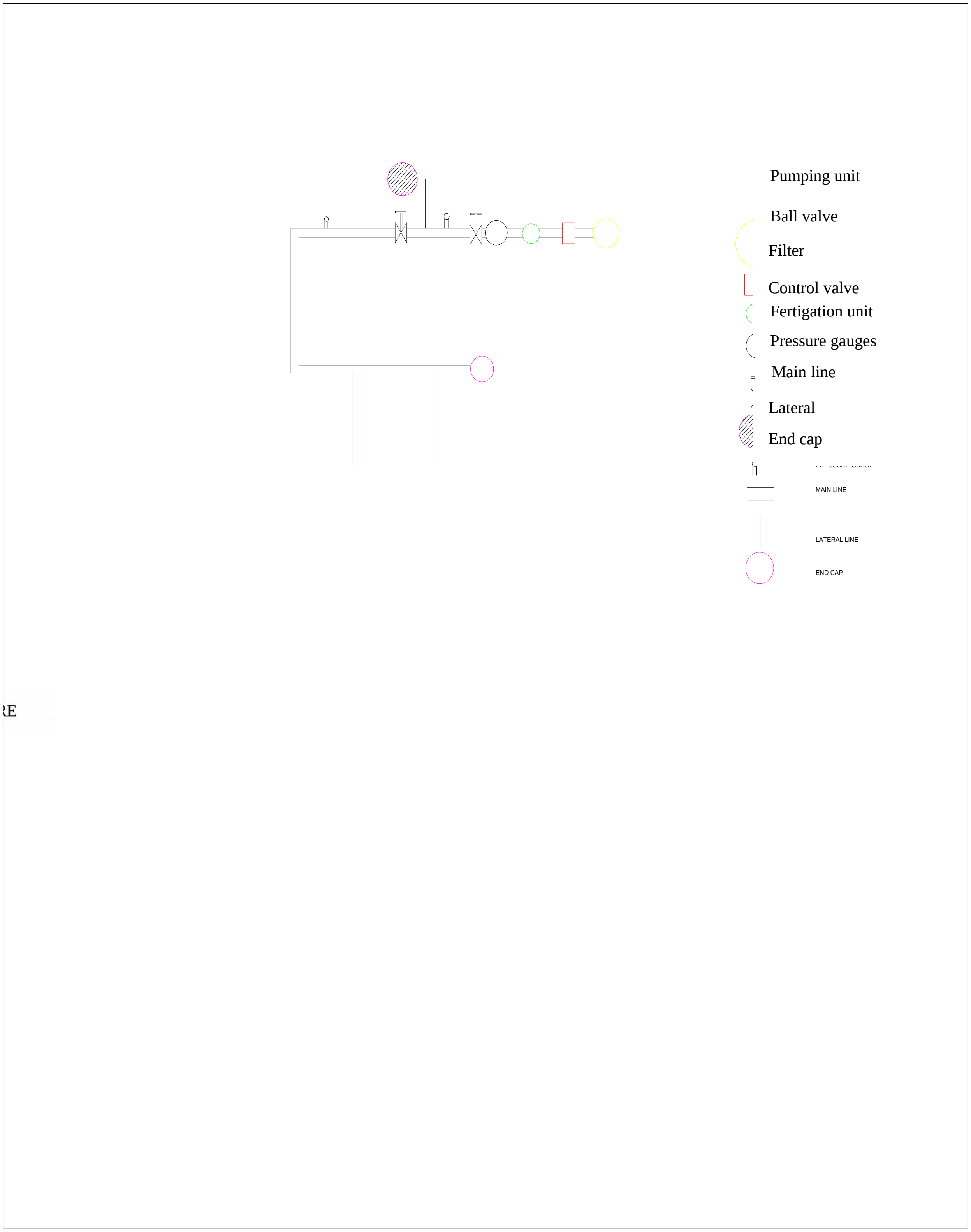

Fig.4 Experimental layout

Plate 1. Experimental set up for ventury injector

Plate 2. Experimental set up for dosmatic fertigation unit

3.3 Performance evaluation of the fertigation equipments.

For the tests conducted for assessing the hydraulic performance of the system. Eight pressure differences of 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7 and 0.8 kg(f)/cm^2 between the inlet and outlet of fertigation equipment were chosen. The pressure indicated at the pressure gauge fitted at the outlet of the fertigation system i.e. at the beginning of the laterals is denoted as the operating pressure of the system. The inlet pressures were selected in the range of 0.4 kg(f)/cm^2 to 1 kg(f)/cm^2 , the normal operating pressure range of a drip irrigation system. The gate valves were adjusted in order to maintain the inlet and outlet pressures.

3. 3. 1 Variation of suction rate with pressure difference

The amount of fertilizer injected into the system is very important in the case of fertigation. The hydraulic performance of the system will vary with respect to the suction rate of the fertilizer into the system. The amount of fertilizer injected into the system was a measure of the suction rate. The suction rate could be varied by varying the pressure difference. Variation of suction rate with pressure difference was studied for ventury injector and dosmatic fertigation unit.

3. 3. 2 Variation of motive flow rate with operating pressure

The inlet and outlet pressure of the ventury injector were adjusted in order to obtain the various pressure differences. The procedure was repeated for various pressure differences. The volume of water collected from each emitter for various pressure differences at a particular time period was noted. Variation of motive flow rate with operating pressure was studied for the ventury injector, fertilizer tank and the dosmatic fertigation equipment.

3. 3. 3 Variation of motive flow rate with suction rate

For studying the hydraulic performance of the ventury injector, the suction rate and motive flow rate for different inlet and outlet pressure were observed.

3. 4 Hydraulic performance of drip and fertigation system

The hydraulic performance of the drip and fertigation system was studied with respect to emitter coefficient of manufacturing variation, emitter flow variation and uniformity coefficient. These factors are dependent on the operating pressure of the system. The flow from each inline emitter was collected using catch cans for 10 minutes and the corresponding discharge rate was calculated. The Christiansen uniformity coefficient, emitter coefficient of manufacturing variation and emitter flow variation were worked out as suggested by Christiansen, Karmeli (1974) and Bralts *et al*. (1981)

3. 4. 1 Emitter coefficient of manufacturing variation

The emitter coefficient of manufacturing variation was used as a measure of the anticipated variations in the discharge of emitters. The inline drippers were tested for various operating pressures of 0.2, 0.3, 0.4, 0.5, 0.6 and 0.7 kg(f)/cm^2 and the coefficient of manufacturing variation were determined after connecting the dosmatic fertigation unit to the mainline. The pressure indicated by the pressure gauge fitted at the outlet of the fertigation system was denoted as the operating pressure of the system. The discharge from the emitters was collected for various operating pressures for a particular period of time. The discharge from the inline emitters was collected and the manufacturing coefficient of variation was determined for various operating pressures after connecting the dosmatic fertigation unit in the mainline.

3.4.2 Emitter flow variation

The distribution efficiency and the application efficiency will depend upon the variation of emitter flow along the lateral line and the variation of amount of flow from the sub main into the lateral. The discharges from a set of emitters were collected to study the emitter flow variation with respect to operating pressures, after connecting the dosmatic fertigation unit to the mainline. The various operating pressures were 0.1, 0.2, 0.3, 0.4 and 0.5 kg(f)/cm^2. The operating pressures were adjusted by regulating the gate valve at the inlet of the laterals. The maximum and minimum discharges from the set of emitters at various operating pressures were chosen to calculate the emitter flow variation. The emitter flow variation was determined by the equation suggested by Bralts *et al*. (1982)

3.4.3 Uniformity coefficient

To find out the uniformity coefficient, the discharges from the emitters of the first line and second line laterals were collected for a particular period of time for various operating pressures

The uniformity coefficient was calculated using the formula

$$\mathbf{Cu} = \left(1 - \frac{\sum x}{mn}\right) \times 100$$

Where,

Cu - Uniformity coefficient.

x - Numerical deviation from the average observations

m - Average value of all observation.

n - Total number of observations.

3.5 FIELD EXPERIMENT

3.5.1 Climatic condition

The place is situated at 10^0 51' 23" N and 75^0 59'13" E elevation of 29 ft. The experiment was conducted during 2011- 2012 to evaluate the response of chilli to fertigation, drip system layout and mulching.

3.5.2 Treatment details

The experiment was laid out with seven treatments, combination consisting of three irrigation levels and two drip system layout.

Main plots: Irrigation levels

1. I_1 : 65% of the daily irrigation requirement.
2. I_2 : 75% of the daily irrigation requirement.
3. I_3 : 85% of the daily irrigation requirement.

Sub plots Drip system layout

1. D_1 : One lateral in between two rows of crop in a bed
2. D_2 : One lateral for each row of crop in a bed

3.5.3 Design and Layout

The experiment was laid out in Randomised Block Design having seven treatment combinations and was replicated thrice.

Plate 3. Uniformity coefficient determination

Table 1. Treatment details

Sl. No.	Treatment	Name	Description
1	T_1	I_1D_I	65% of the daily irrigation requirement, with one lateral for each row of crops in a bed.
2	T_2	I_1D_2	65% of the daily irrigation requirement, with one lateral in between two rows of crop in a bed.
3	T_3	I_2D_1	75% of the daily irrigation requirement, with one lateral for each row of crops in a bed.
4	T_4	I_2D_2	75% of the daily irrigation requirement, with one lateral in between two rows of crop in a bed.
5	T_5	I_3D_1	85% of the daily irrigation requirement, with one lateral for each row of crops in a bed.
6	T_6	I_3D_2	85% of the daily irrigation requirement, with one lateral in between two rows of crop in a bed.
7	T_7		Control

.

T_1- 65 per cent of the daily irrigation requirement, with one lateral for each row crop

T_2- 65 per cent of the daily irrigation requirement, with one lateral in between two rows of crop

T_3- 75 per cent of the daily irrigation requirement, with one lateral for each row crop

T_4- 75 per cent of the daily irrigation requirement, with one lateral in between two rows of crop

T_5- 85 per cent of the daily irrigation requirement, with one lateral for each row crop

T_6- 85 per cent of the daily irrigation requirement, with one lateral in between two rows of crop

T_7- Control plot

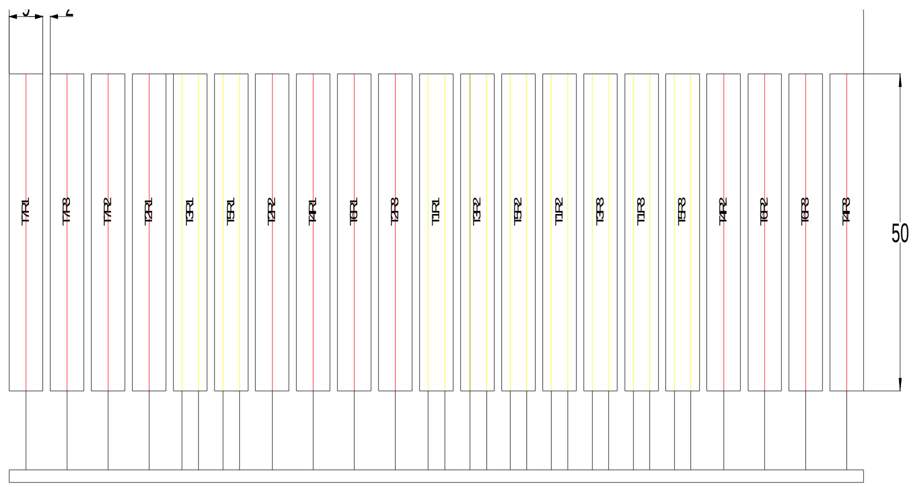

Fig.5 Plan lay out of the experiment with laterals

T_1- 65 per cent of the daily irrigation requirement, with one lateral for each row crop

T_2- 65 per cent of the daily irrigation requirement, with one lateral in between two rows of crop

T_3- 75 per cent of the daily irrigation requirement, with one lateral for each row crop

T_4- 75 per cent of the daily irrigation requirement, with one lateral in between two rows of crop

T_5- 85 per cent of the daily irrigation requirement, with one lateral for each row crop

T_6- 85 per cent of the daily irrigation requirement, with one lateral in between two rows of crop

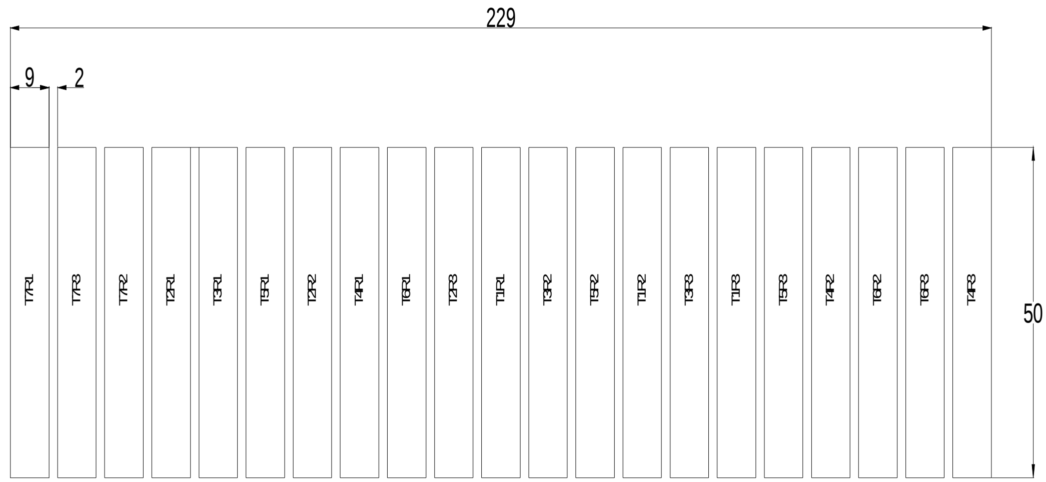

Fig.6 Plan lay out of the field

All dimensions are in mm

3. 6 CULTURAL OPERATIONS

3. 6. 1 Land preparation

The soil type of the experiment field was sandy loam. The field was ploughed using tractor drawn disc plough and pulverized using rotavator. The plots of size 5×1 m^2 were drawn forming ridges around plot. Each plot was levelled manually and then ridges and furrows were formed.

3. 6. 1. 1 Variety : Chilli (*Capsicum Annum*), Ujwala

A spacing of 45 cm × 45 cm, recommended for chilli in the Package of practices recommendations: Crops (KAU, 2002) was adopted.

3. 6. 2 Nursery preparations

Chilli variety ***Ujwala*** was chosen for cultivation. Chilli is a transplanted crop. Seeds were sown in the tray and one month old seedlings were transplanted to the main field. For sowing the seeds, the mixture of coco powder, farm yard manure and soil were filled in the trays. After sowing the seeds, the mixture was again filled and irrigated with a rose can daily in the morning.

3. 6. 3 Mulching

Mulching is the process or practice of covering the soil to make more favourable conditions for plant growth, development and efficient production. When compared to other mulches, plastic mulches are completely impermeable to water and it therefore prevents the direct evaporation of moisture from the soil. It thus limits the water losses and soil erosion over the surface. It also reduces weed growth and increase the water and fertilizer use efficiency. Silver plastic mulch of 30 micron is used for covering the soil in the present study. Silver mulch sheet of 5m length were used in each plots.

Plate 4. Land preparation by rotavator

Plate 5. Beds preparation for transplanting of seedlings

Plate 6. Seedlings for transplanting in the field

Plate 7. Mulch sheet fixing

Plate 8. Mulch sheet placement and hole making

Plate 9. Transplanting of chilli seedling

3.6.4 Transplanting

Transplanting was done on 7th October 2011. Before planting, silver mulch sheets of 30 micron were spread in all plots except the control treatment. In the mulched plots, holes of 10 cm diameter were punched evenly at 50 cm × 50 cm grid points on the LDPE sheets. Seedlings were then planted in these holes. The seedlings planted were given initial shade protection for four days.

The transplanting was done at a spacing of 50 × 50 cm with 22 plants in each plot. The total plant population was 462 numbers. Gap filling was done within a week after transplanting to ensure optimum plant population.

3.6.4.1 Intercultural operations and weeding

Intercultural operations were carried out thrice, at 20, 45 and 60 days after transplanting followed by two hand weeding at 40 and 50 days after transplanting.

3.6.4.2 Plant protection measures

Plant protection measures were adopted for incidents of pest and disease attacks using recommended dose of chemicals.

3.6.4.3 Fertilizer application

Recommended dose of fertilizer was applied as per treatments in twenty equal splits at four days interval through fertigation. Nitrogen, phosphorus and potassium were the main nutrients required for the growth. Among these, major portion of phosphorous was applied as basal application through *rajphos.* Nitrogen and potassium were applied in the form of urea and *polyfeed* (19:19:19) by dosmatic fertigation unit.

3.7 Irrigation requirement

For better establishment of seedlings, immediately after transplanting, irrigation was given using rose cans. Scheduling of irrigation was done according to treatments, commencing from 20 days after transplanting. Evaporation was recorded from USWB class A open pan evaporimeter (mm/day) installed at in the meteorological observatory. The monthly water requirement was estimated on the basis of monthly pan evaporation data and it was about 1.75 litre/day/ plant. The discharge rate of the inline dripper was 4 lph. So the time required for irrigation in order to get 1.75 l/day/ plant for each plant in different treatment is given in Table 2.

3.7.1 Estimation of crop water requirement

Water requirement of crops is a function of evapotranspiration rate. Irrigation water requirement was calculated for different seasons. The maximum discharge required during anyone of the three seasons is adopted for design. The daily water requirement for fully grown plants was calculated as

$$V = E_p \times K_c \times K_p \times W_p \times S$$

$$= 10 \times 1 \times 0.7 \times 1 \times 0.50 \times 0.50$$

$$= 1.75 \text{ l / day / plant}$$

3.7.2 Scheduling of Irrigation

Irrigation schedules were planned to provide the estimated water requirement of the crop. Irrigation was scheduled based on the daily crop water requirement of the crop. In order to determine the optimum water requirement for the crops, three irrigation levels were adopted which were 65, 75 and 85 percent of water requirement of chilli. The discharge rate of the emitter was 4 litres per hour at a nominal pressure of 1.5 kg (f) /cm^2. Water requirement for each treatment is shown in Table 3.

3.8 Installation of drip system and fertigation unit

Irrigation water was pumped through 7.5 kw motor pump set and conveyed through the main line of 63mm diameter PVC pipes after filtering through the screen filter. From the main pipe, sub main of 40mm diameter PVC pipes were installed. From the sub main, laterals of 14mm diameter LDPE were installed. Each lateral was provided with individual tap control for improving irrigation. Along the laterals, inline drippers were fixed at spacing of 50cm. The number of laterals installed was based on the number of rows of crops grown. The discharge rate of single dripper is 4 litres per hour.

Sub main and laterals were closed at the end with the end cap. After installation, trial run was conducted to access the mean discharge rate and uniformity coefficient. This was taken into account for fixing the irrigation application time. During the irrigation period an average uniformity coefficient of 90 to 95 per cent was observed. Laterals were placed for each row per plot and in between two rows per plot, with eleven emitters in each lateral at a discharge rate of 4 litres per hour. Scheduling of irrigation at 65, 75 and 85 per cent of irrigation requirement for each day was commenced after the transplanting.

3.9 Fertigation Scheduling

The fertigation was given at weekly intervals. The entire phosphorous was applied as basal application. Nitrogen and potassium were applied through fertigation with twenty equal splits from third week to tenth week after planting. Water soluble fertilizers were used in this experiment. The recommended dose of fertilizer requirement for the chilli crop was 75: 40: 25 kg/ha. The recommended soluble fertilizers were applied simultaneously in a combined form to the plant root zone. The

Table 2. Time required for irrigation of each treatments.

Sl. No.	Treatments	Time required for irrigation (min)
1	T_1	17.83
2	T_2	35.66
3	T_3	21.08
4	T_4	42.16
5	T_5	24.32
6	T_6	48.64

Table 3. Amount of water requirement for each treatment

Sl. No.	Treatments	Amount of water required (l/day/plant)
1	T_1 and T_2	1.1
2	T_3 and T_4	1.3
3	T_5 and T_6	1.5

Table 4. Fertilizer requirement for Chilli

(Recommended dose of N: P: K is 75: 45: 20 kgha^{-1})			
Treatment (%)	Fertilizer required (g)		
	Urea (46: 0: 0)	Polyfeed (19: 19: 19)	Rajphos
100	1025	1243	709
Control	220	270	56

calculated amount of phosphorous was applied manually through *Rajphos* as a basal dose. Urea and polyfeed (19:19:19) were the fertilizers applied through fertigation.

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3.9.1 Fertigation through dosmatic fertigation unit.

The fertigation was given at weekly intervals. The entire phosphorous was applied as basal in the form of rajphos. N and K were applied through fertigation in the form of Urea and polyfeed with twenty equal splits from 3rd week to 10th week after planting. The applied dose of N, P and K for chilli is given in Table 4.

3.10. Determination of Water use efficiency

The fruit yield obtained for each treatment was divided by the quantity of water used consumptively for the respective treatments by this method. Water use efficiency was worked out and expressed in kg/ha and the total water utilized in mm.

WUE = *ha*
kg/¿
¿
Yield¿
¿

3.11. Determination of Fertilizer use efficiency

The fertilizer use efficiency was computed as described

FUE = *ha*
kg/¿
¿
ha
kg/¿
¿
Total quantity of nutrient applied¿
Yield¿
¿

3.12. Soil moisture distribution pattern

In order to analyze the variation in soil moisture at different depths, the gravimetric method of moisture content determination was made. The size of this wetted area is a function of irrigation and surface infiltration rates. In drip irrigation system, both the vertical and horizontal wetting fronts are important and a two dimensional moisture regime in the soil profile must be considered. Soil samples were taken using soil augers. The samples were taken from the desired depths of 0, 5, 10 and 20cm at particular distance of 5, 10 and 15cm laterally away from the plant.

Soil moisture contour maps were plotted by using computer software package 'Surfer' of windows version.

3.13. COLLECTION OF EXPERIMENTAL DATA

3.13.1 Biometric observations

For analyzing the growth pattern of the crop, four plants were selected randomly from the net plot area in each treatment and were tagged to record the various observations at 45 days interval from the day of transplanting. The parameters and procedures followed are given as follows, height of the plant, Number of branches/plant, Number of leaves in total branches, Stem girth, Yield and yield attributes

3.13.1.1 Height of the plant

The average height of the randomly selected plants grown under each treatment was taken. The measurement was taken from the ground surface to the shoot tip for the selected plants at monthly interval.

3.13.1.2 Number of branches per plant

Number of branches per plant were counted in randomly selected four plants at 45, 90, 135 days after transplanting and at harvest.

3.13.2. Yield (kg/ha)

Harvesting of the crops was done treatment wise after attaining maturity. After the first harvest, other harvests were done at an interval of 10 days. The first yield was taken two month after transplanting. The total of the seven harvests gave the total yield.

3.14 Statistical Analysis

Statistical analysis was done by two factor analysis of variance. Firstly one factor analysis was done to compare the six treatments over control. Then two factor analyses were carried out with factor A as levels of irrigation and factor B as drip system layout.

Plate 10. Chilli in field

Plate 11. Matured chilli after harvesting

RESULTS AND DISCUSSION

The thesis work has been undertaken with the objectives of evaluation of the fertigation equipments, standardization of irrigation requirement and lay out for drip system for chilli under plastic mulching. The cost economics of the drip system for chilli is also worked out.

4.1 Performance evaluation of fertigation equipment

4.1.1 Evaluation of ventury injector

The ventury injector was tested for variation of suction rate with pressure difference, variation of motive flow rate with pressure difference and for variation of motive flow rate with suction rate.

4.1.1.1 Variation of suction rate with pressure difference

The amount of fertilizer injected into the system is very important in the case of fertigation. The hydraulic performance of the system will vary with respect to the suction rate of the fertilizer into the system.

The suction rate increased with the increase in pressure difference. For a pressure difference of 0.1 kg(f)/cm^2, the amount of fertilizer injected into the system main line was 0.083 L/min which was lesser than the suction rate of 0.103 L/min for a pressure difference of 0.2 kg(f)/cm^2. The suction rate increased from 0.083 to 0.23 L/min with the increase in pressure difference. The percentage increase in suction rate for a pressure difference from 0.1 to 0.8 kg(f)/cm^2 was 63 per cent. The variation of suction rate with the pressure difference for ventury injector is shown in Fig.7 and expressed by the exponential equation,

$$\mathbf{Y = 0.083e^{1.051x} \qquad (R^2 = 0.91)}$$

where,

Y - suction rate (L/min)

x - pressure difference (kg(f)/cm^2)

The variation of suction rate with pressure difference for ventury injector is given in Appendix-II.

4.1.1.2 Variation of motive flow rate with pressure difference

In order to study the hydraulic performance of ventury injector, the variation of motive flow rate with pressure difference was observed. For a pressure difference of 0.1 kg(f)/cm^2, the motive flow rate obtained was 14.6 L/min. From the graph we can understand that as the pressure difference increases the motive flow rate also increases considerably. Similarly for a pressure difference of 0.6 kg(f)/cm^2, the motive flow rate obtained was 23.5 L/min and for a pressure difference of 0.7 kg(f)/cm^2, the motive flow rate was 26.54 L/min. The maximum flow rate of 27.13 L/min was obtained for a pressure difference of 0.8 kg(f)/cm^2. The increase in suction rate was 46 per cent for a pressure difference from 0.1 to 0.8 kg(f)/cm^2. (The variation of motive flow rate with pressure difference in ventury injector is given in Appendix-III)

The variation in the flow rate is due to the change in the operating pressure. High flow rates are attributed to high operating pressures and low flow rates to low operating pressures. The variation of motive flow rate with pressure difference can be explained on the basis of the Bernoulli’s equation which states that the total energy remains the same. At low pressure the flow through the bypass that is the line connected with the ventury is minimum. The variation of motive flow rate with respect to pressure difference is shown in Fig.8 and expressed by the exponential equation,

$$\mathbf{Y = 14.5\, e^{0.875x} \qquad (R^2 = 0.95)}$$

Where,

Y - Motive flow rate (L/min)

x - Pressure difference (kg (f)/cm^2)

4.1.1.3 Variation of motive flow rate with suction rate

For the comparison of injection rates of ventury injector, the suction rate and motive flow rate for different inlet and outlet pressure were measured.

The variation of motive flow rate with respect to the suction rate was as presented in figure 9. For a pressure difference of 0.1 kg(f)/cm^2, the amount of fertilizer injected into the system was 0.083 L/min and the motive flow rate obtained was 14.6 L/min. As the suction rate increased, the motive flow rate also increased. For a suction rate of 0.17 L/min, the motive flow rate was 23.5 L/min. When the suction rate increased from 0.083 L/min to 0.23 L/min, the motive flow rate also increased from 14.6 L/min to 27.13 L/min for a pressure difference of 0.1 to 0.8 kg(f)/cm^2.The increase in suction rate was 63 per cent for pressure difference of 0.1 to 0.8 kg(f)/cm^2. The variation of suction rate respect to the motive flow rate is shown in Fig.9 and expressed by the exponential equation,

$$\mathbf{Y = 0.003e^{1.99x} \qquad (R^2 = 0.96),}$$

Where,

Y - motive flow rate (L/min).

x - suction rate (L/min).

The motive flow rate of ventury injector increased with pressure difference. The variation of suction rate with motive flow rate is given in Appendix-IV

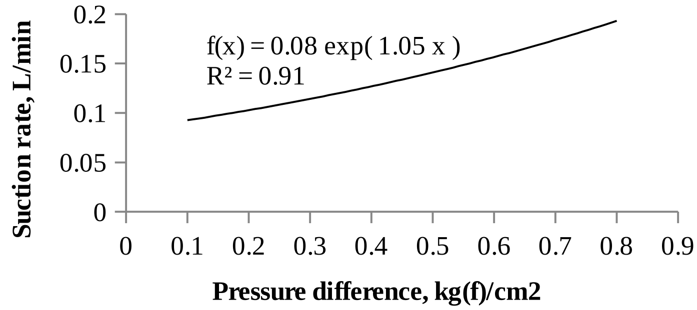


Fig.7 Variation of suction rate with pressure difference for ventury injector

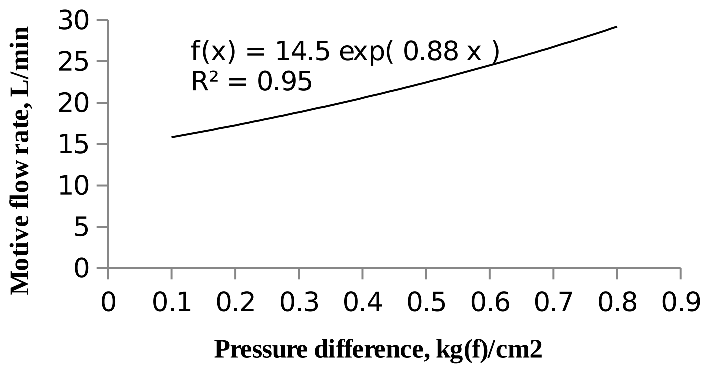


Fig.8 Motive flow rate with pressure difference for ventury injector

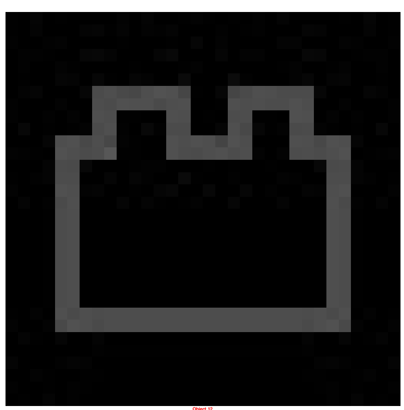


Fig.9 Variation of motive flow rate with suction rate for ventury injector

4.1.2 Performance evaluation of dosmatic fertigation unit

4.1.2.1 Variation of suction rate with pressure difference

Dosmatic fertigation unit or differential pressure tanks are a widely used injection device for fertigation in micro-irrigation systems, but guidelines for managing a fertigation system using such a device are lacking.

As the pressure difference increased the amount of fertilizer injected into the main line system also increased. (The variation of suction rate with pressure difference for dosmatic fertigation unit is given in Appendix-V). For dosmatic fertigation unit the suction rate was lesser than that of the ventury injector due to the lesser motive flow rate. For a pressure difference of 0.1 kg(f)/cm^2, the suction rate was 0.023 L/min and for a pressure differences of 0.2 kg(f)/cm^2 the suction rate was 0.046 L/min. The maximum suction rate of 0.163 L/min was obtained for a pressure difference of 0.8 kg(f)/cm^2.The increase in suction rate was 86 per cent for a pressure difference from 0.1 to 0.8 kg(f)/cm^2. The variation of suction rate with pressure difference for dosmatic fertigation unit is shown in Fig.10 and expressed by the exponential equation,

$$\mathbf{Y = 0.025e^{2.543x} \quad (R^2=0.91)}$$

Where,

Y - Suction rate (L/min)

x - Pressure difference (kg(f)/cm^2)

4.1.2.2 Variation of motive flow rate with pressure difference

The variation of motive flow rate with pressure difference was studied in order to find out the performance evaluation of dosmatic fertigation unit. In the case of dosmatic fertigation unit, for a pressure difference of 0.1 kg(f)/cm^2 the motive flow rate was 1.1 L/min. The motive flow rate was 1.99 L/min for a pressure difference of 0.7 kg(f)/cm^2. As the pressure difference increased the motive flow rate also increased. This is in agreement with Boman *et al.*, 2004 reported that higher the pressure differences in the irrigation main line, higher the flow rate in the pump. For the same pressure difference of 0.8 kg(f)/cm^2 the motive flow rate was 2.03 L/min for dosmatic fertigation unit and 27.13 L/min for ventury injector which was very higher. So the dosmatic fertigation can be used for motive flow rates above 1.1 L/min. Thus this system can be used for small fields which require less discharge to the tune of 1.1 L/min and above. (The variation of motive flow with pressure difference for dosmatic fertigation unit is given in Appendix.VI). The percentage increase in motive flow rate was 45 per cent for a pressure difference from 0.1 to 0.8 kg (f) /cm^2. The variation of motive flow rate with pressure difference is shown in Fig.11 and expressed by the exponential equation,

$$\mathbf{Y = 1.088e^{0.870x} \qquad (R^2 = 0.94)}$$

where,

Y- Suction rate (L/min)

x - Pressure difference (kg(f)/ cm^2)

4.1.2.3 Variation of motive flow rate with suction rate.

For the comparison of injection rates of each fertigation equipment, the suction rate and motive flow rate for different inlet and outlet pressure were measured. From the graph it was seen that the motive flow rate of dosmatic fertigation unit was very less as compared to the ventury injector for the same pressure difference. The motive flow rate of the ventury injector increased with the increase in the suction rate. For a pressure difference of 0.1 kg(f)/cm^2, the amount of fertilizer into the system was 0.023 L/min and the motive flow rate obtained was 1.1 L/min. As the suction rate increases, the motive flow rate also increases. (The variation of motive flow rate with pressure difference for dosmatic fertigation is given in Appendix-VII). For a suction rate of 0.023 L/min, the motive flow rate was 1.1 L/min in dosmatic fertigation unit. When the suction rate increased from 0.023 L/min to 0.163 L/min, the motive flow rate also increased from 1.1 L/min to 2.03 L/min for a pressure difference of 0.1 to 0.8 kg(f)/cm^2.The increase in suction rate was 85 per cent for a pressure difference from 0.1 to 0.8 kg(f)/cm^2. The variation of suction rate with motive flow rate is shown in Fig.12 and expressed by the exponential equation,

$$\mathbf{Y = 0.004e^{1.824x} \qquad (R^2 = 0.93)}$$

where,

Y - motive flow rate (L/min)

x - suction rate (L/min)

The motive flow rate of dosmatic fertigation unit was very less as compared to ventury injector and the fertilizer tank. So it can be used for small fields also.

4.1.3 Performance evaluation of fertilizer tank

4.1.3.1 Variation of motive flow rate with pressure difference

In order to study the hydraulic performance of fertilizer tank, the variation of motive flow rate with pressure difference was studied. The inlet and outlet pressure of the fertilizer tank were adjusted in order to obtain the various pressure differences. The procedure was repeated for various pressure differences. The volume of water collected from each emitter for various pressure differences at a particular time period was noted.

For a pressure difference of 0.1 kg(f)/cm^2, the motive flow rate obtained was 6.6 L/min which was lesser than that of ventury injector and greater than that of the dosmatic fertigation unit. (The variation of motive flow rate with pressure difference for fertilizer tank is given in Appendix-VIII). As the pressure difference increased the motive flow rate also increased considerably. Similarly for a pressure difference of 0.6 kg(f)/cm^2, the motive flow rate obtained was 10.6 L/min and for a pressure difference of 0.7 kg(f)/cm^2, the motive flow rate was 11.9 L/min. The maximum flow rate of 12.21 L/min was obtained for a pressure difference of 0.8 kg(f)/cm^2.The motive flow rate of the fertilizer tank was higher than that of the dosmatic fertigation unit and lesser than that of the ventury injector for the same pressure difference. The increase in motive flow rate was 44 per cent for a pressure difference from 0.1 to 0.8 kg(f)/cm^2 in the case of fertilizer tank. Thus fertilizer tanks can be used for motive flow rates more than 6.6 L/min. The variation of motive flow rate with pressure difference is shown in Fig.13 and expressed by the exponential equation,

$$\mathbf{Y = 6.54\, e^{0.868\, x}\ (R^2 = 0.940)}$$

Where,

Y - Motive flow rate (L/min)

x - Pressure difference (kg(f)/cm^2)

4.1.4 Comparison of performance of different fertigation equipments

4.1.4.1 Variation of suction rates with pressure difference

An increase in suction rate was observed in the case of the fertigation equipments with increased pressure difference. In case of dosmatic fertigation unit, suction rate was 0.046 L/min at 0.2 kg(f)/cm^2. A higher value of suction rate of 0.103 L/min was observed in the case of ventury injector. At 0.5 kg(f)/cm^2, the higher value was observed in the case for ventury injector of a suction rate of 0.103 L/min and the lower value was observed in the case of dosmatic fertigation unit with suction rate of 0.046 L/min. At 0.8 kg(f)/cm^2, pressure difference

Fig.10 Variation of suction rate with pressure difference for dosmatic unit

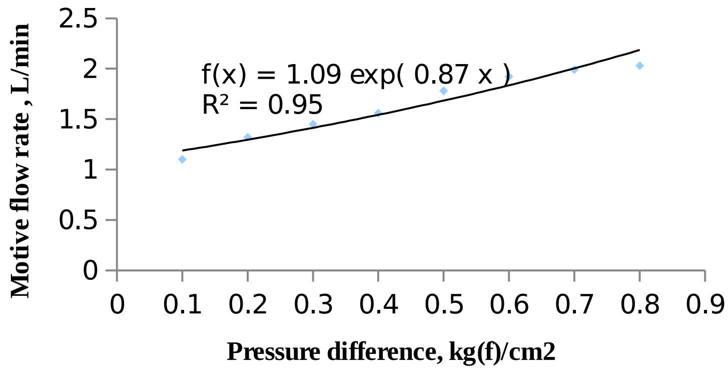


Fig.11 Variation of motive flow rate with pressure difference for dosmatic unit

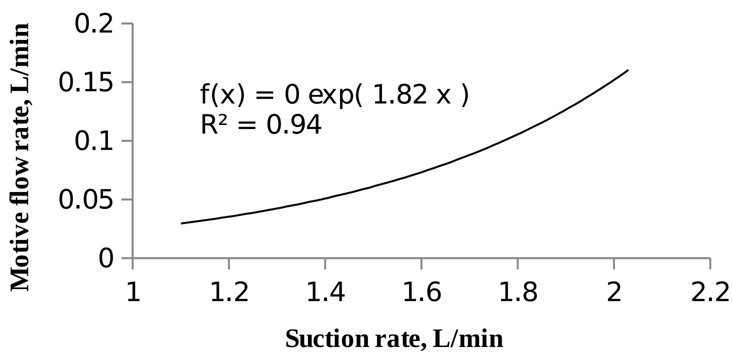


Fig.12 Variation of suction rate with motive flow rate for dosmatic unit

the corresponding suction rate for dosmatic fertigation unit and ventury injector were observed as 0.163 and 0.23 L/min. The suction rate of ventury injector recorded a higher value than the dosmatic fertigation unit. The comparison of variation of suction rate with pressure difference for ventury injector and dosmatic fertigation unit is shown in Fig.14

Variation of suction rate with pressure difference for ventury injectors is expressed by the exponential equation

$$\mathbf{Y = 0.082e^{1.066x}\ (R^2=0.94)}$$

Variation of suction rate with pressure difference for dosmatic fertigation unit was expressed by the exponential equation

$$\mathbf{Y = 0.025e^{2.493x}\ (R^2=0.91)}$$

Where,

Y- suction rate (L/min)

x - pressure difference (kg(f)/cm^2)

The variation of suction rate with pressure difference for ventury injector and dosmatic fertigation unit is given in Appendix-IX.

4.1.4.2 Variation of motive flow rate with pressure difference

In order to compare the hydraulic performance of different fertigation equipments, the variation of motive flow rate with pressure difference was studied. For a pressure difference of 0.1 kg(f)/cm^2, the motive flow rate obtained was 14.6 L/min for ventury injector. From the graph it was seen that as the pressure difference increased the motive flow rate also increased considerably. Similarly in the case of ventury injector, for a pressure difference of 0.6 kg(f)/cm^2, the motive flow rate obtained was 23.5 L/min and for a pressure difference of 0.7 kg(f)/cm^2, the motive flow rate was 26.54 L/min. The maximum flow rate of 27.13 L/min was obtained for a pressure difference of 0.8 kg(f)/cm^2 in ventury injector. The increase in motive flow rate was 46 per cent for a pressure difference from 0.1 to 0.8 kg(f)/cm^2. Similar readings were observed by Jain Irrigation System Limited (Anonymous 1999).

For a pressure difference of 0.1 kg(f)/cm^2, the motive flow rate obtained was 1.1 L/min for dosmatic fertigation unit. From the graph we can understand that as the pressure difference increases the motive flow rate also increases considerably. Similarly in the case of dosmatic fertigation unit, for a pressure difference of 0.6 kg(f)/cm^2, the motive flow rate obtained was 1.92 L/min and for a pressure difference of 0.7 kg(f)/cm^2, the motive flow rate was 1.99 L/min. The maximum flow rate of 2.03 L/min was obtained for a pressure difference of 0.8 kg(f)/cm^2.The increase in motive flow rate was 45 per cent for a pressure difference from 0.1 to 0.8 kg(f)/cm^2.

For a pressure difference of 0.1 kg(f)/cm^2, the motive flow rate obtained was 6.6 L/min for fertlilizer tank. From the graph we can understand that as the pressure difference increases the motive flow rate also increases considerably. Similarly in the case of fertilizer tank, for a pressure difference of 0.6 kg(f)/cm^2, the motive flow rate obtained was 11.5 L/min and for a pressure difference of 0.7 kg(f)/cm^2, the motive flow rate was 11.9 L/min. The maximum flow rate of 12.21 L/min was obtained for a pressure difference of 0.8 kg(f)/cm^2.The increase in motive flow rate was 46 per cent for a pressure difference from 0.1 to 0.8 kg(f)/cm^2. The comparison of variation of motive flow rate with different fertigation equipments is shown in Fig.15

For a pressure difference of 0.1 kg(f)/cm^2, the motive flow rate obtained was 1.1 L/min for dosmatic fertigation unit. From the graph we can understand that as the pressure difference increases the motive flow rate also increases considerably. Similarly in the case of dosmatic fertigation unit, for a pressure difference of 0.6 kg(f)/cm^2, the motive flow rate obtained was 1.92 L/min and for a pressure difference of 0.7 kg(f)/cm^2, the motive flow rate was 1.99 L/min.

Fig.13 Variation of motive flow rate with pressure difference for fertilizer tank

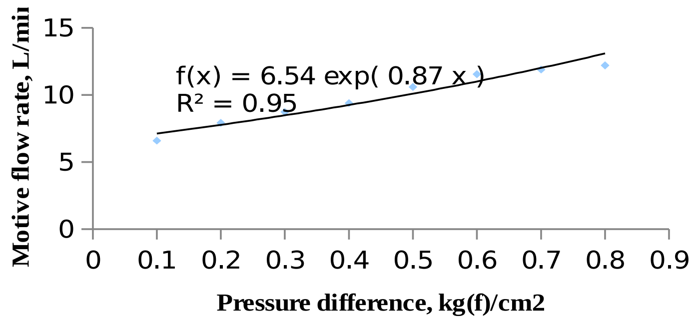


Fig.14 Comparison of suction rate with pressure difference

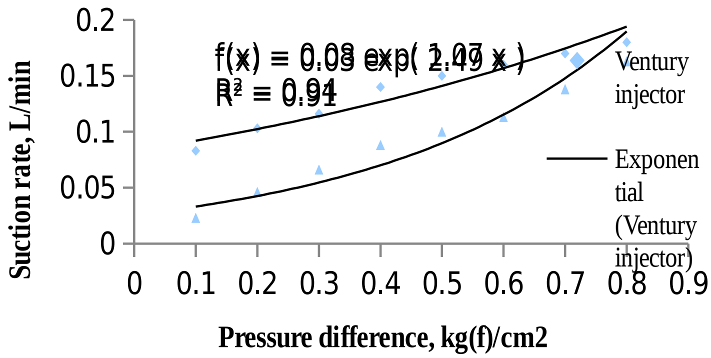


Fig.15 Comparison of motive flow rate with pressure difference

The maximum flow rate of 2.03 L/min was obtained for a pressure difference of 0.8 kg(f)/cm^2.The increase in motive flow rate was 45 per cent for a pressure difference from 0.1 to 0.8 kg(f)/cm^2.

For a pressure difference of 0.1 kg(f)/cm^2, the motive flow rate obtained was 6.6 L/min for fertlilizer tank. From the graph we can understand that as the pressure difference increases the motive flow rate also increases considerably. Similarly in the case of fertilizer tank, for a pressure difference of 0.6 kg(f)/cm^2, the motive flow rate obtained was 11.5 L/min and for a pressure difference of 0.7 kg(f)/cm^2, the motive flow rate was 11.9 L/min. The maximum flow rate of 12.21 L/min was obtained for a pressure difference of 0.8 kg(f)/cm^2.The increase in motive flow rate was 46 per cent for a pressure difference from 0.1 to 0.8 kg(f)/cm^2. The comparison of variation of motive flow rate with different fertigation equipments is shown in Fig.15

Variation of motive flow rate with pressure difference for different fertigation equipments are expressed by the exponential equations,

$Y = 14.5e^{0.484x}$	R^2=0.94	Ventury injector
$Y = 0.65e^{0.868x}$	R^2=0.94	Dosmatic fertigation unit
$Y = 1.088e^{0.87x}$	R^2=0.94	Fertilizer tank

Where,

Y - Pressure difference, kg(f)/cm^2

x - Motive flow rate, L/min

The variation in the flow rate is due to the change in the operating pressure i.e. the observed pressure difference. High flow rates are attributed to high operating pressures and low flow rates to low operating pressures. The variation of motive flow rate with pressure difference can be explained on the basis of the Bernoulli’s equation which states that the total energy remains the same. At low pressure, the flow through the bypass that is the line connected with the ventury was minimum. (Comparison of motive flow rate with pressure difference for different fertigation equipments is given in Appendix-X). The motive flow rate of ventury injector was 14.6 L/min which was higher than that of the fertilizer tank (6.6 L/min) and dosmatic fertigation unit (1.1 L/min) for the pressure difference of 0.1 kg(f)/cm^2. The percentage increase in motive flow rate for ventury injector was 46 per cent which was higher than that of dosmatic fertigation unit (45 per cent) and fertilizer tank (45 per cent) for the pressure difference from 0.1 to 0.8 kg(f)/cm^2.

Due to the high motive flow rate the ventury injector is suitable for application with large number of drippers. Dosmatic fertigation unit recorded less motive flow rate when compared to ventury injector at same pressure difference. Fertilizer tanks are suitable for fields with motive flow rates of 6.6 L/min and above. Hence ventury injectors are suitable for motive flow rates of 14.6 L/min and above. Dosmatic fertigation unit was found to be suitable for small and large number of emitters with motive flow rates 1.1 L/min and above.

4.1.5. Hydraulic performance of the drip system

4.1.5.1 Emitter coefficient of manufacturing variation with operating pressures

The emitter coefficient of manufacturing variation is used as a measure of the anticipated variations in the discharge of emitters. The inline drippers were tested for various operating pressures. The coefficient of manufacturing variation was determined. The manufacturing coefficient of variation was determined at various operating pressures. As the operating pressure increased, the emitter coefficient of manufacturing variation value also increased. For an operating pressure of 0.7 kg(f)/cm^2, the coefficient of manufacturing variation was 17.8 per cent. Variation of coefficient of manufacturing variation with operating pressures in the drip fertigation system is given in Appendix-XI. As per the manufacturing precision in terms of manufacturing coefficient of variation, the Cv≥ 15 per cent was unacceptable as per Michael, (2008). For an operating pressure of 0.5 kg(f)/cm^2, the Cv value obtained was 10.1 per cent which is acceptable good performance. As the operating pressure increased, the emitter coefficient of manufacturing variation value increased. For an operating pressure of 0.2 kg(f)/cm^2, the emitter coefficient of manufacturing variation value was 2.1 per cent which is also recorded as good performance. This is in agreement with Shinde *et al*. (2001) and Kishor *et al.* (2005) reported that the drippers had the Cv value less than 5 per cent indicating the good performance. Variation of emitter coefficient of manufacturing variation with operating pressure is shown in Fig.16 and expressed by the exponential equation,

$$\mathbf{Y = 0.732\ e^{4.801x} \qquad (R^2 = 0.960)}$$

Where,

Y - Emitter coefficient of manufacturing variation

x - Operating pressure (kg(f)/cm^2)

4. 1. 5. 2 Emitter flow variation

The distribution efficiency and the application efficiency will depend upon the variation of emitter flow along the lateral line and the variation of amount of flow from the sub main into the lateral. The maximum and minimum discharges from the set of emitters were measured for various operating pressures to calculate the emitter flow variation.

The emitter flow variation of dosmatic fertigation unit decreased from 25 per cent to 10 per cent for various operating pressures. (Emitter flow variation with various operating pressures of the drip system is given in Appendix-XII). The decrease in emitter flow variation was 60 per cent for operating pressures from 0.1 to 0.5 kg(f)/cm^2. The variation of emitter flow variation with operating pressures is shown in Fig.17 and expressed by the exponential equation,

$$Y = 0.252\ e^{-1.90x} \qquad (R^2 = 0.79)$$

Where,

Y - emitter flow variation, per cent

x - pressure, kg(f)/cm^2

4.1.5.3 Emission uniformity

The variation of uniformity coefficient with operating pressure for the first lateral line for an operating pressure of 1.2 kg(f)/cm^2 is shown in Fig.18 and expressed by the logarithmic equation,

$$Y = 30.53\ \text{In}\ (x) + 99.38 \qquad (R^2=0.972)$$

Where,

Y - Uniformity coefficient, per cent

x - Operating pressure in kg(f)/cm^2.

For the first lateral line the uniformity coefficient was 98 per cent for an operating pressure of 1.2 kg(f)/cm^2 and for the second lateral line the uniformity coefficient was 94 per cent for an operating pressure of 1.2 kg(f)/cm^2. (Variation of uniformity coefficient with operating pressure for the first lateral line is given in Appendix-XIII). This is in agreement with Brain (1989) reported that the inline drip irrigation systems recorded more than 93 per cent uniformity of water distribution. For an operating pressure of 0.1 kg(f)/cm^2 the discharge rate was 27 L/s. The discharge rate was found to increase from 27 to 98 per cent for operating pressure variation from 0.1 to 1.2 kg(f)/cm^2. This is in agreement with Bralts *et al*. (1981) and Solomon (1979) reported that in reality unit to unit emitter discharge is variable. The variation of uniformity coefficient with operating pressure for second lateral line for an operating pressure of 1.2 kg(f)/cm^2 is shown in Fig.19 and expressed by the logarithmic equation

$$Y = 40.55 \text{ In } (x) + 128.6$$

where,

Y - uniformity coefficient, per cent

x - Operating pressure in kg(f)/cm^2.

(Variation of uniformity coefficient with operating pressure for the first lateral line is given in Appendix-X1V). As the distance from the main line increased the discharges from the emitters decreased as the pressure available got decreased. At low operating pressure the discharge from the emitters decreased. Identical observations were made by Sinde *et.al.* 2001.

4.2 Standardization of different irrigation levels and drip system layout

4.2.1 Soil moisture distribution pattern for crop under different drip system layout

The moisture distribution pattern within the effective root zone of crop depends on the capillary action of water from the lateral line and the lateral spread of water through the interconnected pores. Hydraulic conductivity of the subsoil is the primary factor influencing the soil moisture distribution.

The analysis of the data of moisture content 2 and 6 hour after irrigation was done and soil moisture contour maps for the longitudinal cross section of the soil were plotted using computer software package “Surfer” of windows version. The water distribution pattern for a given soil depends on the rate and duration of water application and the spacing of the laterals.

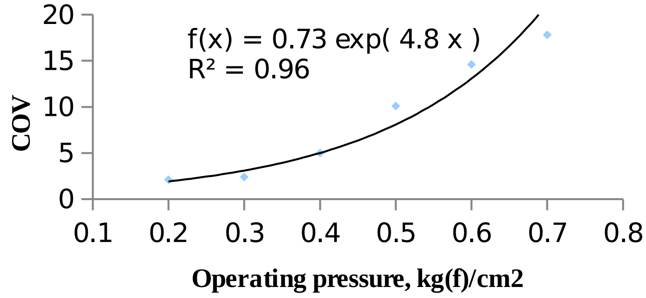


Fig.16 Variation of emitter coefficient of manufacturing variation

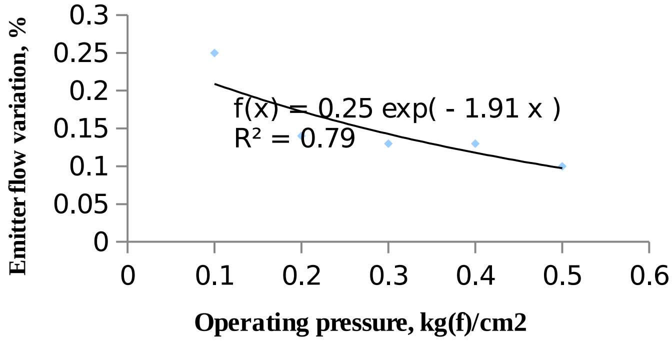


Fig.17 Emitter flow variation of the drip system

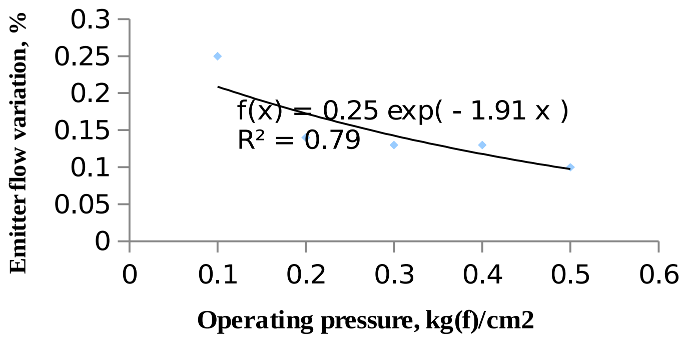


Fig.18 Variation of uniformity coefficient with operating pressure for the first lateral line

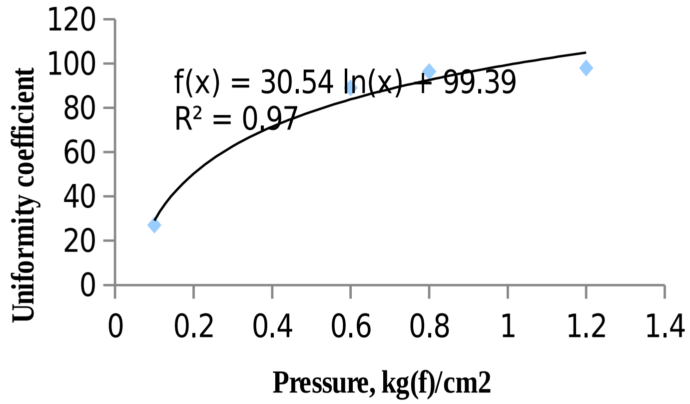


Fig.19 Variation of uniformity coefficient with operating pressure for the second lateral line.

4.2.1.1 Soil moisture distribution pattern for treatment T_1

In order to study the moisture distribution pattern around the plant the soil moisture contents was measured at different depths below the soil surfaces at varying distances along the surfaces. Soil moisture distribution pattern for the treatment T_1, 2hr and 6hr after irrigation is shown in Fig.20 and 21. For the treatment T_1 amount of moisture content decreased as the distance from the plant increased due to lateral spacing. For the treatment T_1 the moisture content near the plant was 9.42 per cent. This is in agreement with Reddy e*t al.* (2001). The moisture content at 5 cm depth near the plant was 8.5 per cent. The moisture content reduced from 8.5 per cent to 3.4 per cent at a depth of 5 cm to 20 cm. The percentage decrease in moisture content near the plant was 60 per cent. At a distance of 10cm from the plant the moisture content increased from 8.3 to 8.56 per cent for a depth of 5 cm from surface. For the treatment $T_{1,}$ the moisture reduced from 8.56 to 3.52 per cent at a depth of 5 cm to 20 cm. The percentage decrease in moisture content at a distance of 10 cm from the plant was 58.8 per cent for a depth of 5 cm to 20 cm.

The moisture content was found to decrease with increase in time. Moisture content was also found to decrease with increase in the lateral distance of 10 cm and at a depth of 20 cm. For the treatment $T_{1,}$ amount of moisture content decreased as the distance from the plant increased due to increase in spacing of laterals. For the treatment $T_{1,}$ the moisture content near the plant was 8.2 per cent, 6 hours after irrigation. The moisture content at 5 cm depth near the plant was 7.6 per cent. The moisture content reduced from 7.6 per cent to 1.85 per cent at a depth of 5 cm to 20 cm. The percentage decrease in moisture content near the plant was 75 per cent. At a distance of 10 cm from the plant the moisture content increased from 7.6 to 5.5 per cent for a depth of 5 cm from surface. For the treatment $T_{1,}$ the moisture reduced from 5.5 to 1.69 per cent at a depth of 5 cm to 20 cm, 6 hours after irrigation. The percentage decrease in moisture content at a distance of 10 cm from the plant was 69 per cent for a depth of 5 cm to 20 cm.

4.2.1.2 Soil moisture distribution pattern for treatment T_2

Moisture content was found to increase with increase in lateral distance of 10cm for the treatment T_2. For the treatment $T_{2,}$ amount of the moisture content increased as the distance from the plant increased due to the increase in spacing of laterals. Soil moisture distribution pattern for the treatment T_2, 2 hr and 6 hr after irrigation is shown in Fig.22 and 23. For the treatment $T_{2,}$ the moisture content near the plant was 5.1 per cent. The moisture at 5 cm depth near the plant was 4.3 per cent. The moisture content reduced from 4.3 to 3.1 per cent at a depth of 5 cm to 20 cm. The percentage decrease in moisture content near the plant was 28 per cent. At a distance of 5 cm near the plant the moisture content reduced from 4.3 to 4 per cent for a depth of 5 cm. For the treatment $T_{2,}$ the moisture content reduced from 4 to 2.7 per cent at a depth of 5 cm to 20 cm. The per cent decrease in moisture content at a distance of 5 cm from the plant was 32.5 per cent for 5 cm to 20 cm depth. At a distance of 10 cm near the plant the moisture content reduced from 5.6 to 3.1 per cent from surface to 20 cm. The percentage decrease in moisture content was 44.6 per cent.

The moisture content was found to decrease with increase in time. Moisture content was found to increase with increase in the lateral distance from the plant at a lateral distance of 10cm and at a depth of 20 cm for the treatment T_2. For the treatment $T_{2,}$ amount of the moisture content increased as the distance from the plant increased due to one lateral in between two row crops.. For the treatment $T_{2,}$ the moisture content near the plant was 2.8 per cent. The moisture at 5cm depth near the plant was 2.4 per cent. The moisture content reduced from 2.4 to 1.4 per cent at a depth of 5 cm to 20 cm. The percentage decrease in moisture content near the plant was 41 per cent. At a distance of 5 cm near the plant the moisture content increased from 2.4 to 3.6 for a depth of 5 cm. For the treatment $T_{2,}$ the moisture content reduced from 3.6 to 1.42 at a depth of 5 cm to 20 cm. The per cent decrease in moisture content at a distance of 5cm from the plant was 1.53 per cent for 5 cm to 20 cm depth. At a distance of 10 cm near the plant the moisture content reduced from 3.2 to 1.3 per cent from surface to 20 cm. The percentage decrease in moisture content was 60 per cent. Moisture content for the treatment T_1 and T_2 are given in the Appendices-XV and XVI.

4.2.1.3 Soil moisture distribution pattern for treatment T_3, T_4, T_5 and T_6

For the treatment T_3 and T_5 amount of moisture content decreased as the distance from the plant increased due one lateral for each row of crops. (Moisture content for the treatment T_1 and T_2 are given in the Appendices - XVII, XVIII, XIX and XX).

For the treatments T_3 and T_5 single lateral for each row crops. Soil moisture distribution pattern for the treatments T_3, $T_{4,}$ $T_{5,}$ $T_{6,}$ 2 hr and 6 hr after irrigation is shown in Fig.24, 25, 26, 27, 28, 29, 30 and 31. The moisture content near the plant was 10.7 per cent for the treatment T_3 and 12.27 per cent for the treatment $T_{5,}$ due to high rate of water application. As compared to the treatments T_3 and $T_{5,}$ soil moisture near the plant was less in the treatments T_4 and $T_{6,}$ due to one lateral in between two row of crops. For the treatment T_4 and the treatment T_6 as the distance from the plant increased the moisture content increased due to one lateral in between two row of crops. This is in agreement with Subbi *et al.* (2005). For the treatments T_3 and $T_{5,}$ the soil moisture at a distance of 5cm from the plant was 9.7 per cent and11.18 per cent due to increase in water application. But for the treatment T_4 and $T_{6,}$ the soil moisture at a distance of 5 cm from the plant was 5.1 per cent and 5.7 per cent. For a distance of 20 cm from the plant the soil moisture increased in the treatments T_4 and $T_{6,}$ due to one lateral in between two row of crops. The moisture present in the soil at a distance of 20 cm was 6.29 per cent. Moisture content was determined 2hr and 6hr after irrigation. For the treatments T_1, T_3 and T_5 as the distance from the plant increased the moisture content decreased. For the treatment T_2, T_4 and T_6 as the distance from the plant increased the moisture content reduced due to one lateral in between two

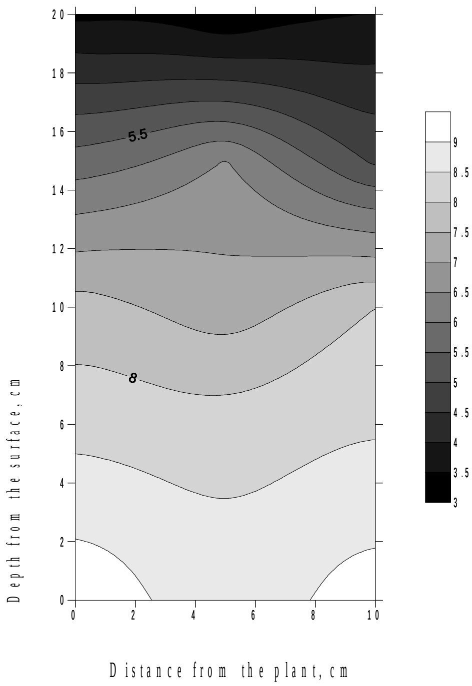


Fig.20 Soil moisture distribution pattern for the treatment T_1, 2 hr after irrigation.

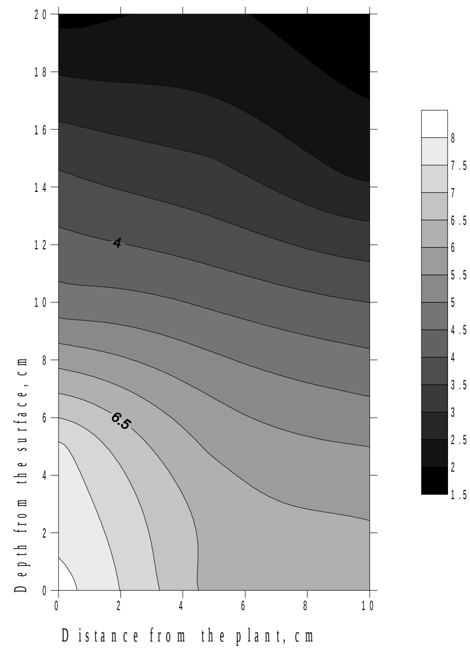


Fig.21 Soil moisture distribution pattern for the treatment T_1, 6 hr after irrigation.

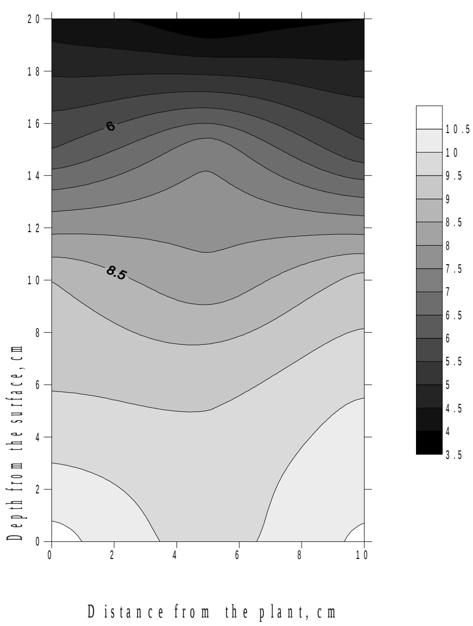


Fig.22 Soil moisture distribution pattern for the treatment T_2, 2 hr after irrigation

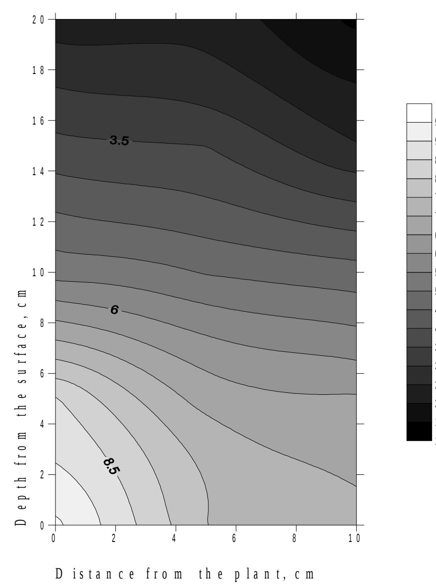


Fig.23 Soil moisture distribution pattern for the treatment T_2, 6 hr after irrigation

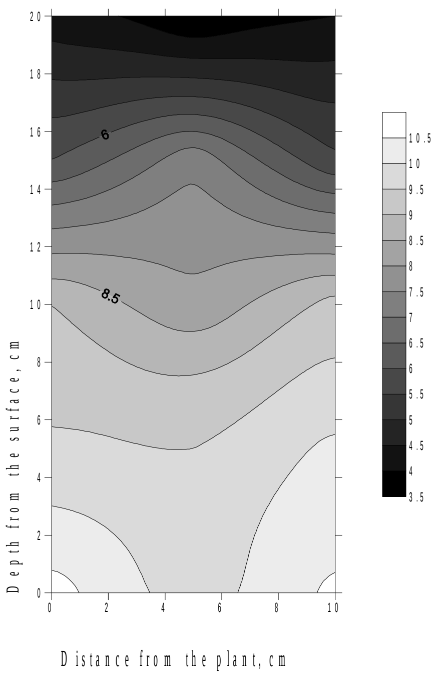


Fig.24 Soil moisture distribution pattern for the treatment T_3, 2 hr after irrigation

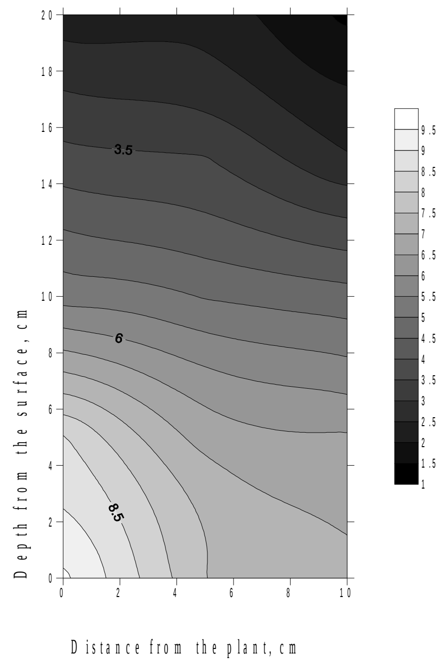


Fig.25 Soil moisture distribution pattern for the treatment T_3, 6 hr after irrigation

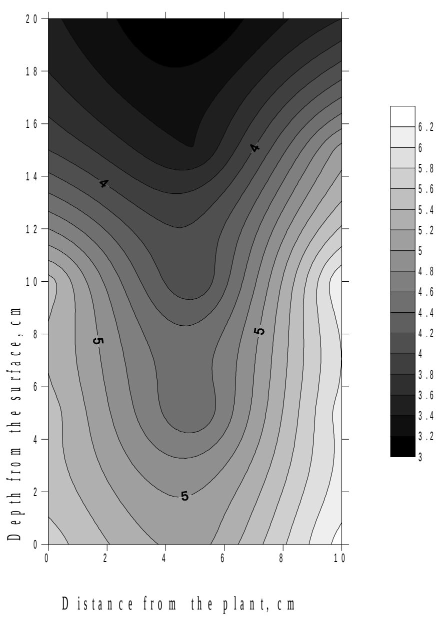


Fig.26 Soil moisture distribution pattern for the treatment T_4, 2 hr after irrigation

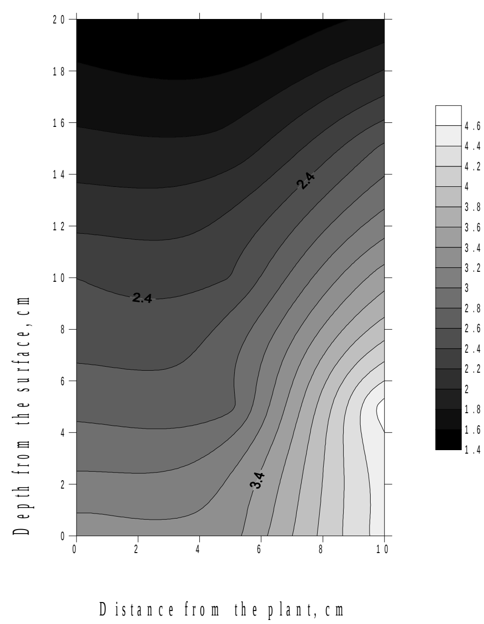


Fig.27 Soil moisture distribution pattern for the treatment T_4, 2 hr after irrigation

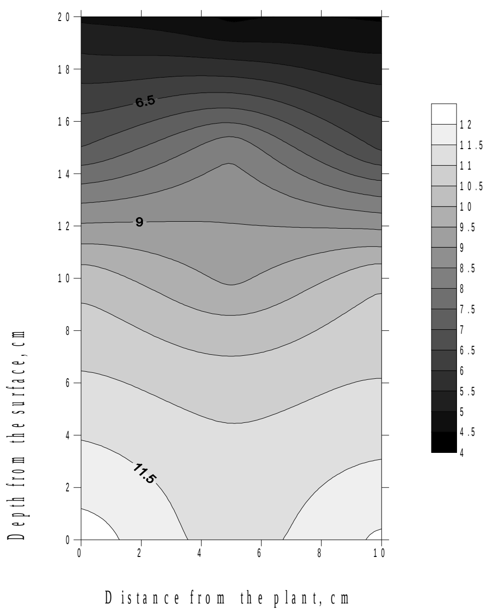


Fig.30 Soil moisture distribution pattern for the treatment T_6, 2 hr after irrigation

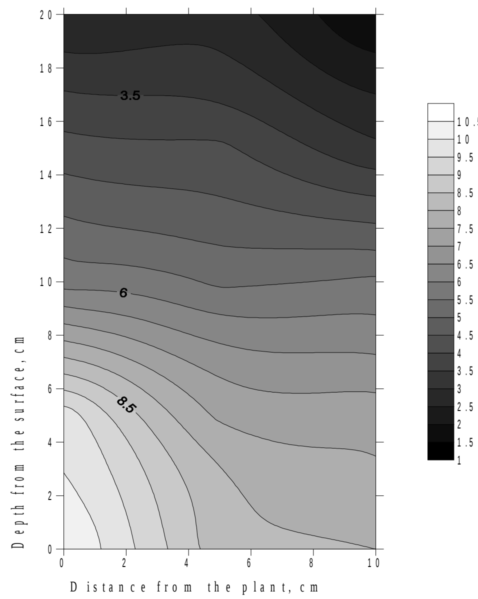
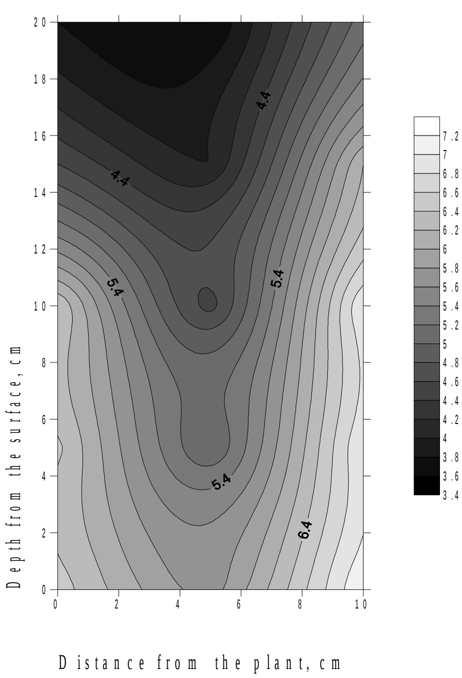


Fig.28 Soil moisture distribution pattern for the treatment T_5, 2 hr after irrigation

Fig.29 Soil moisture distribution pattern for the treatment T_5, 6 hr after irrigation



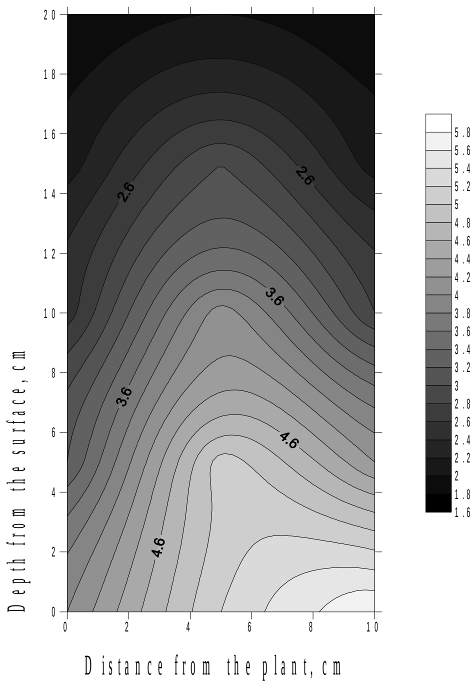


Fig.31 Soil moisture distribution pattern for the treatment T_6, 6 hr after irrigation

row of crops. Along the depth also the moisture present in the soil reduced. The variations proved that one lateral for each row of crops retained more moisture than the one lateral in between two rows of crop.

4.2.2 Statistical analysis

4.2.2.1 Plant height (cm)

The data on plant height at 120 and 160 days after planting as influenced by different treatments, levels of irrigation and drip system layout are presented in the Tables 5, 6, 7 and 8.

The plant height at both stages did not differ significantly with respect to the different treatments over control. The data did not differ significantly either due to the levels of irrigation or due to the different drip system layout and fertigation under plastic mulching. The results indicate that the treatments did not influence plant height either at 120 or at 160 days after planting.

4.2.2.2 Number of leaves

The data on number of leaves as influenced by different treatments, different levels of irrigation and drip system layout, 120 and 160 days after planting are presented in the Tables 9, 10, 11 and 12.

The number of leaves did not differ significantly with respect to the different treatments over control at different stages of plant growth. The data on number of leaves at different stages of plant growth did not differ significantly due to the varying levels of irrigation, drip system layout and fertigation. The results indicate that the treatments did not influence the number of leaves at different stages of plant growth. This is in agreement with Padma and Sivanappan (1978) studies for 2 seasons with brinjal grown by drip irrigation system. They observed that the plant height was not significantly high in brinjal.

Table 5. Plant height (cm) at 120 days after planting as influenced by treatments.

Treatments	I_1	I_2	I_3	Control
D_1	28.08	28.58	29.25	27.00
D_2	26.00	27.92	29.17	
Non significant				

Table 6. Plant height (cm) at 120 days after planting as influenced by different levels of irrigation and drip system layout.

Treatments	I_1	I_2	I_3	Mean
D_1	28.08	28.58	28.33	28.33
D_2	26.00	27.92	31.67	28.53
Mean	27.04	28.25	30.00	28.43
Non significant				

Table 7. Plant height (cm) at 160 days after planting as influenced by the treatments.

Treatments	I_1	I_2	I_3	Control
D_1	29.58	30.33	31.25	28.17
D_2	28.17	29.25	31.25	
Non significant				

Table 8. Plant height (cm) at 160 days after planting as influenced by different levels of irrigation and drip system layout.

Treatments	I_1	I_2	I_3	Mean
D_1	29.58	30.33	30.83	30.25
D_2	28.17	29.25	32.67	30.03
Mean	28.87	29.79	31.75	30.19
Non significant				

Table 9. Number of leaves at 120 days after planting as influenced by the treatments

Treatments	I_1	I_2	I_3	Control
D_1	19.91	20.58	21.16	19.25
D_2	19.16	19.25	21.08	
Non significant				

Table 10. Number of leaves at 120 days after planting as influenced by different levels of irrigation and drip system layout.

Treatments	I_1	I_2	I_3	Mean
D_1	19.92	20.58	21.16	20.56
D_2	19.17	19.25	21.08	19.83
Mean	19.54	19.92	21.21	20.91
Non significant				

Table 11. Number of leaves at 160 days after planting as influenced by the treatments

Treatments	I_1	I_2	I_3	Control
D_1	21.50	21.92	22.50	20.92
D_2	21.33	21.58	22.33	
Non significant				

Table 12. Number of leaves at 160 days after planting as influenced by different levels of irrigation and drip system layout.

Treatments	I_1	I_2	I_3	Mean
D_1	21.50	21.92	22.50	21.97
D_2	21.33	21.58	22.33	21.75
Mean	21.42	21.75	22.42	21.86
Non significant				

4.2.2.3 Number of branches

The data on number of branches at 120 days after planting as influenced by different treatments, levels of irrigation and drip system layout are presented in the Tables 13 and 14. The number of branches at 120 days after planting as influenced by different treatments and different levels of irrigation is shown in Fig.32 and 33.

The maximum value of number of branches was observed for the treatment T_4 (6.7) and the treatment T_6 (6.7). The minimum value was seen for the treatment T_7 (2.8). The treatments T_1 (5.8), T_2 (6.1) and T_5 (6.5) were on par with the treatment T_6. In control (T_7) the water was applied through surface irrigation and reduction in the number of branches may be due to less WUE. The number of branches in the case of six treatments was more as compared with the control because of water application through drip system and plastic mulching. This is in agreement with Padma and Sivanappan (1978) studies for 2 seasons with brinjal grown by drip irrigation. They observed that the plant height was not significantly high but the number of branches was more and the yield was above normal.

From the data presented in the Table.14, it is seen that the different levels of irrigation showed significant difference. With respect to the number of branches, the maximum value in the case of irrigation level was seen in I_3 (7.5). The level of irrigation I_2 (6.3) was on par with the irrigation level I_3. The irrigation level I_2 was on par with the I_1 (5.2). The minimum value of number of branches was observed for the irrigation level I_1. Among the three irrigation levels the amount of water applied was more in the case of I_3, so the growth parameter like number of branches were more in the case of I_3. This is in agreement with the observation made by Rajbir *et al.* (2003) revealed that irrigation applied at 80 per cent pan evapotranspiration gave significantly higher yield.

The data on number of branches at 160 days after planting as influenced by different treatments, levels of irrigation and drip system layout are presented in Tables 15 and 16. The number of branches at 160 days after planting as influenced by different treatments and different levels of irrigation is shown in Fig.34 and 35.

The maximum value of branches was observed for the treatment T_5 (8.5). The minimum value was seen for the treatment T_7 (5.5). The data presented in the Table.15 revealed that the treatments showed significant difference in number of branches. The treatments T_3 (7.0), T_4 (7.9) and T_6 (8.2) were on par with the treatment T_5. The minimum mean value was observed in the case of control unit (5.5). So the number of branches were more with respect to six treatments as compared with the control at 160 days after planting.

From the data presented in the Table.16, the different levels of irrigation showed significant difference. With respect to number of branches the maximum value was recorded in the case of irrigation at I_3 (8.5). The level of irrigation I_2 (7.5) was on par with the irrigation level I_3. The irrigation level I_2 was on par with the I_1 (6.1). Among the three irrigation levels the amount of water applied was more in the case of I_3 and so the number of branches was more in the case of I_3.

Table 13. Number of branches at 120 days after planting as influenced by different treatments

Treatments	I_1	I_2	I_3	Control
D_1	5.8^a	4.5^b	6.5^a	2.83^c
D_2	6.1^a	6.7^a	6.7^a	
CD for Treatments = 1.66				

Table 14. Number of branches at 120 days after planting as influenced by different levels of irrigation and the drip system layout

Treatments	I_1	I_2	I_3	Mean
D_1	5.8	6.5	6.7	6.37
D_2	4.5	6.1	6.7	5.87
Mean	5.1^b	6.3^a	7.5^a	6.08
CD for factor A = 1.36	Factor B Non Significant			

Table 15. Number of branches at 160 days after planting as influenced by different treatments

Treatments	I_1	I_2	I_3	Control
D_1	6.5^b	7.0^a	8.7^a	5.5^b
D_2	5.5^b	7.9^a	8.2^a	
CD for Treatments = 1.73				

Table 16. Number of branches 160 days after planting as influenced by different levels of irrigation and the drip system layout.

Treatments	I_1	I_2	I_3	Mean
D_1	6.5	7.0	8.7	7.45
D_2	5.5	7.9	8.2	7.24
Mean	6.0^b	7.5^a	8.5^a	7.35
CD for factor A = 1.8	Factor B Non Significant			

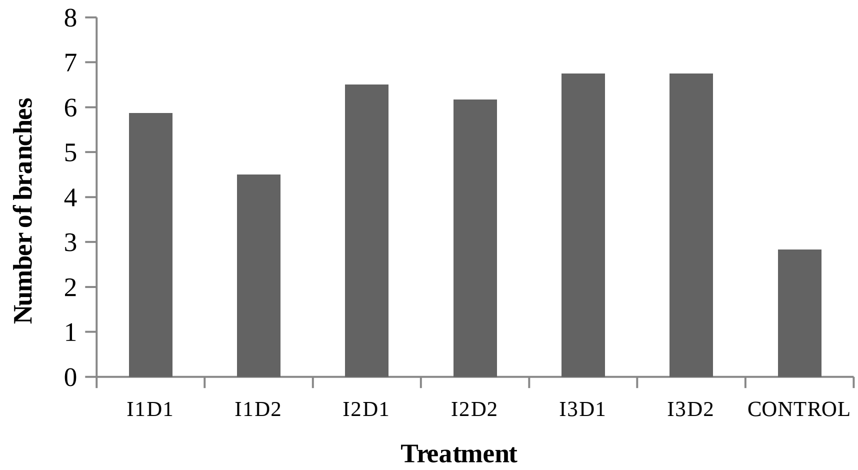


Fig.32 Number of branches at 120 days after planting as influenced by seven treatments

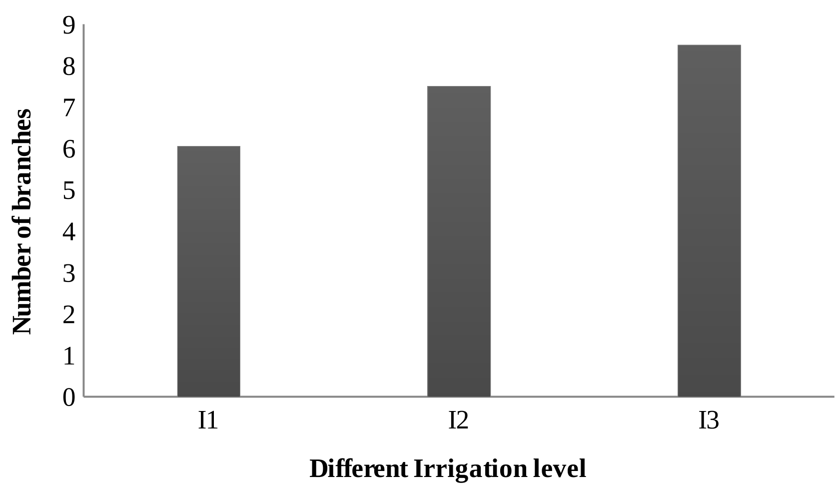


Fig.33 Number of branches at 120 days after planting as influenced by different levels of irrigation

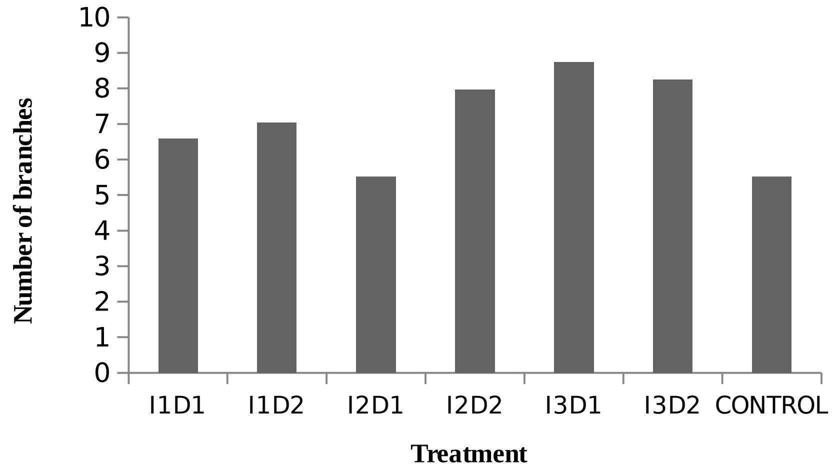


Fig.34 Number of branches at 160 days after planting as influenced by seven treatments

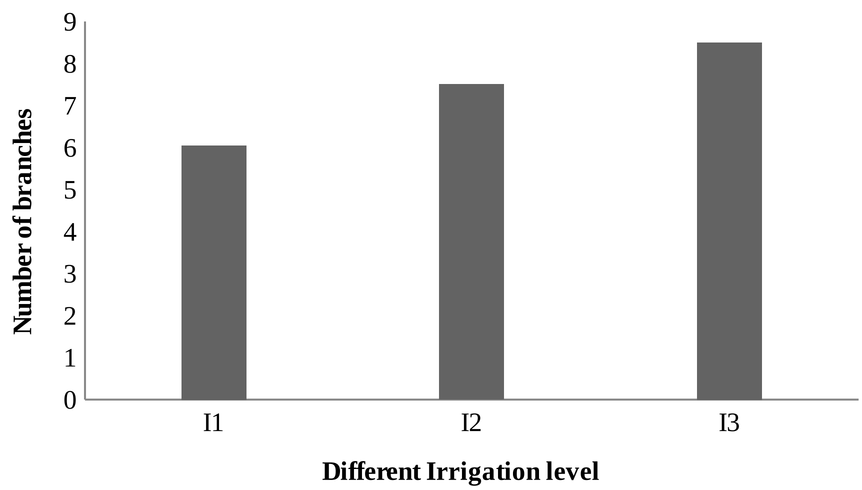


Fig.35 Number of branches at 160 days after planting as influenced by different levels of irrigation

4.2.2.4 Stem girth (cm)

The data on stem girth 120 days after planting as influenced by different treatments, levels of irrigation and drip system layout are presented in Tables 17 and 18. Stem girth at 120 days after planting as influenced by different treatments is shown in Fig.36

The maximum value in the case of stem girth was observed for the treatment T_5 (3.1 cm) and the treatment T_6 (2.6 cm) was on par with the treatment T_5. The minimum value was seen for the treatment T_7 (2.8 cm).

From Table 18 it is understood that the different levels of irrigation and the drip system layout did not show significant difference. The stem girth at 160 days after planting as influenced by different levels of irrigation and drip system layout is presented in Table 19. The stem girth at 160 days after planting did not differ significantly with respect to the different treatments over control. The data did not differ significantly due to different levels of irrigation and the drip system layout and the fertigation under plastic mulching. The results indicated that the treatments did not influence stem girth except at 120 days after planting.

4.2.2.5 Average total yield of chilli (g /plant)

The data on total yield at 180 days after planting as influenced by different treatments, levels of irrigation and drip system layout are presented in Tables 21, 22, 23 and 24. The average yield as influenced by different treatments, levels of irrigation and drip system layout are shown in Fig.37, 38 and 39.

The maximum value in the case of total yield was observed for the treatment T_5 (458.072 g/plant). The minimum value was seen for the treatment T_7 (113 g/plant). The data presented in Table.21 reveals that the seven treatments showed significant difference. The treatments T_6 (448.8 g/plant) was on par with the treatment T_5. The minimum value was observed in the case of control, T_7 (113 g/plant).

Table 17. Stem girth (cm) at 120 days after planting as influenced by different treatments

Treatments	I_1	I_2	I_3	Control
D_1	2.6^b	2.3^b	3.1^a	2.0^c
D_2	2.4^b	2.5^b	2.6^a	
CD for treatments 0.508				

Table 18. Stem girth (cm) at 120 days after planting as influenced by different levels of irrigation

Treatments	I_1	I_2	I_3	Mean
D_1	2.6	2.3	3.1	2.7
D_2	2.4	2.5	2.6	2.5
Mean	2.5	2.4	2.8	2.6
Factor A and B NS				

Table 19. Stem girth (cm) at 160 days after planting as influenced by different treatments

Treatments	I_1	I_2	I_3	Control
D_1	2.6	2.3	3.1	2.1
D_2	2.4	2.5	2.6	
Non Significant				

Table 20. Stem girth (cm) at 160 days after planting as influenced by different levels of irrigation and drip system layout.

Treatments	I_1	I_2	I_3	Mean
D_1	2.7	2.8	3.1	2.8
D_2	2.5	2.8	2.8	2.7
Mean	2.6	2.8	2.9	2.8
Factor A and B NS				

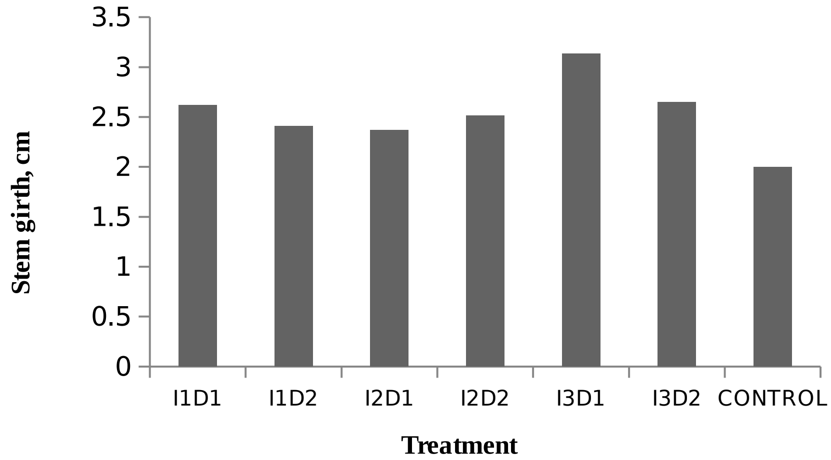


Fig.36 Stem girth (cm) at 120 days after planting as influenced by different treatments.

This is in agreement with Sivanappan and Natarajan (1976) revealed that 26 per cent yield increase on tomato due to drip irrigation compared to surface irrigation.

In the case of treatment T_5 and T_6, the number of branches was also more as compared with the other treatments. Therefore the average total yield was also more in the case of treatments T_5 and T_6. In the case of treatments T_5 and T_6 the amount of irrigation applied was more as compared with the other treatments. So the yield obtained also increased due to the increase in water application. This is in agreement with Jobi *et al.* (1998) and Khistaria (1993). In the case of the control, the lesser WUE due to surface irrigation resulted in low yield. In control treatment yield were not provided with mulches and laterals and there for the fruits per plant from these beds were minimum when compared to others. This is in agreement with the Singh *et al.* (2001) who indicated that the biometric growth of the treatments irrigated at 60 percent level through drip system with plastic mulching performed better yield.

From the data presented in the Table.22, the different levels of irrigation showed significant difference. Yield showed significant difference with different levels of irrigation and drip system layout. The maximum yield value in the case of irrigation level was seen in I_3 (453.436 g/plant).The minimum value in the case of average yield was observed for the irrigation level I_1 (312.2 g/plant). Among the three irrigation levels the amount of water applied was more in the case of I_3, so the average yield was more in the case of I_3. This is in agreement with the Singh *et al.* (2009) and Rajbir *et al.* (2003). The study suggested that it is better to schedule irrigation at 0.8 of pan evaporation on canopy area basis that would maximize the crop production. From the Table 22, the different drip system layout also showed significant difference. The maximum value in the case of yield was obtained for the drip system layout D_1 (381.77 g/plant), one lateral for each row of crops and the minimum yield was obtained for the treatment D_2 (357.217 g/plant), one lateral in between two rows of crop. The maximum yield of D_1 is due to the more amount of irrigation application through the drip system layout. The treatment with one lateral for each row of crops showed better results than their corresponding single lateral arrangements. This was due to the higher moisture level in one lateral for each row of crops with different levels of irrigation. This could be attributed to the fact that high moisture level in one lateral for each row of crops helps in better fruit weight per plant as compared to the plants with one lateral in between two rows of crop. The drip system layout D_2 showed minimum yield (357.217 g/plant)

4.2.2.5 Average total yield of chilli (t/ha)

The data on total yield at 180 days after planting as influenced by different treatments, levels of irrigation and drip system layout are presented in the Tables 21, 22, 23 and 24. The average yield in t/ha as influenced by different treatments, levels of irrigation and drip system layout are shown in Fig.40, 41 and 42.

The maximum yield was observed for the treatment T_5 (18.323 t/ha). The minimum value was seen for the treatment T_7 (4.546 t/ha). This is in agreement with Sivanappan and Natarajan (1976) revealed that 26 per cent yield increase on tomato due to drip irrigation compared to surface irrigation. The data presented in Table.23 revealed that seven treatments showed significant difference. The treatments T_6 (17.952 t/ha) was on par with the treatment T_5. The minimum value was observed in the case of control, T_7 (4.546 t/ha). In the case of treatment T_5 and T_6, the number of branches was more as compared with the other treatments. Therefore the average total yield was also more in the case of treatments T_5 and T_6. In the case of treatments T_5 and T_6 the amount of irrigation applied was more as compared with the other treatments. So the yield obtained was also increased due to the increase in water application. This is in agreement with Jobi *et al.* (1998) and Khistaria (1993). In the case of the control treatment the water applied through surface irrigation resulted in less WUE. The treatment T_1 was on par with the treatment T_3. Control plots were not provided with mulches and laterals and there for the fruits per plant from these beds were minimum in number when compared to others. This is in agreement with the

Singh *et al.* (2001) who indicated that the biometric growth of the treatments irrigated at 60 percent level through drip system with plastic mulching performed better yield.

From the data presented in Table.24 the different levels of irrigation showed significant difference. Average yield showed significant difference with different levels of irrigation and drip system layout. The maximum yield value in the case of irrigation level was seen in I_3 (18.137 t/ha).The minimum value in the case of average yield was observed for the irrigation level I_1 (12.488 t/ha). .Among the three irrigation levels the amount of water applied was more in the case of I_3, so the average yield were more in the case of I_3. This is in agreement with the Singh *et al.* (2009) and Rajbir *et al.* (2003). The study suggested that it is better to schedule irrigation at 0.8 of pan evaporation on canopy area basis that would maximize the crop production. From the Table.22 the different drip system layout also showed significant difference. The maximum value in the case of yield was obtained for the drip system layout D_1, one lateral for each row of crops (15.271 t/ha) and the minimum yield was obtained for the treatment D_2, one lateral in between two rows of crop (14.289 t/ha). The maximum yield of D_1 is due to the more amount of irrigation application through the drip system layout. The treatment with one lateral for each row of crop showed better results than their corresponding one lateral in between two rows of crop arrangements. This is due to the higher moisture level in one lateral for each row of crops with different levels of irrigation. This can be attributed to the fact that high moisture level in one lateral for each row of crops helps in better fruit weight per plant as compared to the plants with one lateral in between two rows of crop. The drip system layout D_2 showed minimum yield (14.289 t/ha).

4.2.3 Water use efficiency

The influence water use efficiency in chilli crop is presented in Table 25. The highest water use efficiency of 25 kg/ha/mm was recorded in treatment T_5 and T_1. The reason for maximum water use efficiency in T_1 due to lesser water used as compared to T_6. The water use efficiency of 25 kg/ha/mm for treatment T_1 was higher than the water use efficiency of 23 kg/ha/mm for the treatment T_3. This was due to lesser water used as compared with the treatment T_3. Similar results were reported by Bao-Zhong and Yuvan (2003). They observed that the maximum WUE of 3.73 kg/ha/mm in drip irrigation at 75 per cent PE and was higher than 100 per cent (3.37 kg/ ha/mm) and 50 per cent PE (3.42 kg/ha/mm)

4.2.3 Fertilizer use efficiency

The fertilizer use efficiency in chilli crop is presented in the Table 26. Increased FUE such as Nitrogen use efficiency (NUE) and Pottasium use efficiency (KUE) with the decreased levels of fertilizer doses were observed in the chilli crop. The highest NUE of 244.26 kg of produce / kg of N was recorded in the treatment $T_{5.}$ Similar findings were observed by Vijayakumar, *et al.* (2010). For the treatment T_6 the NUE of 239.36 kg of produce / kg of N was recorded and for the control was about 60.5 kg of produce / kg of N.

The similar trend was observed in KUE in chilli crop. The maximum KUE of 732.8 and 718.08 of kg of produce / kg of K was observed in the case of the treatment T_5 and T_6. The lowest KUE was observed in the case of control and was about 181.6 kg of produce / kg of K.

Table 21. Yield (g/plant) of chilli as influenced by different treatments.

Treatments	I_1	I_2	I_3	Control
D_1	330.800[c]	356.460[b]	458.072[a]	113[e]
D_2	293.600[d]	329.250[c]	448.800[a]	
CD for Treatments 15.6				

Table 22. Yield (g/plant) of chilli as influenced by different levels of irrigation and drip system layout.

Treatments	I_1	I_2	I_3	Mean
D_1	330.8	356.4	458.0	381.77
D_2	293.6	329.2	448.8	357.21
Mean	312.2[c]	342.8[b]	453.4[a]	369.49
CD for factor A and B 16.97				

Table 23. Yield (t/ha) of chilli as influenced by different treatments.

Treatments	I_1	I_2	I_3	Control
D_1	13.232[b]	14.258[b]	18.323[a]	4.546[f]
D_2	11.744[d]	13.170[c]	17.952[a]	
CD for treatments 0.6275				

Table 24. Yield (t/ha) of chilli as influenced by different levels of irrigation and drip system layout.

Treatments	I_1	I_2	I_3	Mean
D_1	13.232	14.258	18.323	15.271[a]
D_2	11.744	13.170	17.952	14.289[b]
Means	12.488[c]	13.714[b]	18.137[a]	14.780
CD for factor A and B 0.679				

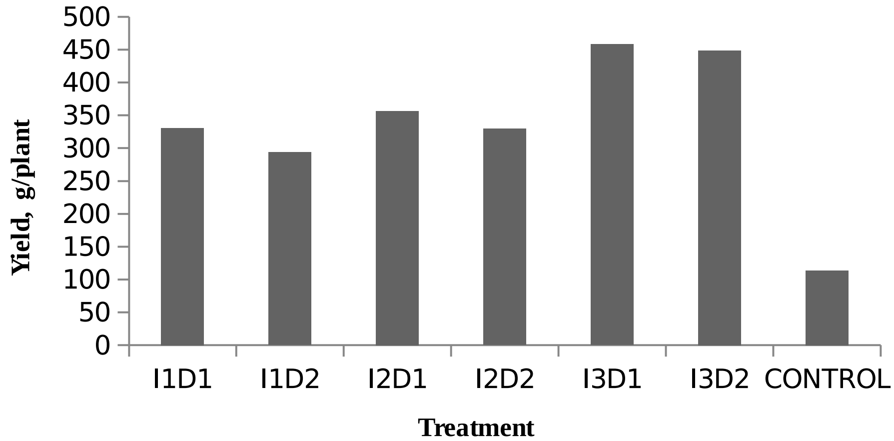


Fig.37 Yield (g/plant) as influenced by different treatments

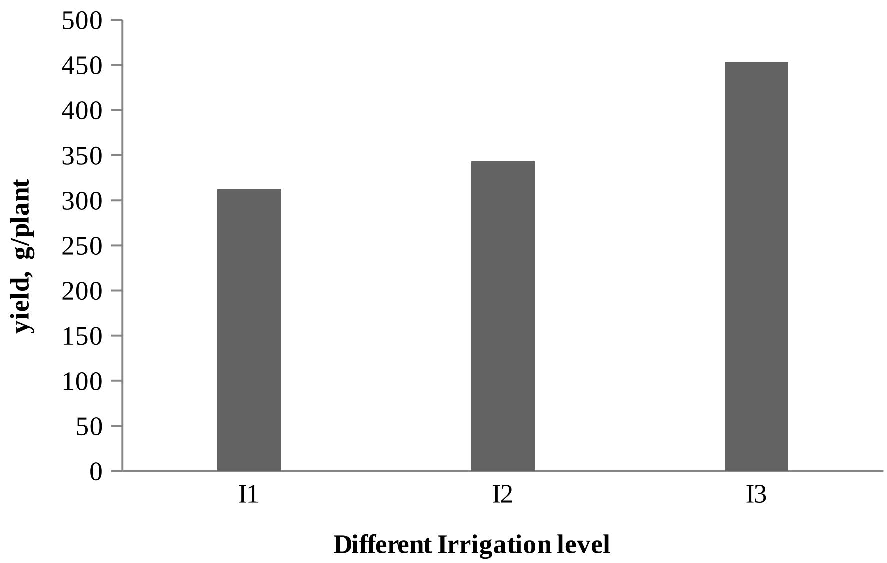


Fig.38 Yield (g/plant) as influenced by different levels of irrigation

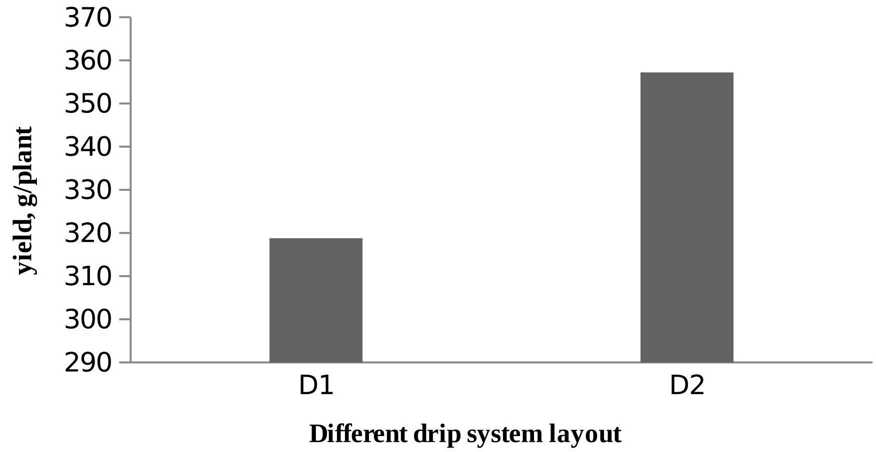


Fig.39 Yield (g /plant) as influenced by different drip system layout.

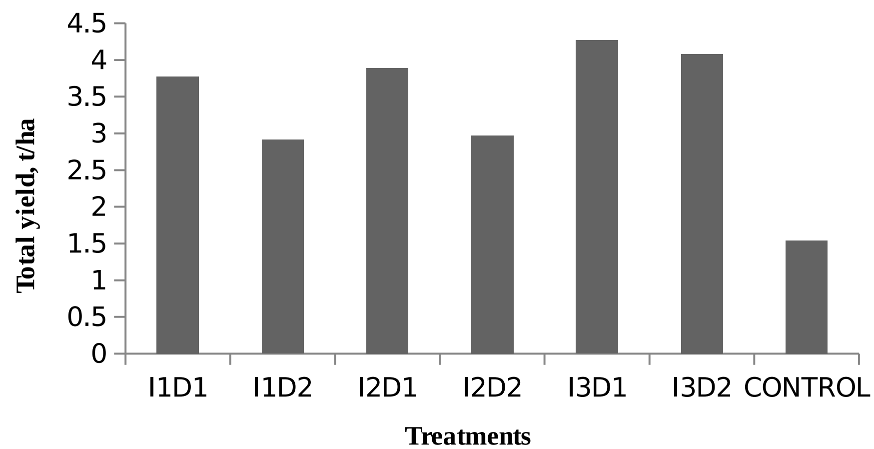


Fig.40 Yield (t/ha) as influenced by different treatments

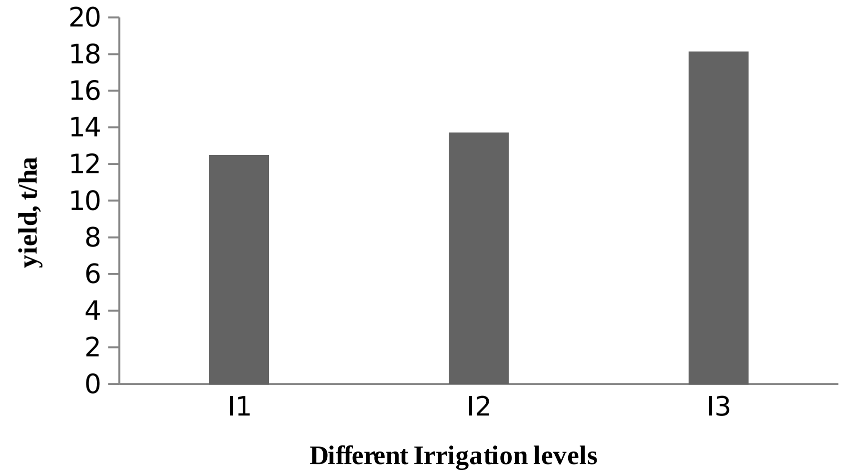


Fig.41 Yield (t/ha) as influenced by different irrigation levels

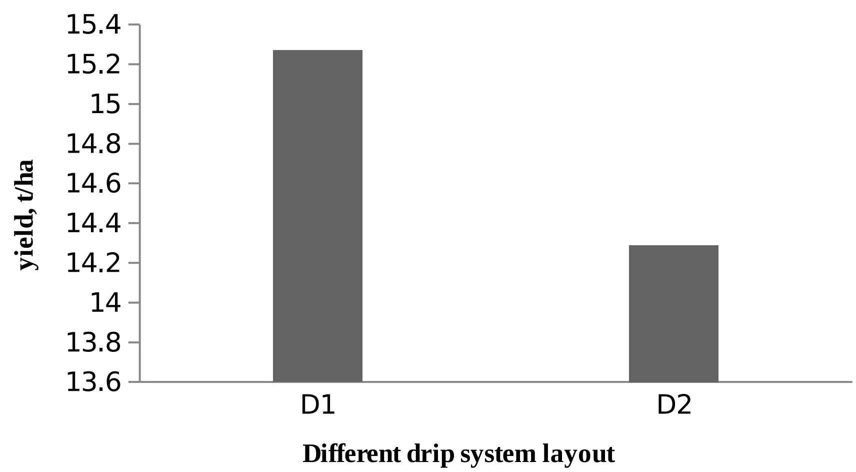


Fig.42 Yield (t/ha) as influenced by different drip system layout

Table 25. Water use efficiency in chilli crop

Treatments	Yield (kg/ha)	Total water used (L/ha)	WUE (kg/ha/mm)
T_1	13232	5280000	25
T_2	11744	5280000	22
T_3	14258	6240000	23
T_4	13170	6240000	21
T_5	18320	7200000	25
T_6	17952	7200000	24

Table 26. Fertilizer use efficiency in chilli crop

Treatments	**Fertilizer applied** kg/ha		**Yield** kg/ha	**NUE** kg of produce / kg of N	**KUE** kg of produce / kg of K
T_1	75	25	13232	176.42	529.28
T_2	75	25	11744	156.58	469.76
T_3	75	25	14258	190.10	570.32
T_4	75	25	13170	175.60	526.80
T_5	75	25	18320	244.26	732.80
T_6	75	25	17952	239.36	718.08
Control	75	25	4540	60.50	181.60

4.3 ECONOMICS OF DRIP FERTIGATION SYSTEM

The economic of the system was worked out by making the following assumptions.

1. The number of crops raised per year was considered as two.
2. The life span of the drip irrigation system was taken as 7 years and the total cost of drip was divided equally for the seven years.
3. The life span of motor was taken as 5 years.
4. Land preparation is done by labour with full day wage taken as Rs 300.
5. The spacing is taken as 50 x 50 cm and the number of plants in 15 m^2 is taken as 66.
6. Soluble fertilizers is completely used for the experimental plot and not for the control plot.

The chilli yield, gross income (₹/ha), net returns (₹/ha) and Benefit Cost ratio of chilli as affected by the level of irrigation water requirement, drip system lay out through fertigation and drip irrigation were determined.

Table 27. Cost of materials used for the drip fertigation system for an area of one hectare

Description	**Unit**	**Quantity**	**Amount, ₹**
PVC pipe 90mm	m	54	5508/-
PVC pipe 75mm	m	164	3780/-
Laterals with inline dripper	m	20100	160800/-
Control valve	75mm	2nos	300/-
Ventury and manifold	¾ ‘’	1 nos	1100/-
Screen filter	10 m^3/hr	1nos	2500/-
Fitting and accessories			4000/-
Total			**1,77,988/-**

Table 28. Cost of inputs used for the drip fertigation systems for an area of one hectare

Description	**Quantity**	**Amount, ₹**
Bavistin	800g	560/-
Mulch sheet	2000m	14000/-
Neem cake	100kg	1600/-
Potash	40kg	800/-
Urea	20kg	120/-
Rajphose	10kg	60/-
19:19:19	50kg	4000/-
Confidor	1000ml	500/-
Pseudomonos	15kg	750/-
Total		**22390/-**

Table 29. Cost of labour charges for 2 season crop

LABOUR COST	**Amount, ₹**
Installation Charges	24900/-
land preparation	4500/-
Bed formation	5100/-
Laying Mulch sheet	5100/-
Nursery preparation	1200/-
Manure application	5400/-
Transplanting	7500/-
Fertilizer application	3000/-
Fertigation	10500/-
Spraying chemicals	5100/-
Weeding	5100/-
Harvesting	18300/-
Total	95700/-

Total fixed cost for drip fertigation system	= ₹177988/-
Consider life span as 7 years	
Total Annual fixed cost for drip fertigation system	= ₹25427/-
Cost of 2hp motor pump set and accessories	= ₹5500/-
Consider life span as 10 years	
Annual fixed cost for motor	= ₹550/-
Total fixed cost	**= ₹25977/-**
Total cost for planting materials	= ₹30000/-
Cost of fertilizers and chemicals	= ₹22390/-
Labour costs	= ₹95700 /-
Total variable cost	= ₹148090/-
Total annual cost	**= ₹1, 74, 067/-**
Total income from crop after 1 year two crops	**= ₹6, 96, 274/-**
B/C ratio of the drip fertigation system	**= 3.8**

Table 30. Chilli cultivated with Drip irrigation and plastic mulch as experimental plot

Total fixed cost for drip fertigation system, ₹	110519/-
Total fixed cost for drip fertigation system(for a life span of 7 years), ₹	15788/-
Cost of 2hp pump set and assecories, ₹	5500/-
Cost of 2hp pump set and assecories(for a life span of 10 years), ₹	550/-
Total annual fixed cost, ₹	16338/-
Total cost for planting materials, ₹	30000/-
Cost of fertilizers and chemicals, ₹	22390/-
Labour cost, ₹	101700/-
Total variable cost, ₹	154090/-
Total Annual cost, ₹	170428/-
Total income from 1 year after 2 crops, ₹	646274/-
B/C	**3.7**

Table 31. Benefit cost ratio of different treatments

Treatments	**Yield, kg/ha**	**Total cost, ₹**	**Gross income, ₹**	**Net income, ₹**	**B/C**
T_1	26464	174066	476352	302286	2.7
T_2	23488	162581	422784	260203	2.6
T_3	28516	174066	513288	339222	3.0
T_4	26340	162581	474120	311539	2.9
T_5	36640	174066	659520	485454	3.8
T_6	35904	162581	646272	483691	3.9
Control	12502	118390	225036	106646	1.9

The total annual cost for the drip fertigation system was ₹1, 74, 066 and the total income from the crop production after 1 year two crop was ₹6, 96, 274. Benefit cost ratio for each treatment with the assumption made as explain earlier is presented in Table 31. The benefit cost ratio treatment T_3, 75 per cent of the irrigation requirement with one lateral for each row of crops was 3.0. This is in agreement with Tamil Mani *et al.* (2010) studies in brinjal crop. They revealed that the maximum benefit cost ratio of 2.9 was noted in drip irrigation at 75 per cent of PE. The benefit cost ratio for treatment T_5 was 3.8 and treatment T_6 was 3.9. Even though the yield for the treatment T_5 was high, the benefit cost ratio stands high for treatment T_6. The high value of benefit cost ratio for treatment T_6 was due to the reduction in the quantity of material for drip irrigation system. In treatment T_6 only a single lateral is provided on a bed in between two rows of crop. For treatment T_5 each row of the crop is provided with a separate lateral. On the basis of benefit cost ratio treatment T_6 is recommended for adoption.

SUMMARY AND CONCLUSION

The present study was taken up with the objective of determining the effect of fertigation, drip system layout and different levels of irrigation for chilli under plastic mulching. The performance evaluation of different fertigation equipments was also done. The statistical design was Factorial Randomized Block Design consisted of 21 plots with seven treatments and three replications. The growth and the yield parameters were compared statistically.

The performance evaluation of the fertigation equipments ventury injector, dosmatic fertigation unit and fertilizer tank was carried out. The suction rate was found to vary directly with respect to the pressure drop in the fertigation equipment. At 0.5 kg(f)/cm^2, the higher value was observed in the case of ventury injector with suction rate of 0.103 (L/min) and the lower value was observed in the case of dosmatic fertigation unit with suction rate of 0.046 (L/min). At 0.8 kg(f)/cm^2 pressure drop, the corresponding suction rate for ventury injector and dosmatic fertigation unit were observed as 0.23 and 0.163 (L/min) respectively. Ventury injector was found to have high suction rates when compared to dosmatic fertigation unit. The performance of the fertigation system depended on the fertilizer suction rate.

The hydraulic performance of different fertigation equipments was studied with respect to variation of motive flow rate with pressure difference. The maximum flow rate of 27.13 L/min was obtained for a pressure difference of 0.8 kg(f)/cm^2 in ventury injector. The increase in motive flow rate was 46 per cent for a change in pressure difference from 0.1 to 0.8 kg(f)/cm^2 for ventury injector. Similarly in the case of dosmatic fertigation unit, for a pressure difference of 0.6 kg(f)/cm^2, the motive flow rate obtained was 1.92 L/min and for a pressure difference of 0.7 kg(f)/cm^2, the motive flow rate was 1.99 L/min. For dosmatic fertigation unit, maximum flow rate of 2.03 L/min was obtained for a pressure difference of 0.8 kg(f)/cm^2. In the case of fertilizer tank maximum flow rate of 12.21 L/min was obtained for a pressure difference of 0.8 kg(f)/cm^2. The motive flow rate of ventury injector was 14.6 L/min which was higher than that of the fertilizer tank 6.6 L/min and dosmatic fertigation unit 1.1 L/min at the pressure difference of 0.1 kg(f)/cm^2.

Dosmatic fertigation units can be used for motive flow rates of 1.1 L/min and above. Fertilizer tanks can be effectively utilized for motive flow rates of 6.6 L/min and above. Ventury injectors can be used for motive flow rates of 14.6 L/min and above. Thus the ventury injectors are suitable for chilly cultivation when the land area is more.

The hydraulic performance of the drip and fertigation system was studied with respect to emitter coefficient of manufacturing variation, emitter flow variation and uniformity coefficient also. The emitter coefficient of manufacturing variation was found to increase with operating pressure. For an operating pressure of 0.7 kg(f)/cm^2, the coefficient of manufacturing variation was 17.8 per cent. For an operating pressure of 0.5 kg(f)/cm^2, the coefficient of manufacturing variation was 10.1 per cent which is acceptable as good performance.

The emitter flow variation of the drip irrigation system was found to decrease with increase in operating pressures. The emitter flow variation was also worked out with respect to uniformity coefficient. The variation of uniformity coefficient with operating pressure is expressed as

$$\mathbf{Y = 30.65e^{2.248x} \qquad (R^2=0.66)}$$

Where,

Y = pressure in kg(f)/cm^2

x = uniformity coefficient, per cent

Moisture contents were determined 2hr and 6hr after irrigation. For the treatments T_1, T_3 and T_5, as the distance from the plant was increased the moisture content decreased. For the treatment T_2, T_4 and T_6, as the distance from the plant was increased the moisture content reduced due to increase in spacing of laterals. Along the depth also the moisture present in the soil reduced. The variations proved that one lateral for each rows of crop retained more moisture than one lateral in between two rows of crop.

The data on plant height, number of leaves, number of branches and stem girth at 120 and 160 days after planting as influenced by different treatments, levels of irrigation and drip system layout were observed. The average yield of chilli was taken 160 days after planting. The result revealed that the plant height and number of leaves at both stages did not differ significantly with respect to the different treatments over control. The data did not differ significantly either due to the levels of irrigation or due to the different drip system layout and fertigation under plastic mulching. The data on number of branches as influenced by different treatments and levels of irrigation showed significant difference at 120 and 160 days after planting. With respect to the number of branches, it is seen that the maximum number of branches in the case of irrigation level was seen in I_3 (8). In case of number of branches, the level of irrigation I_2 (7) was on par with the irrigation level I_3. The irrigation level I_2 was on par with the I_1 (6). The minimum number of branches was observed for the irrigation level I_1 at 120 days after planting.

The seven treatments showed significant difference in the case of average yield (t/ha). The maximum yield was observed for the treatment T_5 (18.323 t/ha), 85 per cent of the irrigation requirement with one lateral for each row of crops. The treatments T_6 (17.952 t/ha), 85 per cent of the irrigation requirement with one lateral in between two row of crops was on par with the treatment T_5. The minimum yield was observed in the case of control, T_7 (4.546 t/ha). With respect to average yield the different levels of irrigation and the drip system layout showed significant difference.

The maximum yield value in the case of irrigation level was seen in I_3 (18.137 t/ha), 85 per cent of the irrigation requirement. The minimum yield was observed for the irrigation level I_1 (12.488 t/ha), 65 per cent of the irrigation requirement. When different drip system layout were taken into consideration, the maximum yield was obtained for the drip system layout D_1 (15.271 t/ha), one lateral for each row of crops and the minimum yield was obtained for the drip system layout, D_2 (14.289 t/ha) one lateral in between two rows of crops. This can be attributed to the fact that high moisture level in one lateral for each row of crops helps in better fruit weight per plant as compared to the plants with one lateral in between two rows of crops.

The total annual cost for the drip fertigation system was ₹1, 74, 066 and the total income from the crop production after 1 year two crop was ₹6, 96, 274. The benefit cost ratio for treatment T_5, 85 per cent of the irrigation requirement with one lateral for each row of crop was 3.8 and treatment $T_{6,}$ 85 per cent of the irrigation requirement with one lateral in between two rows of crop was 3.9. Even though the yield for the treatment T_5 was high, the benefit cost ratio stands high for treatment T_6. The high value of benefit cost ratio for treatment T_6 was due to the reduction in the quantity of material for drip irrigation system. In treatment T_6 only single lateral is provided on a bed in between two rows of crop. For treatment T_5 each row of the crop is provided with a separate lateral. On the basis of benefit cost ratio treatment T_6 is recommended for adoption.

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Appendix-I

Average Rainfall in the experimental site

Months	Rainfall (mm)
10-Mar	072.6
20-Mar	039.7
31-Mar	008.8
10-Apr	072.6
20-Apr	039.7
30-Apr	008.8
10-May	003.1
20-May	000.8
31-May	147.0
10-Jun	097.3
20-Jun	341.0
30-Jun	183.2
10-Jul	404.5
20-Jul	086.0
31-Jul	235.0
10-Aug	126.0
20-Aug	144.0
30-Aug	016.2
10-Sep	386.5
20-Sep	134.1
30-Sep	034.7
10-Oct	084.8
20-Oct	072.3
30-Oct	057.2
10-Nov	127.5
20-Nov	10.50

Appendix-II

Variation of suction rate with pressure difference for ventury injector

Pressure difference (kg (f)/cm^2)	Suction rate (L/min)
0.1	0.083
0.2	0.103
0.3	0.116
0.4	0.140
0.5	0.150
0.6	0.160
0.7	0.170
0.8	0.230

Appendix-III

Variation of motive flow rate with pressure difference for ventury injector

Pressure difference (kg (f)/cm^2)	Motive flow rate (L/min)
0.1	14.60
0.2	17.60
0.3	19.40
0.4	20.90
0.5	23.76
0.6	23.50
0.7	26.54
0.8	27.13

Appendix-IV

Variation of suction rate with motive flow rate for ventury injector

Suction rate (L/min)	Motive flow rate (L/min)
0.083	14.60
0.103	17.60
0.116	19.40
0.140	20.90
0.150	23.76
0.160	23.50
0.170	26.54
0.230	27.13

Appendix-V

Variation of suction rate with pressure difference for dosmatic unit

Pressure difference (kg (f)/cm^2)	Suction rate (L/min)
0.1	0.023
0.2	0.046
0.3	0.066
0.4	0.088
0.5	0.100
0.6	0.113
0.7	0.138
0.8	0.163

Appendix-VI

Variation of motive flow rate with pressure difference for dosmatic unit

Pressure difference (kg (f)/cm^2)	Motive flow rate (L/min)
0.1	1.10
0.2	1.32
0.3	1.45
0.4	1.56
0.5	1.78
0.6	1.92
0.7	1.99
0.8	2.03

Apenndix-VII

Variation of suction rate with motive flow rate for dosmatic unit

Suction rate (L/min)	Motive flow rate (L/min)
0.023	1.10
0.046	1.32
0.066	1.45
0.088	1.56
0.100	1.78
0.113	1.92
0.138	1.99
0.163	2.03

Appendix-VIII

Variation of motive flow rate with pressure difference for fertilizer tank

Pressure difference (kg (f)/cm^2)	Motive flow rate (L/min)
0.1	06.60
0.2	07.92
0.3	08.74
0.4	09.40
0.5	10.60
0.6	11.55
0.7	11.90
0.8	12.29

Appendix-IX

Comparison of suction rate with pressure difference for different fertigation equipments.

Pressure difference (kg (f)/cm^2)	Suction rate of ventury (L/min)	Suction rate of dosmatic (L/min)
0.1	0.083	0.023
0.2	0.103	0.046
0.3	0.116	0.066
0.4	0.140	0.088
0.5	0.150	0.100
0.6	0.160	0.113
0.7	0.170	0.138
0.8	0.230	0.163

Appendix-X

Comparison of motive flow rate with pressure difference for different fertigation equipments

Pressure difference (kg (f)/cm^2)	Motive flow rate of ventury (L/min)	Motive flow rate of dosmatic (L/min)	Motive flow rate of fertilizer tank (L/min)
0.1	14.60	1.10	06.60
0.2	17.60	1.32	07.92
0.3	19.40	1.45	08.74
0.4	20.90	1.56	09.40
0.5	23.76	1.78	10.60
0.6	23.50	1.92	11.55
0.7	26.54	1.99	11.90
0.8	27.13	2.03	12.29

Appendix-XI

Variation of emitter coefficient of manufacturing variation with operating pressures in the drip fertigation system

Operating pressure kg (f)/cm^2	Coefficient of manufacture variance
0.2	02.1
0.3	02.4
0.4	05.0
0.5	10.1
0.6	14.6
0.7	17.8

Appendix-XII

Emitter flow variation with operating pressures

Operating pressure kg (f)/cm^2	Emitter flow variation
0.1	0.25
0.2	0.14
0.3	0.13
0.4	0.13
0.5	0.10

Appendix-XIII

Variation of uniformity coefficient with operating pressure for the first lateral line.

Pressure (kg f/cm^2)	0.1	0.3	0.6	0.7	0.8	1	1.2
Discharges	1.425	2.6	3.8	3.8	4.0	4.74	4.32
	1.300	2.5	3.7	3.7	3.8	4.80	4.08
	0.750	2.5	3.9	3.8	3.8	4.80	4.08
	0.750	2.4	3.7	3.6	3.6	4.68	3.96
	0.850	2.4	3.7	3.6	3.6	4.80	4.08
	0.852	2.4	3.3	3.6	3.6	4.56	3.96

Appendix-XIV

Variation of uniformity coefficient with operating pressure for the second lateral line.

Pressures kg (f)/cm^2	0.1	0.3	0.6	0.7	0.8	1	1.2
Discharges	0.750	2.2	3.7	3.6	3.90	4.56	3.90
	0.675	2.2	3.7	3.6	3.90	4.56	3.90
	0.450	2.1	3.6	3.5	3.84	4.44	3.84
	0.450	2.0	3.7	3.5	3.84	4.44	3.84
	0.600	2.0	3.6	3.4	3.72	4.32	3.84
	0.600	2.0	3.6	3.5	3.60	4.30	3.60

Appendix-XV

Moisture content for the treatment T_1

Moisture content for the treatment T_1 , Two hour after irrigation						
		Near the plant	5cm	10cm	15cm	20cm
1.	Near the plant	9.42	8.50	7.70	5.70	3.40
2.	5cm distance from the plant	8.60	8.30	7.20	6.52	3.10
3.	10cm distance from the plant	9.30	8.56	8.00	4.90	3.52
Moisture content for the treatment T_1 , six hour after irrigation						
		Near the plant	5cm	10cm	15cm	20cm
1.	Near the plant	8.20	7.60	4.70	3.40	1.85
2.	5cm distance from the plant	6.30	5.90	4.40	3.00	2.10
3.	10cm distance from the plant	6.50	5.50	4.00	2.20	1.69

Appendix-XVI

Moisture content for the treatment T_2

Moisture content for the treatment T_2 , two hour after irrigation						
		Near the plant	5cm	10cm	15cm	20cm
1.	Near the plant	10.70	09.60	9.00	6.00	4.20
2.	5cm distance from the plant	09.70	09.50	8.10	7.40	3.50
3.	10cm distance from the plant	10.60	10.10	9.20	5.60	4.00
Moisture content for the treatment T_2 , six hour after irrigation						
		Near the plant	5cm	10cm	15cm	20cm
1.	Near the plant	9.60	8.54	5.30	3.64	2.24
2.	5cm distance from the plant	7.50	6.80	4.96	3.50	2.32
3.	10cm distance from the plant	7.20	6.56	4.70	2.53	1.40

Appendix-XVII

Moisture content for the treatment T_3

Moisture content for the treatment T_3 , two hour after irrigation						
		Near the plant	5cm	10cm	15cm	20cm
1.	Near the plant	10.70	9.60	9.00	6.00	4.20
2.	5cm distance from the plant	09.70	9.50	8.10	7.40	3.50
3.	10cm distance from the plant	10.60	10.1	9.20	5.60	4.00
Moisture content for the treatment T_3 , six hour after irrigation						
		Near the plant	5cm	10cm	15cm	20cm
1.	Near the plant	9.60	8.54	5.30	3.64	2.24
2.	5cm distance from the plant	7.50	6.80	4.96	3.50	2.32
3.	10cm distance from the plant	7.20	6.56	4.70	2.53	1.40

Appendix-XVIII

Moisture content for the treatment T_4

Moisture content for the treatment T_4 , two hour after irrigation						
		Near the plant	5cm	10cm	15cm	20cm
1.	Near the plant	5.70	5.50	5.50	4.00	3.45
2.	5cm distance from the plant	5.10	4.40	4.00	3.40	3.00
3.	10cm distance from the plant	6.29	6.10	6.20	5.10	3.60
Moisture content for the treatment T_4 , six hour after irrigation						
		Near the plant	5cm	10cm	15cm	20cm
1.	Near the plant	3.32	2.75	2.40	1.88	1.50
2.	5cm distance from the plant	3.32	2.75	2.40	1.88	1.40
3.	10cm distance from the plant	4.50	4.70	3.51	2.65	1.64

Appendix.XIV

Moisture content for the treatment T_5

Moisture content for the treatment T_5, two hour after irrigation						
		Near the plant	5cm	10cm	15cm	20cm
1.	Near the plant	12.27	11.30	10.33	7.00	4.91
2.	5cm distance from the plant	11.18	10.90	09.37	8.40	4.37
3.	10cm distance from the plant	12.09	11.20	10.42	6.40	4.43
Moisture content for the treatment T_5, six hour after irrigation						
		Near the plant	5cm	10cm	15cm	20cm
1.	Near the plant	10.50	9.80	5.80	4.20	2.50
2.	5cm distance from the plant	08.20	7.40	5.40	4.10	2.80
3.	10cm distance from the plant	08.00	7.30	5.60	3.10	1.50

Appendix-XX

Moisture content for the treatment T_6

Moisture content for the treatment T_6, two hour after irrigation						
		Near the plant	5cm	10cm	15cm	20cm
1.	Near the plant	6.5	6.5	6.4	4.6	3.8
2.	5cm distance from the plant	5.7	5.0	4.5	4.0	3.6
3.	10cm distance from the plant	7.2	7.0	7.0	6.2	5.1
Moisture content for the treatment T_6, six hour after irrigation						
		Near the plant	5cm	10cm	15cm	20cm
1.	Near the plant	4.0	3.2	2.5	2.1	1.8
2.	5cm distance from the plant	5.2	5.1	4.1	3.0	2.0
3.	10cm distance from the plant	5.8	4.2	2.8	2.1	1.8

Appendix-XXI

a. Plant height (cm) at 120 days after planting as influenced by different treatments

ANALYSIS OF VARIANCE TABLE						
K Value	Source	Degrees of freedom	Sum of squares	Mean square	F value	Probability
1	Replication	02	009.983	40.991	0.216	NS
2	Treatments	06	024.833	04.139	0.179	NS
3	Error	12	276.810	23.067		
	Total	20	311.625			

b. Plant height (cm) at 120 days after planting as influenced by different levels of irrigation and drip system layout

ANALYSIS OF VARIANCE TABLE						
K Value	Source	Degrees of freedom	Sum of squares	Mean square	F value	Probability
1	Replication	02	027.250	13.625	0.58	NS
2	Factor A	02	014.146	07.073	0.30	NS
4	Factor B	01	004.014	04.014	0.17	NS
6	AB	02	003.174	01.587	0.06	NS
3	Error	12	231.667	23.167		
	Total	20	280.250			

c. Plant height (cm) at 160 days after planting as influenced by different treatments

ANALYSIS OF VARIANCE TABLE						
K Value	Source	Degrees of freedom	Sum of squares	Mean square	F value	Probability
1	Replication	02	001.839	00.920	0.042	NS
2	Treatments	06	030.369	05.062	0.232	NS
3	Error	12	261.577	21.798		
	Total	20	293.786			

d. **Plant height (cm) at 160 days after planting as influenced by different levels of irrigation and drip system layout**

ANALYSIS OF VARIANCE TABLE						
K Value	Source	Degrees of freedom	Sum of squares	Mean square	F value	Probability
1	Replication	02	021.382	10.691	0.6402	NS
2	Factor A	02	017.215	08.608	0.5154	NS
4	Factor B	01	003.125	03.125	0.1871	NS
6	AB	02	001.646	00.823	0.0493	NS
3	Error	10	166.993	16.99		
	Total	17	210.361			

Appendix-XXII

a. **Number of leaves at 120 days after planting as influenced by different treatments**

ANALYSIS OF VARIANCE TABLE						
K Value	Source	Degrees of freedom	Sum of squares	Mean square	F value	Probability
1	Replication	02	009.042	4.521	0.453	NS
2	Treatments	06	014.030	2.338	0.234	NS
3	Error	12	119.542	9.962		
	Total	20	142.613			

b. **Number of leaves at 120 days after planting as influenced by different levels of irrigation and drip system layout.**

ANALYSIS OF VARIANCE TABLE						
K Value	Source	Degrees of freedom	Sum of squares	Mean square	F value	Probability
1	Replication	02	019.882	9.941	1.0214	NS
2	Factor A	02	008.215	4.108	0.4220	NS
4	Factor B	01	002.347	2.347	0.2412	NS
6	AB	02	001.174	0.587	0.0603	NS
3	Error	10	097.326	9.733		
	Total	17	128.944			

c. Number of leaves at 160 days after planting as influenced by different treatments

ANALYSIS OF VARIANCE TABLE						
K Value	Source	Degrees of freedom	Sum of squares	Mean square	F value	Probability
1	Replication	02	08.256	4.128	0.59	NS
2	Treatments	06	05.655	0.942	0.13	NS
3	Error	12	83.077	6.923		
	Total	20	96.988			

d. Number of leaves at 160 days after planting as influenced by different levels of irrigation and drip system layout

ANALYSIS OF VARIANCE TABLE						
K Value	Source	Degrees of freedom	Sum of squares	Mean square	F value	Probability
1	Replication	02	15.257	7.628	1.1090	NS
2	Factor A	02	03.111	1.556	0.2261	NS
4	Factor B	01	00.222	0.222	0.0323	NS
6	AB	02	00.028	0.014	0.0020	NS
3	Error	10	68.785	6.878		
	Total	17	87.403			

Appendix -XXIII

a. Number of branches at 120 days after planting as influenced by different treatments

ANALYSIS OF VARIANCE TABLE						
K Value	Source	Degrees of freedom	Sum of squares	Mean square	F value	Probability
1	Replication	02	01.487	0.743	0.5686	NS
2	Treatments	06	38.123	6.354	4.8601	S
3	Error	12	15.688	1.307		
	Total	20	55.298			
Critical difference for Treatments 1.66						

b. Number of branches at 120 days after planting as influenced by different levels of irrigation and drip system layout

ANALYSIS OF VARIANCE TABLE						
K Value	Source	Degrees of freedom	Sum of squares	Mean square	F value	Probability
1	Replication	02	04.372	2.186	2.5683	NS
2	Factor A	02	07.901	3.951	4.6415	S
4	Factor B	01	01.445	1.445	1.6977	NS
6	AB	02	01.523	0.762	0.8948	NS
3	Error	10	08.511	0.851		
	Total	17	23.753			
Critical difference for factor A 1.3						

c. Number of branches at 160 days after planting as influenced by different treatments

K Value	Source	Degrees of freedom	Sum of squares	Mean square	F value	Probability
1	Replication	02	01.482	0.741	0.5347	NS
2	Treatments	06	30.241	5.040	3.6377	S
3	Error	12	16.627	1.386		
	Total	20	48.350			
Critical difference for factor B 1.712						

d. Number of branches at 160 days after planting as influenced by different levels of irrigation and drip system layout

ANALYSIS OF VARIANCE TABLE						
K Value	Source	Degrees of freedom	Sum of squares	Mean square	F value	Probability
1	Replication	02	01.053	0.526	0.3653	NS
2	Factor A	02	18.210	9.105	6.3211	S
4	Factor B	01	00.201	0.201	0.1392	NS
6	AB	02	03.188	1.594	1.1065	NS
3	Error	10	14.404	1.440		
	Total	17	37.055			
Critical difference for factor A 1.77						

Appendix –XXIV

a. Stem girth (cm) at 120 days after planting as influenced by different treatments

ANALYSIS OF VARIANCE TABLE						
K Value	Source	Degrees of freedom	Sum of squares	Mean square	F value	Probability
1	Replication	02	0.374	0.187	1.5927	NS
2	Treatments	06	2.215	0.354	3.0141	S
3	Error	12	1.410	0.118		
	Total	20	3.910			
Critical difference for treatments 0.508						

b. Stem girth (cm) at 120 days after planting as influenced by different levels of fertigation and drip system layout.

ANALYSIS OF VARIANCE TABLE						
K Value	Source	Degrees of freedom	Sum of squares	Mean square	F value	Probability
1	Replication	02	0.531	0.266	2.1874	NS
2	Factor A	02	0.703	0.351	2.8924	NS
4	Factor B	01	0.147	0.147	1.2079	NS
6	AB	02	0.303	0.151	1.2456	NS
-7	Error	10	1.215	0.121		
	Total	17	2.898			

c. Stem girth (cm) at 160 days after planting as influenced by different treatments

K Value	Source	Degrees of freedom	Sum of squares	Mean square	F value	Probability
1	Replication	02	0.549	0.274	2.868	NS
2	Treatments	06	1.599	0.267	2.786	NS
3	Error	12	1.148	0.096		
	Total	20	3.296			

d. Stem girth (cm) at 160 days after planting as influenced by different levels of irrigation and drip system layout.

ANALYSIS OF VARIANCE TABLE						
K Value	Source	Degrees of freedom	Sum of squares	Mean square	F value	Probability
1	Replication	02	0.689	0.345	3.5823	NS
2	Factor A	02	0.280	0.140	1.4578	NS
4	Factor B	01	0.138	0.138	1.4325	NS
6	AB	02	0.049	0.049	0.5143	
3	Error	10	0.096	0.096		
	Total	17				

Appendix -XXV

a. Yield (g/plant) of chilli as influenced by different treatments

ANALYSIS OF VARIANCE TABLE						
K Value	Source	Degrees of freedom	Sum of squares	Mean square	F value	Probability
1	Replication	02	000067.218	00033.609	000.280	NS
2	Treatments	06	237877.892	39646.315	341.026	S
3	Error	12	001395.068	00116.256		
	Total	20	239340.178			
Critical difference for the treatments 15.6						

b. Yield (g/plant) of chilli as influenced by different levels of irrigation and drip system layout.

ANALYSIS OF VARIANCE TABLE						
K Value	Source	Degrees of freedom	Sum of squares	Mean square	F value	Probability
1	Replication	02	00068.806	000034.4	000.26	NS
2	Factor A	02	66230.990	331115.4	251.50	S
4	Factor B	01	2714.519	002714.5	020.6	S
6	AB	02	600.773	000000.3	002.2	NS
3	Error	10	1316.359	000131.6		
	Total	17	70931.447			
Critical difference for the factor A and B 16.97						

c. Yield (g/plant) of chilli as influenced by different treatments

ANALYSIS OF VARIANCE TABLE						
K Value	Source	Degrees of freedom	Sum of squares	Mean square	F value	Probability
1	Replication	02	000.108	00.054	000.20	NS
2	Treatments	06	380.605	63.434	341.02	S
3	Error	12	002.232	00.186		
	Total	20	382.944			
Critical difference for the treatments 0.625						

d. Yield (t/ha) of chilli as influenced by different treatments

ANALYSIS OF VARIANCE TABLE						
K Value	Source	Degrees of freedom	Sum of squares	Mean square	F value	Probability
1	Replication	02	000.100	00.054	000.20	NS
2	Factor A	06	380.605	63.430	341.02	S
3	Error	12	002.200	00.186		
	Total	20	382.900			

e. Yield (t/ha) of chilli as influenced by different levels of irrigation and drip system layout.

ANALYSIS OF VARIANCE TABLE						
K Value	Source	Degrees of freedom	Sum of squares	Mean square	F value	Probability
1	Replication	02	000.110	00.055	000.26	NS
2	Factor A	02	105.970	52.980	251.56	S
4	Factor B	01	004.343	04.343	20.621	S
6	AB	02	000.961	00.481	2.2819	NS
3	Error	10	002.106	00.211		
	Total	17	113.490			
Critical difference for factor A and B 0.679						

ABSTRACT

The study "Impact of fertigation and drip system layout on performance of Chilli (*Capsicum annum*)" was taken up with the objective of determining the effect of fertigation, drip system layout and different levels of irrigation for chilli under plastic mulch. Different fertigation equipments like ventury injector, dosmatic fertigation unit and fertilizer tank were tested to study the hydraulic performance of the system. Ventury injector for fertilizer application was found to have high suction rate in comparison with dosmatic fertigation unit. The suction rate and motive flow rate was found to vary directly with respect to the pressure drop between the inlet and outlet of the fertigation equipment. Ventury injector can be used only if the discharge rate is above 14.6 L/min. Dosmatic fertigatrion unit and fertilizer tank can be used if the discharge rate is above 1.1 L/min and 6.6 L/min. The moisture distribution pattern under different drip field layout was observed. The moisture content near to the plant base was found to be high and decreases as the distance from the emitters increased. The effect of different irrigation levels and drip system layout under plastic mulch on the performance of Chilli (*Capsicum annum*), **Ujwala** variety was also studied. The number of branches, stem girth and yield showed significant difference between the treatments. The yield showed significant difference with different levels of irrigation and drip system layout. Maximum yield of 18.32 t/ha was observed for the treatment $T_{5.}$ The treatments T_6 (17.952 t/ha) was on par with the treatment T_5. The benefit cost ratio for treatment T_5, 85 per cent of the irrigation requirement with one lateral for each row of crop was 3.8 and treatment $T_{6,}$ 85 per cent of the irrigation requirement with one lateral in between two rows of crop was 3.9. Even though the yield for the treatment T_5 was high, the benefit cost ratio stands high for treatment T_6. The high value of benefit cost ratio for treatment T_6 was due to the reduction in the quantity of material for drip irrigation system