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Performance evaluation of drip irrigation under high density planting of papaya

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Abstract
Papaya (*Carica papaya* L.) belongs to family caricaceae is one of the most important remunerative fruit crop cultivated throughout the tropical and subtropical region of our country. Drip irrigation is one of the most efficient methods of water application to crops. It has high water use efficiency and hence should be adopted on a large scale for various horticultural crops like papaya. Drip irrigation method is very efficient for supplying irrigation water to the plant precisely to root zone. Drip water system applies water slowly to keep soil moisture within the desire range of plant growth. Therefore, these experiments had been planned to be conducted for assessing the effect of drip irrigation on papaya in high density orchard with following objectives: To estimate uniformity coefficient of emitter discharge, To develop a relation between pressure and emitter discharge, To estimate crop water requirement of papaya under high density planting, To calculate the cost of installation of drip irrigation for papaya. To evaluate the performance evaluation of drip irrigation system are Emitter discharge and operating pressure. Based on the results obtained, the following conclusions can be drawn: The uniformity coefficient was acceptable (94.67 – 96.62 %) for all the pressure setting but was highest at 1 kg/cm^2 (96.62 %). The variation of average discharge along the laterals was erratic, Coefficient of uniformity increases with decrease in emitter flow variation and total cost of installation of drip irrigation system for papaya under high density planting was found to be 1, 87,575 Rs / ha.

Keywords: drip, tube well, electric motor, PVC and LLDPE pipe

Introduction
Papaya (*Carica papaya* L.) belongs to family caricaceae is one of the most important remunerative fruit crop cultivated throughout the tropical and subtropical region of our country. It is a native of tropical America and introduced from Philippines through Malaysia to India during 16th century. Papaya has gained more importance owing to its palatability, fruit ability throughout the year, early fruiting and highest productivity per unit area and multifarious uses like food, medicine and industrial input. The fruit is rich source of vitamin A, B and C. Green fruit papaya contain protease enzyme 'papin' which has diverse use in pharmaceutical and food industries.
The area under papaya in India is 98000 ha and has production at 39.29 lakh tonnes with an average productivity of 37.0 t/ha. It is mainly cultivated in Andhra Pradesh, Gujarat, Karnataka, West Bengal, Chhattisgarh, Assam, Maharashtra and Tamil Nadu.
India is the second largest fruit producer in the world and Andhra Pradesh secure second position in fruit production in India. Unfortunately productivity of all fruit in India is very low as compared to other fruit growing countries of the world. Papaya responds well to water management. The plant is highly sensitive to water logged condition and hence it is not important to prevent wet condition in papaya irrigation. In well-drained soil, irrigation at shorter interval during early crop stages result in good establishment and also encourages better plant development on other hand.
Water is one the most important and unfortunately one of the scarce natural resource available on earth. Drip irrigation is one of the most efficient methods of water application to crops. It has high water use efficiency and hence should be adopted on a large scale for various horticultural crops like papaya. It is the most efficient (90-95%), more uniform rate of water application with less maintenance along with 20% to 70% water saving and increased crop production prospects. This technology can be used to irrigate the crop with poor quality of water. The system helps not only in water saving, but also in the growing crops in saline soils.
Drip irrigation method is very efficient for supplying irrigation water to the plant precisely to root zone. In this method water is supplied at slower rate over a longer period of time at regular intervals through low pressure delivery system to meet evapotranspiration demand of water. Drip water system applies water slowly to keep soil moisture within the desire range of plant growth.

Therefore, these experiments had been planned to be conducted for assessing the effect of drip irrigation on papaya in high density orchard with following objectives:

1. To estimate uniformity coefficient of emitter discharge.
2. To develop a relation between pressure and emitter discharge.
3. To estimate crop water requirement of papaya under high density planting.
4. To calculate the cost of installation of drip irrigation for papaya.

Review of literature

Christiansen (1942) [5] define coefficient of uniformity (C_u) to quantify the degree of flow variation, the mathematical relationship for C_u is given as:

$$C_u = (1\text{-}dq/q)$$

Where,
q = mean emitter flow
dq = mean absolute variation from the mean emitter flow

Keller *et al*. (1974) suggested a simpler form for the emitter flow:

$$Q = K_c H^x$$

Where,
Q = average flow through emitter
K_C =multiplying constant specific to emitter
H = initial pressure at the head of lateral
X = flow exponent, whose value depend on flow

Srinivas (1996) [15] evaluated papaya water relations, growth, yield and water use under drip irrigation at different evaporation-replenishment rates (20, 40, 60, 80, 100 and 120% of United States Weather Bureau Class A Pan evaporation) with subsurface drip (at 250 mm depth in the soil) and surface drip irrigation at Bangalore, India between 1990 and 1992. He observed that increasing the evaporation-replenishment rates from 20 to 120% increased the relative leaf water content by 13.2%, transpiration rate by 18.8%, plant height by 21.9%, stem girth by 12.5%, fruit number by 88.3% and yield by 34.6%. The yield during the 36 months after planting was 96.7 t/ha with 20% evaporation-replenishment rate and 130.2 t/ha with 120% evaporation-replenishment rate. Fruit yield differences above 60% evaporation-replenishment rates were not significant. Water use from 0 to 36 months after planting increased with an increase in evaporation-replenishment rates (from 1651 mm to 4208 mm at the 20% and 120% replenishment rates, respectively). Water-use efficiency (WUE) over this period decreased from 58.6 to 30.9 kg ha-1 mm-1 at the 20% and 120% replenishment rates, respectively. He also concluded that subsurface drip irrigation resulted in significantly higher yields (averaging 121.4 compared with 160.6 t/ha-1) and WUE (averaging 40.6 compared with 37.2 kg ha-1 mm-1) than surface drip irrigation.

Narendra *et al*. (2002) examined the effects of irrigation (40, 60, 80, or 100% water through drip irrigation) with or without mulching (with 25 micron thick black plastic mulch) on the growth and yield of papaya cv. CO-2 in Raipur, Chhattisgarh, India. Basin irrigation with or without plastic mulch were used as a control. Drip irrigation resulted in higher water use efficiency than basin irrigation. Increased yield and water use efficiency were obtained when drip irrigation was supplemented with mulching. They concluded that drip irrigation (60% of water) with mulching gave the highest yield (812.42 q/ha), plant height (172.75 cm), girth (36.67 cm), leaf number (39.92), fruit length (23.04 cm) and circumference (34.33 cm), fruit number (31.27 per plant), fruit weight (1613.77 g), pericarp thickness (3.05 cm), total soluble solid content (14.13%), net returns (Rs. 150409/ha), and benefit cost ratio (1:2.85), as well as the earliest flowering and fruit set (20 days earlier than the control). Drip irrigation of 100% water resulted in the highest water use efficiency (180.54 q ha-1 mm-1).

Suresh *et al*. (2004) [17] evaluated the effect of drip irrigation and mulching on the performance of papaya (Pusa Dwarf) on calcareous soil in Andhra Pradesh, India during 2001 and 2001-02. The conducted experiments on irrigation treatments were drip irrigation with V volume of water (T1), drip irrigation with 0.8 V volume of water (T2), drip irrigation with 0.6 V volume of water (T3), basin irrigation (T4), drip irrigation with V volume of water + mulch (T5), drip irrigation with 0.8 V + mulch (T6), drip irrigation with 0.6 V + mulch (T7) and, basin irrigation with V volume of water + mulch (T8). They resulted the highest average fruit length of 86 cm in T5 and highest average fruit number per plant (24.1) was obtained with T6. They concluded that the highest average fruit weight (0.97 kg), yield (23.2 kg/plant) was obtained with T6 and B: C ratio was highest (10.96) under T6, while the lowest (4.56) was obtained under T4.

Goenaga *et al*. (2004) [9] stated that there is a scarcity of information regarding the optimum water requirement for papaya (*Carica papaya*) grown under semiarid conditions with drip irrigation in the tropics. They conducted two-year study to determine water requirement, yield, and fruit quality traits of papaya cv Red Lady subjected to five levels of irrigation. The irrigation treatments were based on Class A pan factors that ranged from 0.25 to 1.25 in increments of 0.25. Drip irrigation was supplied three times a week on alternate days. They concluded that significant effects of irrigation on number of fruits, yield and fruit length. Irrigation treatments did not have a significant effect on brix (sweetness). They also concluded that the marketable fruit weight (75 907 kg/ha) was obtained from plants irrigated according to a pan factor of 1.25 and papaya grown under semiarid conditions should be irrigated according to a pan factor of not less than 1.25.

Coelho *et al*. (2007) [6] conducted a study at the Reconcavo Baiano (Bahia, Brazil) to evaluate the Sunrise Solo papaya (*Carica papaya*) yield under different trickle irrigation systems. They treated with surface drip along plant rows (1), surface drip between plant rows (2), buried-drip along plant rows (3), buried drip between plant row (4) and micro sprinkler (one emitter for two plants). There were no significant differences among treatments in terms of plant growth (stem diameter, plant height and total leaf area) on the first year. They concluded that the differences among treatments were larger for leaf area, where treatments 5 and 1 showing higher values than the treatments. They resulted micro sprinkler and surface drip irrigation along row crops provided more adequate conditions for soil water distribution with cumulative productivities of 76.47 and 82.58 tonnes/ha, respectively, which is about 38% more than the values obtained from the other systems.

Sandeep *et al.* (2008) [11] the study was conducted to evaluate the head loss in main line and lateral line for drip irrigation system. The study involved four types of emission devices viz. dripper, micro-tube, drip-in and drip tape. The head loss was calculated by measuring loss in pressure head in actual length of main and lateral line at four locations of the system with different spacing and operating pressure head. The minimum and maximum head loss in main and lateral line was for drippers and micro-tubes, respectively. Empirical equations for head loss combined for all emission devices and individual for each emission device were developed.

Materials and Methods
This chapter deals with description of materials used and methods for collection of data to analyze the performance evaluation and crop water requirement of drip irrigation under high density planting of papaya.

Experimental site
The field investigation was conducted at water management plot of South upland adjoining to ANGRAU farm during March to November, 2016. It lies at 25.98^{0}N latitude, 85.67^{0}S longitudes and at an altitude of about 52.00 meter above the sea level. The field has an approximate uniform topography with deep and well drained sandy loam soil.

Climate
The climate of the study area is humid subtropical and receives fairly good amount of south west monsoon. The average annual rainfall in the area is 1620 mm. Out of which nearly 1026 mm (80.78%) occurs in the monsoon months. The average minimum and maximum temperatures during the hottest months of May to June goes up to 3 ^{0}– 4 ^{0}C and 43^0 - 44 ^{0}C respectively. The metrological data such as temperature, rainfall and pan evaporation during crop period were obtained from metrological observatory located at about 0.5 km away from the experimental site.

Water table condition
The water table fluctuates from 1.0 m to 6.0 m depending upon the rainfall pattern and pumping rate. The highest position of water table is during monsoon which slowly drops to an alarming limit during summer season.

Experimental field layout
A plot of size 47 m × 20.5 m was selected with papaya plantation. The whole plot was divided into two parts along the length separated by sub main. The row to row and plant to plant spacing was 1.7 m×1.3 m.

Water source
An existing shallow tube well available near the site was used as the source of irrigation water. The diameter of the tube well was 8 inch and a submersible pump was used for water lifting.

Fig 3.1: Laying of laterals in Papaya plot

Description of the installed drip system and pumping unit

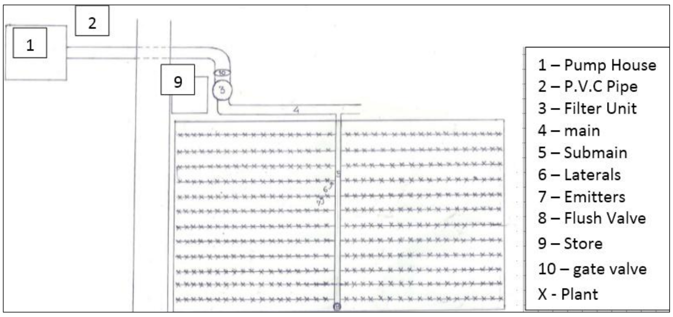

Fig 3.2: Detailed Layout of experimental plot

In this section, the detailed information about the installed system and pumping unit are presented. The detailed information about main line, submain, laterals, emitters, filters and pumping unit are also given.

Mainline
Main line (160 mm PVC pipe, 6 kg/cm^2) was laid beneath the ground surface on the normal land slope at a depth of 60 cm. Filters and bypass assemblies were at a distance of 1 m from the papaya plot. The main line was joined with the screen filter the total length of main pipe from screen filter to sub main was measured as 24m.

Submain
The sub main line (75 mm PVC pipe, 6 kg/cm^2) was also laid on the normal slope and 60 cm below the ground surface the total length of sub main was 21 m.
The one flush valve was installed at the end of the sub main. Before starting the pump, the end plug was opened to remove the entrapped air from the drip irrigation line.

Laterals
For laterals (16 mm LLDPE, 2.6 kg/cm^2) pipes were laid over the ground surface. The laterals were connected to sub main and lateral length for papaya crop was 46 m and the number of laterals was 12.

Emitters
Emitters were fitted on laterals near the plant of papaya. The emitters were fitted to the laterals after making a hole on the laterals at a distance equal to the plant spacing. Total number of emitters were used in the papaya plot was 432. The end of each laterals were closed with an end plug.

Filter
A metal screen filter of Jain irrigation make with 50 m^3/ hr capacity was provided on the delivery side to check the flow of impurities and suspended sand particles in the mainline so that clogging of emitters are minimized.

Pumping unit
The pump used was a submersible which gives the water supply at desired pressure. The pump is driven by 20 HP electric motor. The pump supplies the irrigation water through the filter to the main line. There was bypass assembly and the venture assembly for regulation of pressure and application of fertilizers through the system.

Fig 3.3: Screen fileter and pressure guage

Performance evaluation

To evaluate the performance of the system pump was started and all the leakages from the various points were checked properly. Dust and other foreign materials entered into the system were removed through the flush. After five minutes, flush valve were closed and the drip irrigation system was operated for the evaluation of its performance. The data on the following parameters were collected for performance evaluation of drip irrigation system.

1. Emitter discharge
2. Operating pressure

   The procedure followed for evaluating the various parameters is given below

Emitter discharge measurement

After removing the entrapped air from the different components of the system like main, sub main and laterals through flush valve and attending the stable flow condition at a desired operating pressure, the observation were taken.

The discharge was collected in small beakers 100 ml for a fixed duration of 60 seconds of various operating pressures viz. , 0.6, 0.8, 1.0, 1.2 kg/cm^2 and was measured by a measuring flask. The various emitter locations were selected randomly and thus the observation were taken for the emitters at serials 1, 4, 8, and 16 for both eastern and western segments. The laterals number 1, 2, 3, 4, 5, 7, 8, 9, 10, 12 were selected for the observation.

The mean emitter discharge for the individual laterals:

$$q = \sum_{i=0}^{n} \frac{q_i}{n} \quad ... 3.1$$

Where,

q_i = Discharge of individual emitter

n = No. of emitters.

And the mean emitter discharge for the whole plot,

$$q = \sum_{i=0}^{m} \frac{q_i}{m} \quad … 3.2$$

Where,

q_i = Discharge of individual laterals

m = No. of laterals

Uniformity coefficient of individual laterals

$$C_u = \left(1 - \frac{\delta q}{q}\right) \times 100 \quad ... 3.3$$

Where,

C_u = Uniformity coefficient for lateral (%)

q = Mean emitter discharge of the lateral.

δq = Average of the absolute deviation of emitter discharge from the mean emitter discharge of the lateral.

Uniformity coefficient for the whole plot, C_u

$$C_u = \left(1 - \frac{\delta q}{q}\right) \times 100 \quad … 3.4$$

Where,

C_u = uniformity coefficient for whole plot, (%)

q = Mean lateral discharge of the plot.

δ q_p= Average of the absolute deviation of lateral discharge from the mean lateral discharge of the plot.

Emitter flow variation for individual laterals,

$$q_v = \left(\frac{q_{max} - q_{min}}{q_{max}}\right) \times 100 \quad … 3.5$$

Where,

Q_{max} = Maximum emitter discharge along the laterals.

q_{min} = Minimum emitter discharge along the laterals.

Pressure-discharge relationship

Pressure discharge relationship was established by using the equation given by Keller (1974). This is given below:

$$q = K \times H^x \quad … 3.6$$

Where,

Q = Average flow rate through the emitter

K = Multiplying constant specific to the emitter

H = Initial pressure head of lateral

X = Flow component, whose value depends on the flow regime

Water requirement

Water was supplied to plants by drip irrigation system. The volume of water was supplied in the drip irrigation system according to consumptive use of the plant. The consumptive use of the plant is a plant function, surface are covered by the plant and evaporation rate. According to the Ministry of Agriculture, Department of Agriculture and Co-operation, Horticulture Division, New Delhi. The daily water requirement or consumptive use of the plants can be calculated as under.

$$V = E_p \times K_c \times K_p \times K_r \times A \quad … 3.7$$

Net volume of water V_n, to be applied could be expressed as

$$V_n = V - R_e \times A \quad … 3.8$$

The total volume of water applied per plot per day.

Total volume = V_n × no of plant

Where,

V = Water requirement or consumptive use of the plant

(l /plant/day)
E_p = Pan evaporation (mm/day)
K_p = Pan factor (its value is taken as 0.8 for USWB type pan)
K_r = Coverage factor (taken to be 0.75)
A = Row spacing × plant spacing (m^2)
R_e = Effective rainfall (cm)
K_c = Crop coefficient of fully grown plant.
'A' when multiplied by K_r will yield the wetted area under drip irrigation.

Cost of installation for papaya crop
The cost of installation is divided in two parts i.e., fixed cost and variable cost. The fixed cost includes the cost of filters, bypass assembly, fertilizer injector etc. This cost do not depends on the extent of area covered.
Apart from the filters, bypass assembly, fertilizer injector etc., there are some components to be installed whose cost depends on the area to be covered. The cost of these components is known as variable cost. This includes the cost of emitters, laterals, flush valve end plug, sub main, pipelines etc.

Results and Discussion
This chapter is concerned with the result obtained and discussion related with the evaluation of the performance of drip irrigation system and crop water requirement under high density planting of papaya. The mean emitter discharge and coefficient of uniformity and pressure discharge relationship has been calculated for whole plot. Crop water requirement for papaya under high density has also been calculated. Finally the cost of installation of drip irrigation system for papaya under high density has been calculated.

Performance evaluation of the system
For evaluating the hydraulic performance, the drip irrigation system was operated at different pressures viz., 0.6, 0.8, 1.0 and 1.2 kg/cm^2, and emitter discharge was measured. The uniformity coefficient was also determined.

Emitter discharge
The emitter discharge obtained at different atmospheric pressure viz., 0.6, 0.8, 1.0 and 1.2 kg/cm^2 is presented in table 4.1.
From the table 4.1, it can be observed that the variation in the discharge has no relation with the location of the laterals which may be due to variation in the entrance losses and other hydraulic properties of the individual emitter. Taking the plot as a whole the mean emitter discharge at the operating pressure 0.6, 0.8, 1.0 and 1.2 kg/cm^2 observed to be 3.55, 4.14, 4.64, and 5.22 lph respectively.

Pressure discharge relationship
From the fig. 4.1, it is clear that emitter discharge increases exponentially with increase in pressure head. The maximum mean emitter discharge (5.22 lph) was found at 1.2 kg/cm^2 and minimum mean emitter discharge (3.55 lph) at 0.6 kg/cm^2. The value of k_e and x were found to be 1.284 and 0.5672 respectively by the regression of pressure head and mean emitter discharge. The emitter flow function for the plot is established as:

$$q = 1.284 \; H^{0.5672} \qquad \dots 4.1$$

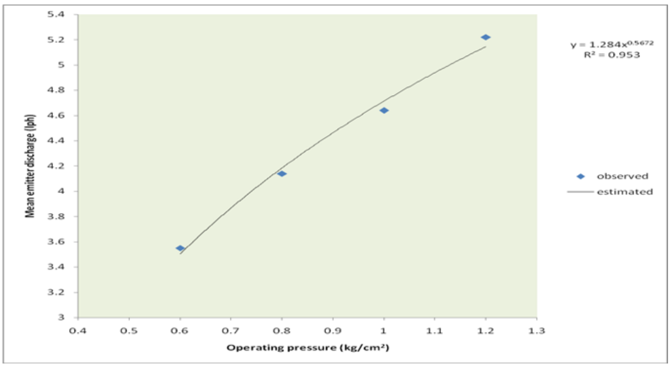

Fig 4.1: Variation of emitter discharge with operating pressure

The mean emitter flow for the individual laterals and the whole plot was determined and a relationship between emitter discharges was established as shown in fig. 4.1, which statistics the standard relationship (equation 3.2).

Uniformity coefficient and emitter flow variation
The uniformity coefficient for the individual laterals and the whole plot was calculated at different operating pressure are presented in table 4.1.
The emitter flow variation for individual laterals and the whole plot were also determined and was correlated with uniformity coefficient. It was found that the uniformity coefficient is decreasing with increase in emitter flow variation but, at some critical points, it fails as its equation involves the discharge of only two points or laterals i.e., maximum and minimum discharge and does not account for the discharge at other points or laterals.
It was found that that the uniformity coefficient varied from 94.67 per cent to 96.62 per cent and emitter flow variation (q_{var}) varied from 5.03 to 2.59 per cent which is within the recommended range.
The maximum uniformity coefficient (96.62%) was found at a pressure 1.0 kg/cm^2 with emitter flow variation 2.39%. From this pressure, the uniformity coefficient was decreasing with either increase or decrease in pressure. The result obtained at different pressure is tabulated below:

Table 4.1: Average discharge (lph) and Uniformity Coefficient (%) at different Operating Pressure (kg/cm^2)

Serial No.	Operating Pressure (kg/cm^2)	Average discharge(lph)	Uniformity Coefficient (%)
1	0.6	3.55	94.67
2	0.8	4.14	95.85
3	1.0	4.64	96.62
4	1.2	5.22	96.56

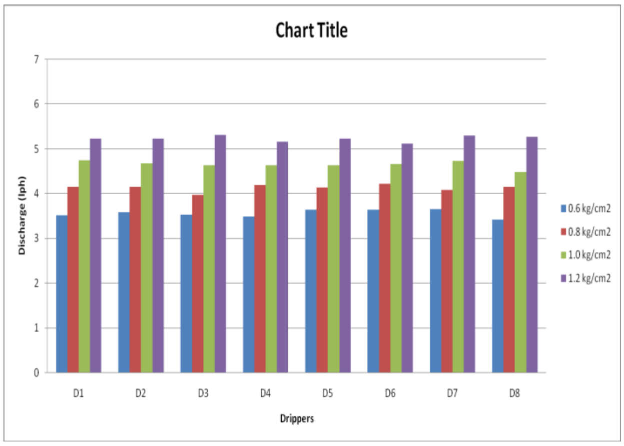

Fig 4.2: Discharge variation along the laterals through

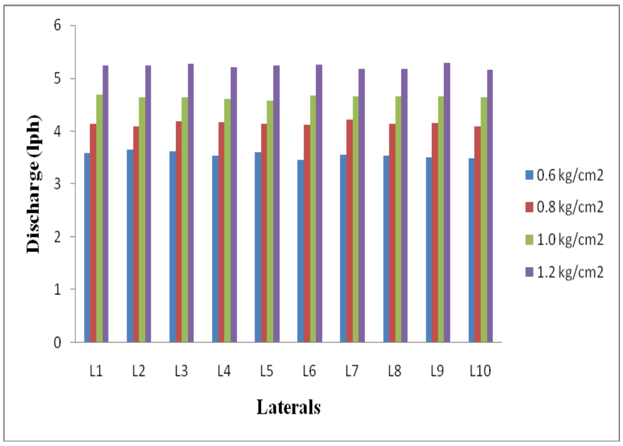

Fig 4.3: Discharge variation along the submain through drippers laterals

Table 4.2(a): Emitter discharge (lph) at operating pressure 0.6 kg/cm^2

Lateral No.	Emitter								q_{avg}	δq	C_u	q_{var}
	1	2	3	4	5	6	7	8				
1	3.56	3.78	3.46	3.56	3.74	3.54	3.86	3.24	3.59	0.150	95.80	16.062
2	3.74	3.54	3.62	3.24	3.96	3.64	3.62	3.84	3.65	0.147	95.95	18.181
3	3.25	3.86	3.68	3.58	3.42	3.84	3.74	3.52	3.61	0.168	95.32	15.803
4	3.68	3.46	3.28	3.34	3.3	3.94	3.82	3.42	3.53	0.212	93.98	16.751
5	3.85	3.28	3.8	3.82	3.46	3.58	3.92	3.12	3.60	0.243	93.23	20.40
6	3.41	3.66	3.34	3.64	3.26	3.62	3.56	3.24	3.46	0.153	95.56	16.475
7	3.36	3.48	3.64	3.24	3.92	3.98	3.48	3.36	3.55	0.216	93.90	18.592
8	3.48	3.24	3.72	3.58	3.82	3.68	3.52	3.28	3.54	0.16	95.48	15.183
9	3.6	3.82	3.24	3.56	3.54	3.12	3.34	3.84	3.50	0.205	94.13	18.75
10	3.26	3.72	3.52	3.28	3.98	3.24	3.68	3.26	3.49	0.232	93.34	18.59
For whole plot									3.55	0.189	94.67	5.034

q_{avg} = mean emitter discharge
C_u = coefficient of uniformity
δq = average of the absolute deviation of emitter discharge from the mean emitter discharge of the lateral
q_{var} = emitter flow variation (%)

Table 4.2(b) Emitter discharge (lph) at operating pressure 0.8 kg/cm^2

Lateral No.	Emitter								q_{avg}	δq	C_u	q_{var}
	1	2	3	4	5	6	7	8				
1	3.98	3.86	4.32	4.46	4.28	3.94	3.82	4.44	4.13	0.237	94.25	14.349
2	4.02	4.24	4.16	3.94	4.16	4.36	3.92	3.88	4.08	0.145	96.45	16.009
3	4.42	4.12	3.96	4.26	4.38	3.92	4.06	4.46	4.19	0.182	95.65	12.107
4	3.92	3.96	4.24	4.56	3.82	4.44	4.24	4.12	4.16	0.207	95.01	16.228
5	4.26	4.36	4.04	3.86	4.18	4.28	3.84	4.26	4.13	0.166	95.97	16.926
6	4.36	4.08	3.86	3.92	4.42	3.98	4.28	4.12	4.12	0.169	95.89	12.669
7	4.12	4.24	3.98	4.32	4.18	4.68	3.96	4.26	4.21	0.157	96.26	15.384
8	3.94	4.08	4.16	4.24	3.96	4.28	4.36	4.12	4.14	0.167	97.16	9.633
9	4.48	4.26	4.02	4.12	3.98	4.36	3.92	4.06	4.15	0.162	96.08	12.5
10	4.02	4.28	3.86	4.28	4.06	3.94	4.38	3.84	4.08	0.173	95.75	12.328
For whole plot									4.14	0.171	95.85	3.200

q_{avg} = mean emitter discharge
C_u = coefficient of uniformity
δq = average of the absolute deviation of emitter discharge from the mean emitter discharge of the lateral
q_{var} = emitter flow variation (%)

Table 4.2(c) Emitter discharge (lph) at operating pressure 1.0 kg/cm^2

Lateral no.	Emitter								q_{avg}	δq	C_u	q_{var}
	1	2	3	4	5	6	7	8				
1	4.96	4.56	4.48	4.72	4.68	4.9	4.62	4.52	4.68	0.135	97.16	9.677
2	4.38	4.54	4.64	4.86	4.64	4.52	4.84	4.76	4.64	0.129	97.21	9.876
3	4.56	4.68	4.96	4.72	4.58	4.64	4.48	4.52	4.64	0.108	97.67	9.677
4	4.64	5.02	4.6	4.28	4.58	4.32	4.86	4.56	4.60	0.174	96.21	14.741
5	4.86	4.38	4.44	4.92	4.64	4.54	4.62	4.26	4.58	0.177	96.12	13.414
6	4.98	5.12	4.72	4.34	4.68	4.72	4.58	4.24	4.67	0.214	95.41	17.187
7	4.82	4.64	4.96	4.38	4.64	4.82	4.92	4.38	4.65	0.185	96.05	16.693
8	4.62	4.56	4.82	4.76	4.58	4.42	4.96	4.62	4.66	0.134	97.12	10.887

9	5.06	4.56	4.34	4.48	4.68	4.82	4.76	4.58	4.66	0.17	96.35	14.229
10	4.56	4.72	4.38	4.82	4.64	4.92	4.68	4.42	4.64	0.142	96.93	10.975
For whole plot									4.64	0.157	96.62	2.396

q_{avg} = mean emitter discharge
C_u = coefficient of uniformity
δq = average of the absolute deviation of emitter discharge from the mean emitter discharge of the lateral
q_{var} = emitter flow variation (%)

Table 4.2(d): Emitter discharge (lph) at operating pressure 1.2 kg/cm^2

Lateral no.	Emitter								q_{avg}	δq	C_u	q_{var}
	1	2	3	4	5	6	7	8				
1	5.66	4.82	5.2	5.38	5.5	4.96	5.2	5.14	5.23	0.210	95.97	14.840
2	5.12	4.8	5.6	5.18	5.34	5.24	5.12	5.56	5.24	0.191	96.35	14.285
3	5.24	5.3	5.28	5.5	5.12	4.78	5.8	5.2	5.27	0.192	96.35	17.586
4	5.38	5.24	4.82	4.96	5.46	5.2	5.22	5.34	5.20	0.156	96.98	16.721
5	5.02	5.36	5.1	4.96	5.3	5.48	5.26	5.48	5.24	0.163	96.87	9.489
6	5.1	5.24	5.54	5.12	4.9	5.38	5.32	5.46	5.25	0.167	96.81	16.552
7	5.34	5.5	5.18	4.84	4.72	5.28	5.36	5.24	5.18	0.201	96.10	14.181
8	5.2	5.28	5.42	4.9	5.48	4.82	5.18	5.12	5.17	0.171	96.69	12.043
9	5.12	5.46	5.58	5.6	4.98	5.12	5.26	5.26	5.29	0.186	96.47	16.0714
10	5.04	5.24	5.32	5.12	5.46	4.94	5.24	4.92	5.16	0.155	96.99	9.890
For whole plot									5.22	0.179	96.56	2.595

qavg = mean emitter discharge
Cu = coefficient of uniformity
δq = average of the absolute deviation of emitter discharge from the mean emitter discharge of the lateral
qvar = emitter flow variation (%)

Table 4.3: Weekly, Rain fall, Pan Evaporation crop water requirement of papaya

Week	Rainfall (mm)	Pan Evaporation (mm/week)	Crop Coefficient (K_c)*	Pan Coefficient (K_p)**	Coverage Coefficient (K_r)	Area under One Papaya plant,m^2(A)	Requirement (V) l/Plant/week	Volume applied (V_n) l/Plan /week
3.3.16 to 7.3.16	0	9.6	0.6	0.8	0.75	2.21	7.63	7.63
8.3.16 to 15.3.16	0	43.5	0.6	0.8	0.75	2.21	34.60	34.60
16.3.16 to 22.3.16	0	25.4	0.6	0.8	0.75	2.21	20.20	20.20
23.3.16 to 31.3.16	2.5	43.1	0.6	0.8	0.75	2.21	34.29	28.77
1.4.16 to 7.4.16	18.0	26.6	0.6	0.8	0.75	2.21	21.16	0
8.4.16 to 15.4.16	0.0	46	0.6	0.8	0.75	2.21	36.59	36.60
16.4.16 to 22.4.16	12.0	43.1	0.6	0.8	0.75	2.21	34.29	7.77
23.4.16 to 30.4.16	14	47.1	0.6	0.8	0.75	2.21	37.47	6.53
1.5.16 to 7.5.16	9.5	32.1	0.7	0.8	0.75	2.21	29.80	8.80
8.5.16 to 15.5.16	3.2	52.8	0.7	0.8	0.75	2.21	49.00	41.93
16.5.16 to 22.5.16	37.6	36	0.7	0.8	0.75	2.21	33.41	0.0
23.5.16 to 31.5.16	100.8	53.2	0.7	0.8	0.75	2.21	49.38	0.0
1.6.16 to 7.6.16	0	32.7	0.7	0.8	0.75	2.21	30.35	30.35
8.6.16 to 15.6.16	36.6	50.5	0.7	0.8	0.75	2.21	46.87	0.0
16.6.16 to 22.6.16	55.1	28.3	0.7	0.8	0.75	2.21	26.27	0.0
23.6.16 to 30.6.16	207.6	45.2	0.7	0.8	0.75	2.21	41.95	0.0
1.7.16 to 7.7.16	152.2	19.9	0.7	0.8	0.75	2.21	18.47	0.0
8.7.16 to 15.7.16	32.8	36.4	0.8	0.8	0.75	2.21	38.62	0.0
16.7.16 to 22.7.16	55.8	23.6	0.8	0.8	0.75	2.21	25.03	0.0
23.7.16 to 31.7.16	58.4	33.7	0.8	0.8	0.75	2.21	35.75	0.0
1.8.16 to 7.8.16	76.9	20.1	0.8	0.8	0.75	2.21	21.32	0.0
8.8.16 to 15.8.16	39	15.9	0.8	0.8	0.75	2.21	16.87	0.0
16.8.16 to 22.8.16	125.5	7	0.8	0.8	0.75	2.21	7.42	0.0
23.8.16 to 31.8.16	13.2	18.6	0.8	0.8	0.75	2.21	19.73	0.0
1.9.16 to 7.9.16	69.9	16.1	0.8	0.8	0.75	2.21	17.07	0.0
8.9.16 to 15.9.16	46.6	31.2	0.8	0.8	0.75	2.21	34.00	0.0
16.9.16 to 22.9.16	67.6	23.6	0.8	0.8	0.75	2.21	25.03	0.0
23.9.16 to 30.9.16	6.3	32.1	0.8	0.8	0.75	2.21	34.05	20.12
1.10.16 to 7.10.16	0	37.8	1	0.8	0.75	2.21	50.12	50.12
8.10.16 to 15.10.16	14	33.12	1	0.8	0.75	2.21	43.91	12.98
16.10.16 to 22.10.16	0	17.5	1	0.8	0.75	2.21	23.20	23.21
23.10.16 to 31.10.16	0	46.3	1	0.8	0.75	2.21	61.39	61.39
Total	1255.1		1004.43	391.03	1.767			

Irrigation requirement of papaya under high density
The weekly irrigation requirement of the papaya crop was estimated using equations (3.7) and is shown in table 4.2. Whenever there was an excess rainfall in a particular month as compared to crop water requirement, no water was applied to the crop. The water requirement by drip irrigation in papaya plant for the time of fruiting was 1004 liters per plant. The volume of water applied by drip irrigation was 391 liters per plant.

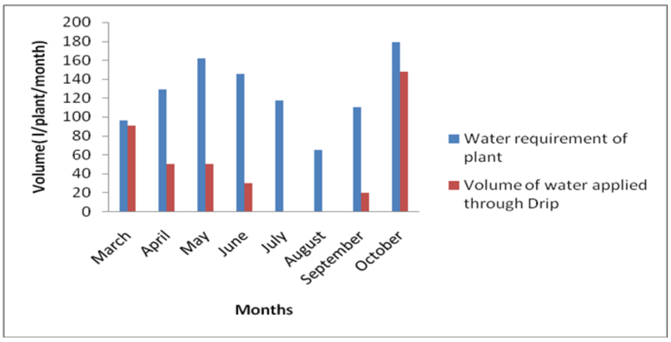

Fig 4.4: Crop water requirement and volume applied through drip system

Cost of installation of drip irrigation system
The cost of installation is divided in two parts i.e., fixed cost and variable cost. The fixed cost includes the cost of filters, bypass assembly, fertilizer injector etc. This cost do not depends on the extent of area covered.
Apart from the filters, bypass assembly, fertilizer injector etc., there are some components to be installed whose cost depends on the area to be covered. The cost of these components is known as variable cost. This includes the cost of emitters, laterals, flush valve end pluck, submain, main pipelines etc.
Both the fixed cost and variable cost were calculated separately and then added to get the total cost of installation of drip irrigation system for papaya under high density.

Fixed cost

Table 4.4(a) Calculation of fixed cost

Sl. No	Components	Unit	Quantity	Unit cost (Rs.)	Amount (Rs.)
1	Jain super clean filter	No.	1	6863.00	6863.00
2	Venturi mainfold	No.	1	4401.00	4401.00
3	Venturi assembly	No.	1	984.00	984.00
4	Gun metal valve	No.	2	8853.00	17706.00
5	By pass assembly	No.	1	2332.00	2332.00
Total					32286.00

Installation charges 12.5 % on material value = 4035.50 Rs.
VAT @ 4 % = 1291.44 Rs.
Hence, Total fixed cost = 37612.44 Rs.

Variable cost

Table 4.4(b) Calculation of variable cost

Sl. No	Components	Unit	Quantity	Unit cost (Rs.)	Amount (Rs.)
1	Main	m.	24	191.00	4584.00
2	Submain	m.	21	91.00	1916.00
3	Plain laterals	m.	552	8.00	4416.00
4	J tyrbo key dripper	No.	432	3.25.00	1404.00
5	Flush valve	No.	1	85.00	85.00
Total					12400.00

Installation charges 12.5 % on material value = 1550.37 Rs.
VAT @ 4 % = 496.12 Rs.
Thus, Total variable cost = 14449.74 Rs.
Variable cost per hectare =149963 Rs.
Total cost of installation for papaya plot under high density is 187575 Rs / ha.

Summary and Conclusions
In a world of explosive demographic growth, it is very difficult to keep the pace of production of food in particular with the growing needs for food. Every means must, therefore, be sought to increase agricultural production. Therefore, we should efficiently utilize water, which is a precious natural resource.
India is the second largest fruit producer in the world. Unfortunately productivity of all fruit in India is very low as compared to other fruit growing countries of the world. It is major cause of advocating the adsorption of higher density orchard. Accommodation of the maximum possible number of plant per unit area to get maximum possible profit per unit area of tree volume without impairing the soil fertility status is called high density planting.
Drip irrigation method has prove its superiority over conventional method of irrigation, especially fruit and vegetable crops. It is very efficient for supplying irrigation water to the plant precisely to root zone. In this method water is supplied at slower rate over a longer period of time at regular intervals through low pressure delivery system to meet evapotranspiration demand of water.

Volume of water approaching the consumptive use of plants, thereby minimizing such conventional losses as a deep percolation, runoff, and soil water evaporation. Drip water system applies water slowly to keep soil moisture within the desire range of plant growth.
The experiment was conducted with the following specific objective:

1. To estimate uniformity coefficient of emitter discharge.
2. To develop a relation between pressure and emitter discharge.
3. To estimate crop water requirement of papaya under high density planning.
4. To calculate the cost of installation of drip irrigation for papaya.

A papaya plot of size 47 m × 20.5 m was selected to evaluate the performance of the drip irrigation system and crop water requirement of papaya under high density planting. The field investigation was conducted at water management plot of South upland adjoining to ANGRAU farm during March to November, 2016. The plot was of uniform topography and soil was porous, well drained with good tilt.
In order to evaluate the performance of drip system, the emitter discharge at different emitter location on the emitter on the laterals were noted. Then the mean emitter discharge and uniformity coefficient for all the laterals and the whole plot was calculated. All the observation taken at different pressure viz, 0.6, 0.8, 1.0 and 1.2 kg/cm^2. The weekly water requirement or consumptive use of the plant was also calculated. The cost of installation of drip irrigation system of papaya plot was also calculated.
Based on the results obtained, the following conclusions can be drawn:

1. The uniformity coefficient was acceptable (94.67 – 96.62 %) for all the pressure setting but was highest at 1 kg/cm^2 (96.62 %).
2. The variation of average discharge along the laterals was erratic. That means, it has no relation with the location of drippers on the lateral and pressure.
3. Coefficient of uniformity increases with decrease in emitter flow variation.
4. The weekly water requirement of each plant varied from 7.42 L. to 61.39 L. depending upon the climatic conditions and growth of plant. The total water requirement per plant found to be 1004.43 L.
5. Total cost of installation of drip irrigation system for papaya under high density planting was found to be 1, 87,575 Rs / ha.

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