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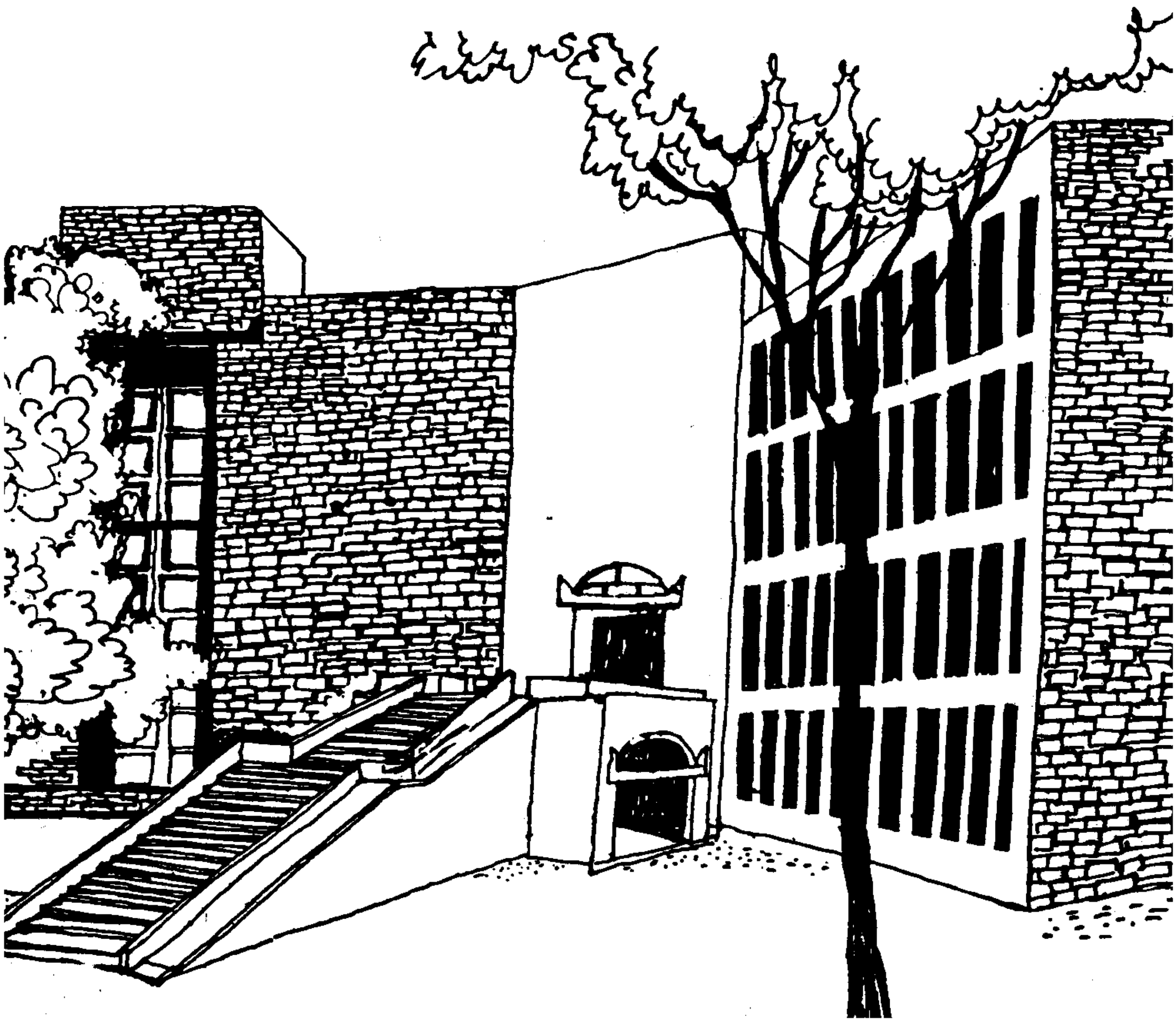

DESIGN OF GREENHOUSE IRRIGATION SYSTEM AT BHUJODI

By

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Design of Greenhouse Irrigation System at Bhujodi

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Abstract

Kutch is extremely arid, hot and short in agricultural quality ground water. Greenhouse is expected to reduce water requirement in such conditions. It is for this reason that this approach is being followed. In the write-up we present the design of irrigation system for greenhouses.

Water Requirement under greenhouse: Literature Review

Water requirement inside greenhouse can be both higher and lower than open field. It is higher, if the greenhouses are heated as in temperate climates. It is reported to lower in unheated houses as are often used in tropical and hot regions. We propose to use greenhouse as a means to increase water productivity in Kutch. This possibility has recently been highlighted by David Mears who stated the following [1].

> "While a greenhouse is generally regarded as necessary to provide a warm environment in cold climates, it has also been shown that with properly designed cooling system it is possible to improve plant growing conditions under extensively hot conditions. Adaptation of modern cooling technologies to Indian conditions will undoubtedly lead to increased opportunities for production of high value plants and materials in areas where the environment is extremely harsh. Protected cultivation also has the potential benefit of substantially increasing plant productivity per unit water consumption which is important in many areas where good quality water sources are severely limited".

Pitam Chandra [2] stated that it has been realised that the greenhouse cultivation actually economise on the water requirement for raising crops. Vapour present in greenhouse air rises thereby reducing the amount of ET. Water consumption needs in plastic greenhouse with drip irrigation and high humidity has been reported to be 30 per cent of those required in conventional greenhouse.

Raman *et al* [3] reported that polyhouse in Navsari reduced the ET of crop by 40 per cent over outside condition. Otto R.F. and Gimenez G. [4] grew Chinese cabbage with drip irrigation in open and under direct cover. Lower solar radiation and high humidity reduced evaporative demand under cover even though leaf area index values in direct cover were higher through season.

Design of drip irrigation system

This involves following

- Estimation of peak water requirement of crop.
- Selection of dripper.
- Design of Lateral, Submain and Main line.
- Selection of Filter, Fertigation, Watermeter, Non Return, Flow control, Pressure Relief and Air release valves.
- Provision of Flushing submains.
- Selection of Pump.

Symbols and Notations

W	Peak water requirement of crop (ltr/day/plant).
A	Available gross area per plant (m^2)
B	Crop coefficient at maturity (dimensionless)
C	Maximum Pan evaporation in the region (mm/day)
D	Pan coefficient (commonly taken as 0.7 to 0.8)
Ha	Horizontal advance of wetting front (cm)
Va	Vertical advance of wetting front (cm)
It	Irrigation time (min.)
V	Total water requirement of plants(m^3)
Q	Capacity of irrigation system (m^3/hr)

Qd, Ql, Qs, Qm	Discharge (m^3/hr or ltr/hr)
Hfal, Hfas	Allowable head loss (m)
Hfl, Hfs, Hfm,	
Hfer, Hfil, Hfit	Head loss (m)
Dl, Ds, Dm	Inside diameter (cm)
Cl, Cs, Cm	Roughness factor (dimensionless)
Ll, ls, lm	Length of pipeline (m)
fl, fs	Outlet factor (dimensionless)
Sd	Dripper spacing on lateral (m)
Tl	Total length of lateral (m)
Eol	Equivalent length for oultlet openings on pipe (m)
Hw	Depth of water level from the ground surface (m)
Hele	Head loss due to elevation in field (m) (upward slope +ve, downward slope -ve)
Ho	Operating head of dripper (m) (usually taken as 10 m)
H	Total head (m)
HP	Horse Power of Motor
Epump	Pump efficiency (70%)
Edrive	Drive efficiency (80%)
Emotor	Motor efficiency (75%)

Subscript d, l, s, m, fil, fer, fit refers to dripper, lateral, submain, main line, filter, fertigation and fittings respectively.

Layout of the System

We intend to grow tomato crop inside greenhouse, spacing of 0.6 x 0.6 m. Tomato will be grown on raised bed of size 0.9 x 20 m. Pathway of 0.2 m is kept between two beds to carry out cultural operations. A middle pathway of 1 m is there for movement inside greenhouse. Layout is shown in **figure 1**.

Peak Water Requirement of Crop

As of now, there is np reliable method to estimate water requirement under controlled environment. We will therefore use the method normally employed to open field conditions.

for open field, peak water requirement of crop is estimated as follows.

$$W = A \times B \times C \times D$$

For Bhuj, maximum pan evaporation is 15 mm/day for tomato, crop coefficient at maturity goes up to 1.05. Gross area is calculated from spacing of crop i.e. for tomato 0.36 m^2.

$$\text{hence, } W = 15 \times 1.05 \times 0.8 \times 0.36$$

$$= 4.5 \text{ ltr/day/plant}$$

As discussed earlier, various researchers had reported reduction in water requirement of crop for greenhouse cultivation (25 to 40 per cent) over bare field grown conditions. Although this would also be true at Bhuj, but for design purpose we will take maximum water requirement of tomato as 4.5 ltr/day/plant. We will check whether it can be reduced in greenhouse.

Selection of Dripper

As per layout, bed to bed spacing for tomato works out 1.1m and hence there will be two rows of tomato on each bed. There are 4 beds in the greenhouse. Soil at greenhouse site is of medium type. So we will use one medium discharge (4 lph), non-pressure compensating, on line dripper. One dripper will feed water to plants on both sides and lateral will be placed on middle line of bed. Drippers will be fixed at every 0.6 m spacing on lateral.

Number of tomato plant / row = row length / spacing of plant in row

$$= 20 / 0.6 \sim 34$$

Total number of plants in greenhouse = Number of rows x (plants/ row)

= 34 x 8 = 272

Total water requirement (V) = 272 x 4.5 = 1224 litres / day

Numbers of drippers per laterals = Lateral length / dripper spacing

= 20 / 0.6 = 34

Total number of drippers in greenhouse = Number of laterals x (Drippers / Laterals)

= 4 x 34 = 136

Capacity of irrigation system (Q) = Total number of drippers x dripper discharge

= 136 x 4 = 544 ltr/hr

Irrigation time is calculated as

$$It = \frac{V}{Q}$$

= 1224/ 544 = 2.25 hrs (135 min.)

Wetting Pattern of dripper

Horizontal and vertical movement of water from point of application is calculated as follows,

$$Ha = 2.526\ (Qd)^{0.754}(It)^{0.515}$$

$$Va = 9.26(Qd)^{0.175}(It)^{0.419}$$

Using above equation of wetting front, 4 lph dripper give a horizontal and vertical advance of water as 89.84cm and 92.16cm respectively after 2.25hrs of irrigation. So whole strip of bed will be wetted and wetting pattern of dripper is satisfactory. Roots of mature tomato go upto 1m below the ground. -

Design of Lateral

For drip system, 20 per cent pressure variation and 10 per cent flow variation are desirable. As we are using non-pressure compensating pressure, allowable head loss in submain and lateral will be 20 per cent of operating head of dripper.

Head loss in lateral, submain, and main line are calculated by using Hazen williams equation which is as follows.

$$H_f = 1526x10^4 x \frac{Q}{C}^{1.852} x (D)^{-4.873} x (L) x f \qquad ......(1)$$

where

H_f	Head loss, m
Q	Discharge, m^3/m
C	Roughness factor for pipe
D	Inside diameter of pipe, cm
L	Pipe length , m
f	Outlet factor (depends on number of outlets)

For lateral pipe,

$$Q_l = \frac{L_l}{S_d} x Q_d$$
$$= 34 \ x \ 4$$
$$= 136 lit / hr$$

Roughness coefficient, Cl = 140 (for LLDPE pipe)

As there are 34 drippers on one lateral, outlet factor for lateral is 0.3. So, equivalent length for each dripper is 0.3 m.

$$E_{ol} = 0.3 \times 34$$
$$= 10.2 \text{ m}$$
$$T_l = L_l + E_{ol}$$
$$= 20 + 10.2$$
$$= 30.2\text{m}$$

Dripper will discharge water in atmospheric conditions. Operating pressure head for dripper is taken as 10m (1.03 kg/cm^2).

Allowable headloss in lateral and submain = 2 m

Of this, we will keep 1.5 m headloss in lateral and 0.5 m for submain.

Using equation (1) for lateral design,

$$15 = 1526 x 10^4 x \frac{0.136}{140}^{1.852} x (D)^{-4.871} x (30.2) x 0.36$$

D = 0.77 cm

= 7.7 mm

Minimum lateral pipe size available in market is 12 mm with internal diameter 9.8 mm. So we will select 12 mm lateral pipe.

Again using ***equation(1)*** for lateral of 12 mm,

Hf_l = 0.53 m

Design of Submain

There are 4 laterals on one submain. Submain is PVC pipe with roughness coefficient of 150.

Qs = 0.136 x 4

= 0.544 m^3/hr

Hfas = 0.5 m

Cs = 150

f = 0.49 (for 4 outlets)

Using equation 1 for submain design,

Required diameter of submain = 11.8 mm

It is quite impossible to drill holes on 15, 20, 25, 32 mm PVC pipe for lateral connections. We will select 40 mm pipe of pressure rating 6 kg/cm^2 for submain.

Using ***equation 1 for*** head loss through pipe of 40 mm (inside diameter 36.55 mm),

H_f = 0.00208 m

Design of Mainline

Distance of water source from plot is assumed as 150 m. So mainline will be of this much length. Mainline will have to carry water for cooling system, irrigation and greenhouse operation which are as follows.

Cooling system	=	37 ltr/min
	=	2.2 m^3/hr
Drip system	=	0.544 m^3/hr
Greenhouse Operation	=	1 lps
	=	3.6 m^3/hr
Total mainline flow, Qm	=	6.36 m^3/hr

Mainline is usually of larger size than submain considering future expansions, so we will choose 63 mm (inside diameter 59.35 mm) pipe. Outlet factor for mainline will be 1.

Using ***equation 1***, head loss of main pipe

$$H_f = 1.526x10^4 x\left(\frac{6.36}{150}\right)^{1.852} x\,(5.935)^{-4.871} x(150)$$

$$= 1.12m$$

Selection of Control Head Unit

Drip system capacity is 0.544 m^3/hr, 3/4"(25 mm) plastic screen filter match this flow requirement. Considering good degree of filtration and future expansion, we will choose 1"(32 mm) plastic disc filter for filtration.

Selection of fertigation unit is based on fertiliser application rate and pressure available at the pump outlet. This will be done as per manufacturers recommendations.

Pressure relief valve is used to release extra pressure developed during opening and closing of valves. This is installed on by-pass arrangement at pump discharge side . Selection is made on pipe size. 2"(50 mm) pressure relief valve will suit our system.

Non return valve is necessary to resist back pressure created by water when we close the discharge valve. This is fitted on the point from which mainline starts. It is usually recommended for rising main on hilly situations to avoid water hammer on the pump. Selection is made on pipe size and pressure. For our system, it is optional.

Air release valves are necessary to remove air inside pipe. These are located near pump and all elevated points on pipeline. Generally 1"(25 mm) or 1/2"(12.5 mm) air release valve are selected in drip system.

Watermeter is used to measure the volume of water applied. Its selection depends on flow capacity and pipe size connection (*manufacturers catalogue*).

Flow control valves are selected on basis of flow capacity of unit and allowable head losses. Generally their sizes are determined on basis of pipe size and manufacturers recommendations. For our system, 11/4"(40 mm) PVC ball valve is suitable for estimated flow of submain.

Flush valves are provided at the end of every submain to flush the submain. For this, end of the submain pipe is brought on the ground and closed with end cap.

Total Head Requirement

Head against which pump will operate for required flow output is total head. It includes all head losses, static head and operating head of dripper.

$$H = H_{fl} + H_{fs} + H_{fm} + H_{fil} + H_{fer} + H_o + H_{ele} + H_w + H_{fit}$$

For our system,

H_{fl} = 0.53m, H_{fil} = 6m, Hw = 10 m (assumed)

H_{fs} = 0.002 m, H_{fer} = 4m, Ho = 10 m

H_{fm} = 1.12m, H_{fit} = 2m, Hele = nil

Total head will be,

$$H = 0.53 + 0.002 + 1.12 + 6 + 4 + 10 + 10$$

$$= 33.65 \text{ m} \approx 35 \text{ m}$$

Selection of Pump

Required pump duty conditions are as follows.

Total flow = $6.36\ m^3/hr$ (1.76 ltr/sec)

Total head = 35 m

Horse-power of the motor is calculated as

$$H.P. = \frac{Q_m\,(LPS)xH}{75\,xEpump\,xEdrivexEmotor}$$

$$= \frac{1.76x35}{75x\,0.7\,x\,0.8\,x\,0.75}$$

$$= 1/.95 \approx 2\,H.P.$$

Pumps available in market close to our requirement are,

Single phase - 2 H.P.

Three phase - 3 H.P.

We will go for 3 H.P. pump set.

Scheduling of Irrigation

Many researchers worked on drip irrigation scheduling. Tensiometers are commonly used to predict the frequency of irrigation with drip irrigation. Tensiometer measures water suction from 0.15 to 0.85 atm (150 to 850 cm of water column).

Soil water suction ranging from 150 to 250 cm is considered optimum for more crop. Pogue and Pooley used tensiometer for measurement of soil water. Irrigation system is turned on when tensiometer showed reading beyond 40 kpa (400 cm H_{2o}) at 30 cm depth. For drip system, risk of moisture stress lies between 35-40 kpa (350-400 cm of H_{2o}).

Goyl and Rivers conducted experiment on irrigation scheduling of vegetables. They put tensiometer at different-depth 15 cm, 30 cm and 45 cm classifying wet, moist and dry irrigation regime. Irrigation was started at tensiometer reading of 45 bars and terminated when moisture tension dropped to 15 bars. Tomato needed 22.8 cm, 14.4 cm and 10.5 cm of water in wet, moist and dry irrigation regime respectively.

We will use tensiometer to decide the frequency of irrigation. They will be installed at various depth i.e. 15 cm, 30 cm and 45 cm below the soil. We will irrigate the greenhouse crop when tensiometer at 30 cm has reading of 50 kpa(0.5 bar) and turned the system off at 10 kpa. Watermeter will be used to measure the amount of water diverted for irrigation.

Design and Irrigation Data of System

Crop	Tomato
Spacing	0.6 x 0.6 m
Area	100 m^2
No. of plants	272
System	Drip
Dripper discharge	4 lph
D/D spacing	0.6 m (one dripper for two plants)
L/L spacing	1.1 m
Maximum pan evaporation	15 mm/day
Peak water requirement	4.5 ltr/day/plant
Irrigation time	2.25 hrs
No. of operations per cycle	1
Irrigation frequency	on basis of tensiometer reading.
Total irrigation time	2.25 hrs (135 min)
Flow per operation	0.544 m^3/hr
Total head	35 m
Pump unit	3 HP, three phase, monoblock
Laterals	12 mm / 2.5 kgf
Submain	40 mm / 6 kgf
Main	63 mm / 4 kgf

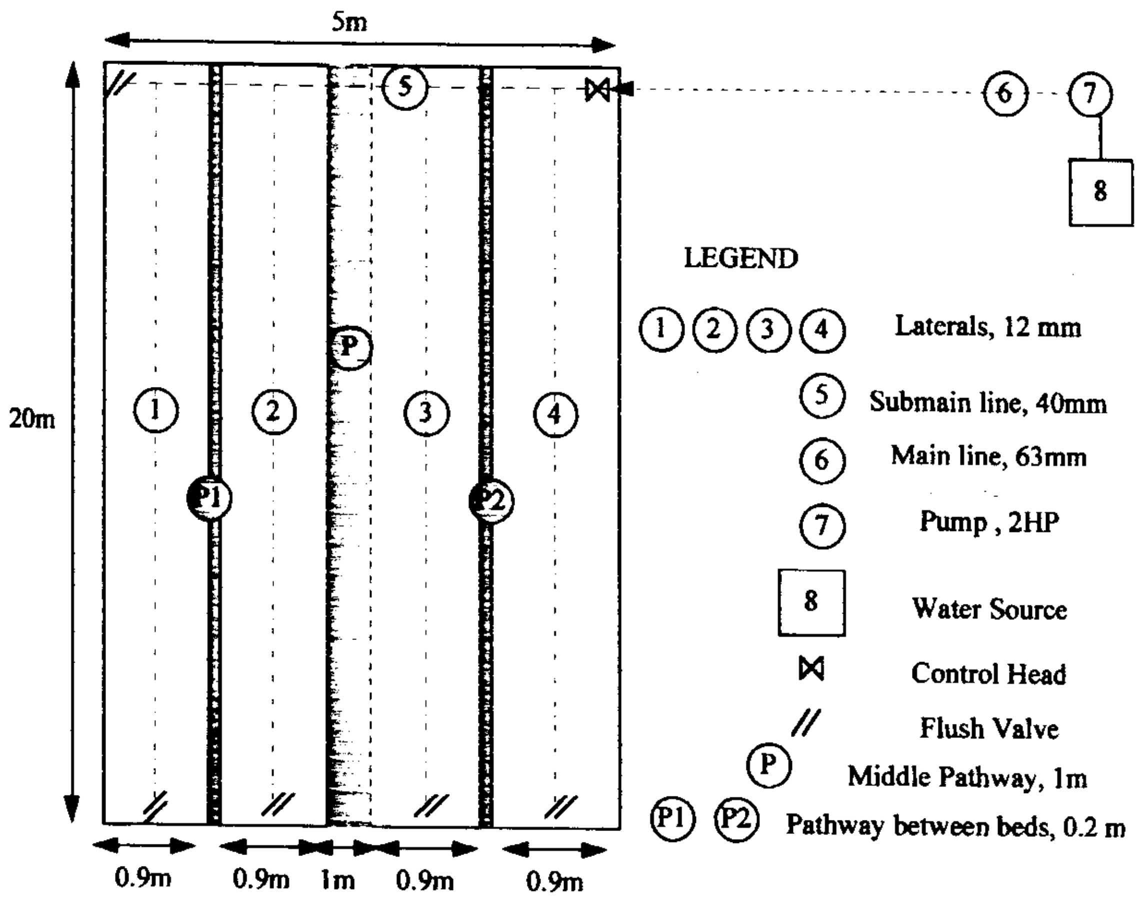

Fig.1 - Layout of Irrigation System

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