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## Design and economic evaluation for the precision farming of tomato crop at Pusa (Bihar)

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### Abstract

Farmers of Bihar grows several vegetables, but due to the lack of proper technology, yield and quality of the product is not at par. The precision farming technique can play a promising role to fill the gap. Keeping in view of the water savings and quality of vegetables and fruits, this work was carried out. This methodological approach and especially the final results provides a guide to the future of precision agriculture to develop. Drip irrigation system was designed for the drippers, laterals, sub-mains, main and the pump. The crop water requirement for the tomato crop as observed from November to April was estimated in the range of 0.051 lpd to 1.47 lpd. The drippers of discharge capacity 2 lph was found suitable for irrigating the tomato crop. The size of the main, submain and lateral was found to be 90 mm, 63 mm and 12 mm, respectively. The size of the pump was calculated to be 7.5 hp, which was suitable for irrigating the tomato crop in one-hectare area. The total cost of the designed drip irrigation system was found to be Rs 161143.00 INR.

**Keywords:** Precision farming, drip irrigation, frictional head loss, crop water requirement

### 1. Introduction

Drip or trickle irrigation is an efficient irrigation method of recent origin, which is becoming increasingly popular in areas of water scarcity and poor-quality irrigation water. In drip irrigation, water is applied frequently at low rates from a low-pressure delivery system comprising of small diameter plastic pipes fitted with outlets, called emitters or drippers, directly to the land surface close to the plant where the roots grow. Due to the frequent application of irrigation water, salts are pushed to the periphery of the moist zone, away from the root spread area. It is suitable to almost all types of soils. In clay soils with low infiltration rates, water is to be applied slowly to prevent surface water ponding and runoff. In sandy soils with high infiltration rates, higher dripper discharge rates will be required to ensure adequate lateral wetting of the soil. Drip irrigation is also advantageous on lands with undulating topography without undertaking major land levelling operations and at places where the soil depth is low and crop values are higher (Michael 2007) <sup>[1]</sup>.

The beneficial effects of drip irrigation compared to other forms of water management are attributed to a uniform water application, controlled root zone development and better disease management since only the soil is wetted whereas the leaf surface remains dry (Lamont, 1991) <sup>[2]</sup>. Another advantage is the possibility of injecting fertilizers directly into the root zone of the crop to enable a uniform and adequate nutrition according to the actual plant demand (Bar-Yosef *et al.*, 1980) <sup>[3]</sup>. The use of drip irrigation and fertigation saves water and fertilizer and gives better plant yield and quality (Papadopoulos, 1992) <sup>[4]</sup>. Keeping these remarkable advantages of drip/trickle irrigation system into consideration, the study was conducted at Dr. Rajendra Prasad Central Agricultural University, Pusa (Bihar).

In the present study, an attempt was made to design the drip irrigation system for the tomato crop for 1 ha area.

Therefore, the present proposed work has been carried out with the following objectives:

1. To determine water requirement for tomato crop.
2. To design a drip irrigation system for tomato crop.
3. To evaluate the economics of the designed drip irrigation system.

### 2. Materials and Method

This chapter deals with the description of materials used and method for the collection of data to calculate the crop water requirement and design the drip irrigation system for tomato crop.

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## 2.1 Crop details

The crop selected for the experimental study was tomato (*Solanum Lycopersicum*). The variety of the tomato crop used was Masina-2. The tomatoes could be harvested up to 150-160 days after sowing. The tomato crop was sowed in November, 2012 and harvested in April.

## 2.2 Experimental site

The field investigation was conducted behind the soil mechanics lab at C.A.E., Dr. Rajendra Prasad Central Agricultural University, Pusa. Pusa is situated on the banks of Budhi Gandak river. It lies at 25°98' N latitude, 85°67' E longitude and is situated at about 52 m above the sea level. The field has an approximate uniform topography with deep and well-drained sandy loam soil type.

## 2.3 Climate

The climate of the study area is humid subtropical and receives fairly good amount of southwest monsoon. The average annual rainfall in the area is 1120 mm, out of which nearly 1026 mm (80.78%) occurs in the monsoon months from July to September.

The yearly minimum and maximum temperature goes up to 3– 4°C in the winters and 43 - 44 °C in the summers, respectively. The metrological data such as rainfall, wind velocity and pan evaporation during the crop period were obtained from the metrological observatory located at Central Tobacco Research Institute, Pusa, Bihar.

## 2.4 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 the water table is during the monsoons which slowly drops to alarming limits during the summers.

## 2.5 Experimental field layout

A plot of size one ha measuring (100m x 100 m) was selected for the design of the drip irrigation system for tomato crop. The plant to plant and row to row spacing was taken as 60 cm x 60 cm.

## 2.6 Water source

An existing shallow tube well available near the site was used as the source of irrigation water to the experimental field.

## 2.7 Soil

The experimental plot was of uniform topography. The soil was of porous nature and was of sandy clay loam type with an average available moisture content of 12 %. The other properties of the soil are listed in table 1.

**Table 1:** Properties of soil at the experimental site at Pusa

S. No.	Particulars	Characteristics
1.	Soil type	Sandy clay loam
2.	pH	8.40
3.	EC	0.36 ds/m
4.	Particles size distribution	Sand-52 %
		Silt-18 %
		Clay-30 %
5.	Bulk density	1.56 g/cc
6.	Hydraulic conductivity	130 cm/day
7.	Basic infiltration rate	2.50 cm/h
8.	Field capacity	22 %

## 2.8 Design procedure

The design procedure steps are listed below:

1. Calculation of crop water requirement
2. Selection of drippers
3. Selection of laterals
4. Selection of submains
5. Selection of mainline
6. Selection of pump
7. Selection of filters and fertilizer equipment
8. Selection of other fitting and accessories.

### 2.8.1 Calculation of peak water requirement of the crop (PWR)

Crop water requirement can be defined as the quantity of water, regardless of its source, required by a crop or diversified pattern of crops in a given period of time for its normal growth under field conditions at a particular place. Water requirements include the losses due to evapotranspiration (ET) or consumptive use plus the losses during the application of irrigation water and the quantity of water required for special operations such as land preparation, leaching and unavoidable percolation losses (Michael and Ojha, 2011) [5].

The crop water requirement mainly depends on:

1. The climate
2. The crop types
3. The growth stages

For calculation of PWR, the maximum evaporation rate and crop coefficient were taken stage wise for the plant. The following formula was used for computing the same.

$$PWR = \frac{E_t \times K_p \times K_c \times K_f \times A}{E}$$

Where,

$E_t$  = daily pan evaporation from class “A” pan evaporimeter (mm/day)

$K_p$  = pan coefficient = 0.7 (FAO)

$K_c$  = crop coefficient.

The value of  $K_c$  depends upon the growing stage, metrological conditions. Value of  $K_c$  for the different growing stages for the tomato crop is as follows:

- 1) Initial stage = 0.45
- 2) Development stage = 0.75
- 3) Middle stage = 1.15
- 4) Maturity stage = 0.80 (FAO)

$$K_f = \text{canopy factor} = \frac{\text{Area of plant shadow at 12 noon}}{\text{Plant spacing} \times \text{Row spacing}}$$

$A$  = Area provided to a plant ( $m^2$ )

$E$  = Efficiency of the system (90 %)

$$\text{No of plants} = \frac{\text{Total area provided}}{\text{Plant spacing} \times \text{Row spacing}}$$

Total PWR = No. of plants  $\times$  PWR for one plant.

### 2.8.2 Selection of dripper

Drippers are available in the market with different discharge rates. The selection criteria was according to the plant water requirement.

Water application rate (AR) = No of drippers per plant  $\times$  Dripper discharge.

$$\text{Irrigation time} = \frac{\text{PWR}}{\text{AR}}$$

$$\text{No of irrigation sections possible} = \frac{\text{No.of hours electricity available}}{\text{Irrigation time}}$$

### 2.8.3 Selection of laterals

It is made up of LLDPE (linear low-density polyethylene), available with different diameters like 12 mm, 16 mm, 20 mm, 25 mm and 32 mm. The length of the laterals to be used depends on the standard dimension ratio (SDR), topography, limiting frictional head loss, and design tolerance of dripper. Where,

$$\text{SDR of Lateral (lph/m)} = \frac{\text{Dripper discharge} \times \text{No of drippers per plant}}{\text{Plant to plant spacing}}$$

For laterals, the frictional loss was calculated by Hazen-Williams formula given below (Pande *et al.*, 2003) <sup>[6]</sup>:

$$H_f = 0.628LD^{-4.865} \left( \frac{100Q}{C} \right)^{1.852}$$

Where,

$H_f$  = Total energy drop by friction at the end of the lateral (m),

$Q$  = Total discharge at the end of the laterals (lps),

$D$  = Internal diameter of pipe (m),

$L$  = Length of the pipe (m),

$C$  = Hazen-Williams constant (friction factor), 150 for PVC/LLDPE.

### 2.8.4 Selection of submain

Submain is made up of PVC or HDPE. Its sizes generally available were 40 mm, 50 mm, 63 mm, 75 mm and 90 mm.

SDR for sub main (lph/m) =

$$\frac{\text{No of plants covered by submain} \times \text{Dripper discharge} \times \text{No of drippers per plant}}{\text{Length of sub main}}$$

For sub main, frictional loss was calculated by the Hazen-Williams formula (Pande *et al.*, 2003) <sup>[6]</sup>:

$$H_f = 0.628LD^{-4.865} \left( \frac{100Q}{C} \right)^{1.852}$$

**Table 2:** Average daily water requirement of tomato crop.

Month	Average Evaporation (mm/month)	K <sub>p</sub>	K <sub>f</sub>	K <sub>c</sub>	Average monthly rainfall (cm)	Area (m <sup>2</sup> )	Average water requirement (l/day/plant)
Nov.	2.55	0.7	0.4	0.45	0.00	0.36	0.128
Dec.	1.02	0.7	0.4	0.45	0.00	0.36	0.051
Jan.	1.53	0.7	0.4	0.45	0.12	0.36	0.077
Feb.	2.87	0.7	0.65	0.75	0.00	0.36	0.391
Mar.	4.02	0.7	0.9	1.15	0.00	0.36	1.16
Apr.	5.10	0.7	0.9	1.15	0.00	0.36	1.47

As per table 2, the daily water requirement for the months of November, December, January, February, March and April was obtained as 0.128, 0.051, 0.077, 0.391, 1.16 and 1.47 (l/day/plant), respectively. The value of water requirement varied from 0.051 l/day/plant to 1.47 l/day/plant. Total numbers of plants in 1 ha area were 27777 and total water requirement was found to be 42637 l/day/ha.

### 3.2 Selection of dripper

Drippers with different discharge rates were available, but the dripper having discharge rate 2 lph was selected because the

### 2.8.5 Selection of main

The PVC or HDPE pipe was used. Its size available was of 50 mm, 63 mm, 75 mm, etc. The frictional head loss in the mainline was also computed by using the Hazen-Williams formula given as under (Pande *et al.*, 2003) <sup>[6]</sup>:

$$H_f = 0.628LD^{-4.865} \left( \frac{100Q}{C} \right)^{1.852}$$

The value of discharge was taken equivalent to the submain in lps, which is given by the following formula:

$$Q = \frac{\text{No of plants covered by sub main} \times \text{dripper discharge} \times \text{No of drippers per plant}}{3600}$$

### 2.8.6 Selection of pump set

The selection of the pump was based on the total head required. The following formula has been used for computing the total head required.

Total head required = (Suction + Delivery) head + head loss in filter + frictional

head loss in (Main + Submain + Lateral) + operating pressure head + frictional head loss in fitting + venturi head loss

And The size of pump is given by:

$$HP = \frac{Q \times H}{75 \times a \times b}$$

Where,  $Q$  = Required discharge (lps),

$H$  = Total head required (m),

$a$  = Efficiency of motor (assumed as 85 %) and  $b$  = Efficiency of pump (assumed as 80 %).

## 3. Results and Discussion

This chapter deals with the results obtained and relevant discussion towards determination of crop water requirement and design of the drip irrigation system for tomato crop at C.A.E., Pusa. It also includes economic evaluation for the designed drip irrigation system.

### 3.1 Water requirement for tomato crop

Water requirement for tomato crop was evaluated using the equation for the peak water requirement (PWR) for the entire crop period, on a daily basis, is given in table 2:

daily crop water requirement per plant was found to be 1.47 lph/day only.

### 3.3 Selection of laterals

Laterals were selected according to SDR graphs available for different diameters. Here, SDR calculated for laterals was found to be 3.33 lph/m.

From SDR curve for 12 mm laterals as shown in figure 1, it was seen that the 12 mm laterals can serve required discharge up to 58 m lengths, Hence, the lateral of 12 mm diameter was selected.

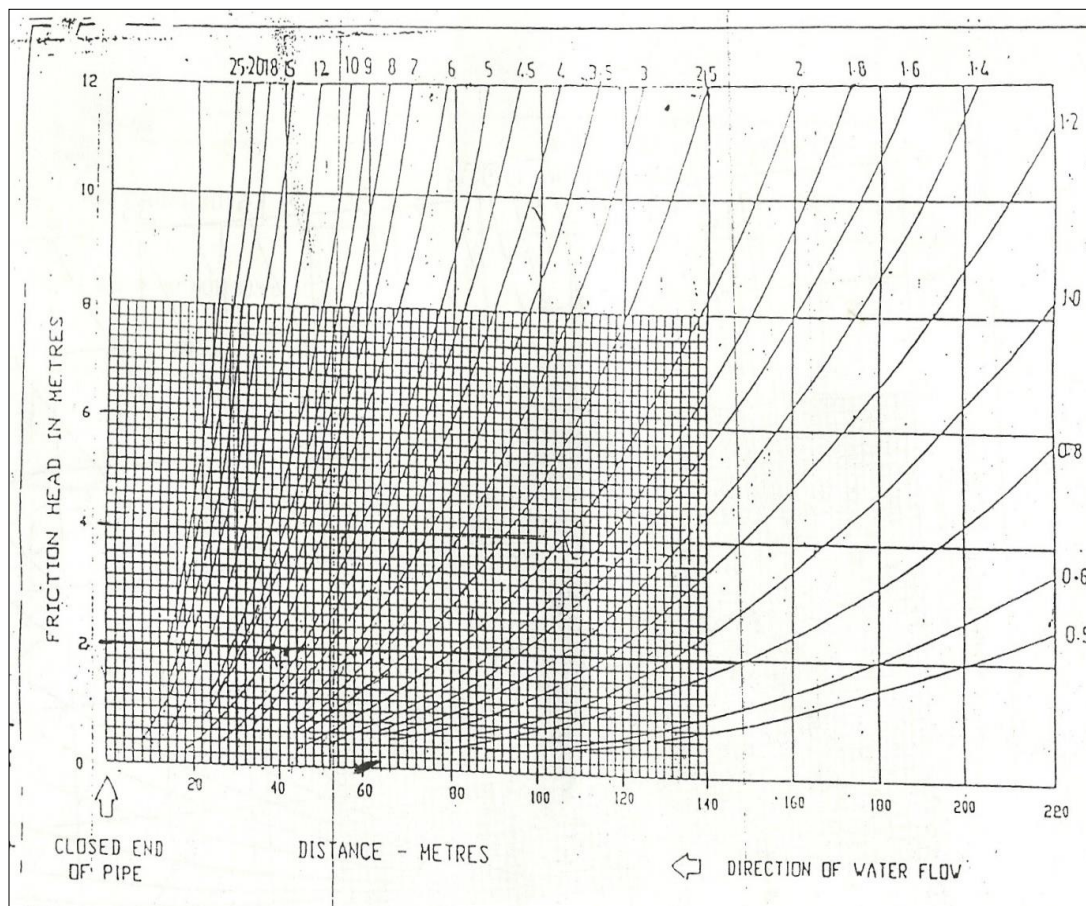


Fig 1: SDR graph for 12 mm lateral size.

### 3.4 Selection of submains

SDR for sub main was determined and the calculated SDR for submain was found to be 277 lph/m. Using the SDR graph available for different diameters of submain, the submain with

diameter 63 mm could serve up to 64 m length, and the pipe could serve the required amount of discharge. Hence, the submain of 63 mm diameter was selected using SDR graph shown in figure 2.

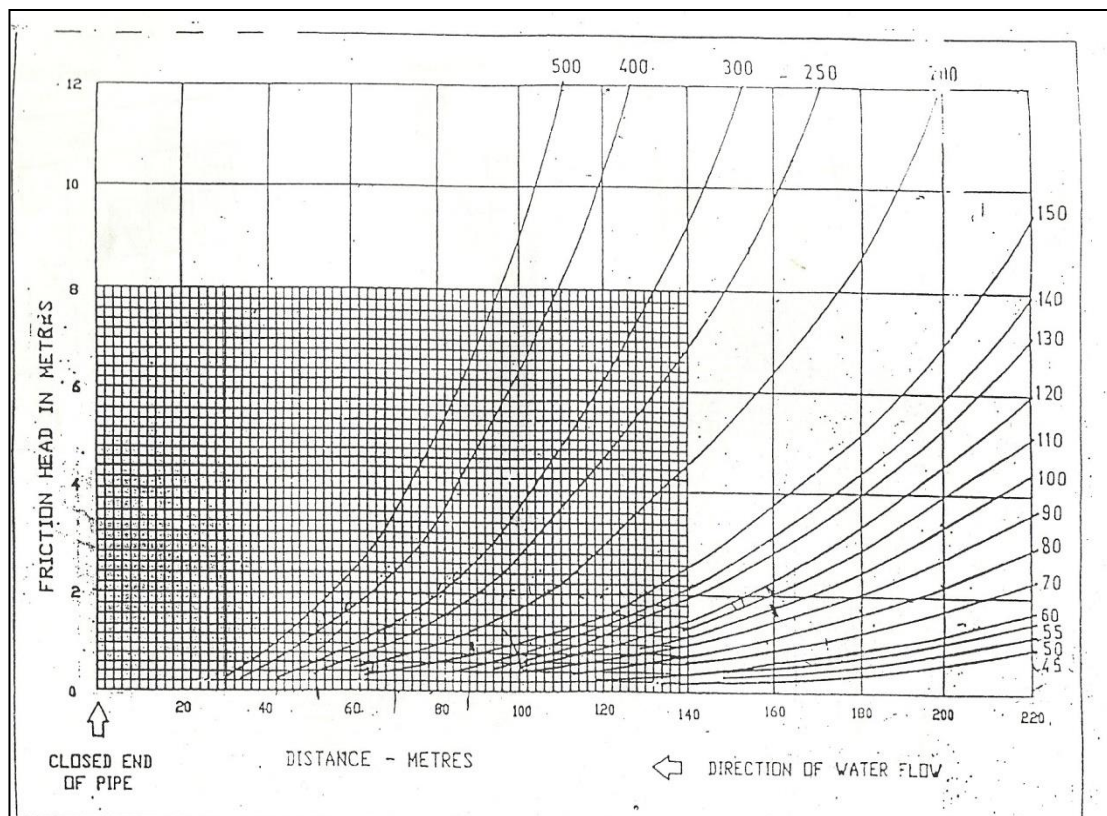


Fig 2: SDR graph for 63 mm sub main size.

### 3.5 Selection of main

For selection and design of the main, flow in main was determined. It was found that flow of main was 7.7 lps, the 90 mm diameter main line would have head loss of 20 m per 1000 m, therefore for a length of 100 m main line the head loss would be 2 m. Hence the main line having 90 mm diameter was selected.

### 3.6 Selection of pump-set

For the selection of pump-set, the total head required was obtained.

The total head included the following:

1. Suction head + delivery head = 13 m
2. Head loss in filter = 5 m (assumed)
3. Frictional head loss in main line, submain and lateral = 4 m

4. Frictional head loss in fitting = 3 m (assumed)

5. Operating pressure = 10 m

6. Ventury head = 5 m (assumed)

Thus, the total head required was found to be 40 m.

### Horsepower calculation

Horsepower required for drip irrigation system was calculated and was found to be 6.03 hp, accordingly the next higher size of the pump of 7.5 hp was selected.

### 3.7 Materials required and cost economics for 1 ha area

The design of the drip irrigation system for tomato crop for one-hectare area required the following materials as given in table 3:

**Table 3:** Materials required for 1 ha area

S. No.	Materials	Length (m)	Diameter(mm)	Nos
1.	Main pipeline	102	90	1
2.	Submain	102	63	2
3.	Laterals	16700	12	334
4.	Drippers	-	-	27777
5.	Filter	-	-	1
6	Fertigation unit	-	-	1
7.	Pump (7.5 hp)	-	-	1
8.	Accessories			
	I. PVC ball valve	-	-	5
	II. PVC flush valve	-	-	2
	III. Nonreturning valve	-	-	1
	IV. Air release valve	-	-	1
	V. Air release valve assembly	-	-	1
	VI. Bypass assembly	-	-	1
	VII. Grommet take off	-	-	400
	VIII End cap	-	-	400
	IX. Poly ring joiner	-	-	400
	X. Other accessories	-	-	-

### 3.8 Cost economics of required materials for 1 ha area

The estimated value of the materials is given in table 4 based on the cost in the market.

**Table 4:** Estimated cost of the materials required

S. No	Particulars	Quantity	Unit	Rate	Amount in (Rs)
1	Main pipe line	102	m	67.80	6915.60
2	Submain	102	m	31.65	3228.30
3	Laterals	16700	m	2.00	33400.00
4	Drippers	27777	Nos	2.95	81942.00
5	Filter	1	Nos	2298.00	2298.00
6	Fertigation unit	1	Nos	1692.00	1692.00
7	Pump (7.5 hp)	1	Nos	17500.00	17500.00
8	Accessories				
	I. PVC ball valve	5	Nos	337.00	1685.00
	II. PVC flush valve	2	Nos	54.90	109.00
	III. Non-returning valve	1	Nos	434.00	434.00
	IV. Air release valve	1	Nos	230.00	230.00
	V. Air release valve assembly	1	Nos	128.50	128.50
	VI. Bypass assembly	1	Nos	1429.00	1429.00
	VII. Grommet take off	400	Nos	2.70	1080.00
	VIII. End cap	400	Nos	1.50	600.00
	IX. Poly ring joiner	400	Nos	2.00	800.00
	X. Other accessories				5% of total amount
9	Total amount (Rs)				161143.00

From the table above, it can be seen that the total estimated cost of drip irrigation system for tomato crop in 1 ha area was found to be Rs 161143.00 INR.



#### 4. Conclusions

Drip irrigation system was designed for the drippers, laterals, sub-mains, main and the pump. The crop water requirement for the tomato crop as observed from November to April was estimated in the range of 0.051 lpd to 1.47 lpd. The drippers of discharge capacity 2 lph was found suitable for irrigating the tomato crop. The size of the main, submain and lateral was found to be 90 mm, 63 mm and 12 mm, respectively. The size of the pump was calculated to be 7.5 hp, which was suitable for irrigating the tomato crop in one-hectare area. The total cost of the designed drip irrigation system was found to be Rs 161143.00 INR.

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