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WATER REQUIREMENT AND CALCULATION OF YIELD FOR DRIP IRRIGATED TOMATO

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Abstract

Climatic variation disturbing the cropping pattern, irrigation scheduling, and yield production. Due to the shortage of water, there is an urgent need to curtail the water supply to the agriculture sector, as agriculture is the primary consumer of water. Water requirement of tomato crop and its scheduling were monitored using CROPWAT software 8. The crop water requirement for the Niphad region tomato crops is 481.9 mm/dec. The irrigation requirement for regions is 329.9 mm/ Dec respectively. The tomato crop required a net water requirement of 313.1 mm. Drip irrigation systems were implemented for irrigation. The yield achieved by drip irrigation is more. Paper insights into the design of Lateral, submain, drip irrigation design, and calculation for the yield of drip irrigation.

The application of the CROPWAT model was implemented to estimate crop water requirement, irrigation water requirement, and to identify the impact of irrigation efficiency on gross irrigation water requirement.

Keywords: CROPWAT, Crop water requirement, Drip irrigation, Evapotranspiration.

1. Introduction

As the occurrence of precipitation throughout India is not uniform, in some parts of India such as Sikkim, west of Bengal, Himalaya region, and Uttar Pradesh more precipitation existence, and districts such as Jaisalmer Rajasthan, Abohar Punjab, Maharashtra some districts like Dhule, Jalgaon, Solapur, etc less precipitation occurs. In the 21st century, India is facing water scarcity in the agriculture sector [1]. The continuous development in the irrigation sector can be strengthening the Indian economy and try to enhance the GDP [2]. As per the planning commission of India 2002 irrigation sector is the principal withdrawal of water [3]. Irrigation sector withdrawals around 84 % of the water from water resources [4]. Due to the increase in population, industrialization, and urbanization demand for water is enhanced in industries and municipal corporations too [5]. Due to the climatic changes, rainfall has occurred and indirectly availability of water is reduced on a large scale [6]. As irrigation is dependent on precipitation, available water resources such as dams, canals, tube wells, groundwater, perennial rivers, etc. To manage the water shortage, it is very essential to save water required for various sources such as industrial, municipal, as well as agriculture sectors too, as more water is required for irrigation [7]. Even farmers have a tendency to apply more water to crops for getting more yield. Its current need to inform farmers regarding the importance of optimum application of water supply and preserving ideal moisture in the soil [8]. It is the principle of irrigation to apply water to the field in order to meet crop evaporation requirements in cases where rainfall is insufficient to raise crops till harvesting [8]. A water project planning and management are dependent on knowing how much irrigation water is required for a particular project. With irrigation water requirements, the right amount of water is applied to the soil at the right time for plant growth [9].

Crop water requirements refer to the overall amount of water needed by a crop and the way in which that crop consumes water from the point of planting to harvest [10]. Water is the basic requirement of crops. The crop can extract minerals from the soil. Water is the media through which crop roots get the minerals present in the soil. Optimum application of water for the field is very essential as in soil optimal moisture needs to be present for proper nourishment of the crop [11]. Due to the excess amount of water crop becomes yellowish as well as optimum yield will not get. Due to

excess amount of water fields get waterlogged [12]. Sufficient aeration is the basic requirement for plant growth. As bacteria present in the soil required air as they can change the organic matter present in soil into food [13]. Optimum moisture can enhance the soil fertility, and organic content in the field in the root zone [14].
CROPWAT (Crop Water Requirements) is a computer program developed by the Food and Agriculture Organization (FAO) of the United Nations. It is used for calculating the water requirements of crops, irrigation scheduling, and assessing crop water productivity. CROPWAT 8 is specifically designed for estimating water requirements for different crops under a variety of agro-climatic conditions. Calculation of crop water requirements: CROPWAT 8 calculates crop water requirements based on various climatic parameters, such as temperature, humidity, wind speed, and solar radiation. It takes into account crop characteristics, growth stages, and crop coefficients. CROPWAT 8 contains a comprehensive crop database with information on a wide range of crops. This enables users to select the appropriate crop for their analysis and obtain accurate water requirement estimates.

To achieve the maximum germination index, it is essential to apply the optimum water [15]. Well-organized and optimum application of water for agriculture throughout India is insufficient. Hence there is an urgent need to improve and manage the irrigation scheduling Using CROPWAT 8 and Validation of data Using Mathematical Modelling.

2. Study Area and requirement of Data

The experimental work has been performed during the period of the rainy (01st August to 24th Sept 2019) season in the village of Makhamalabad in the Nashik region lies between a latitude of 20°02’17.48’’N and Longitude 73°53’42.90’’E, and altitude 563 meters above mean sea level. The average annual rainfall and temperature are 812 mm and 28.8°c respectively. Fig 1a., represent the left bank canal of Godavari River, Nashik. Fig 1b., Insights the Google earth image of the study area. Fig 1c., shows the location map.

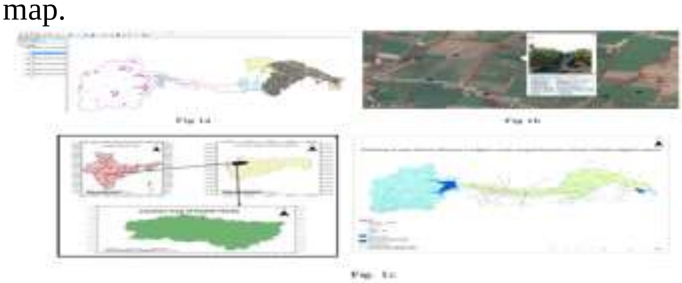

Figure 1a. Study area of Left bank canal of Godavari River at Nashik. Fig 1b. Google earth image of study area. Fig 1c. Location map of study area

The main source of irrigation water for the Nasik irrigation area is the left bank canal of the Godavari River. The originates in the Western Ghats of the Godavari of central India near Nasik in Maharashtra. The irrigation system in the Godavari River consists of the left bank canal, which is connected to branch canals made of concrete. The total length of the main canal is approximately 51.54 km having a discharge of 8.49 cusec. Kherwadi and Sukena which cover the area 4193 ha. The improvement in irrigation systems in the Godavari River is one of the most important attempts in the Nasik area to implement more effective irrigation technologies by improving the existing delivery system. 15 days climatic condition such as temperature, humidity, sunshine/radiation, and wind speed of Nashik region has been illustrated in table 1. The longitude and the latitude are 74.0625 and 19.8265 respectively.

Table 1. Climatic condition of the study area Niphad, Nashik

Max Temperature (°C)	Min Temperature (°C)	Wind (m/s)	Relative Humidity	Solar W/m^2
28.069	15.446	2.257	0.46419	16.471

	26.434	10.89	1.797	0.44063	18.681
3.	25.967	10.818	2.458	0.51563	18.471
	29.16	13.353	1.721	0.5643	17.910
	28.714	9.966	1.420	0.5154	18.023
	28.705	10.644	1.506	0.5051	18.549
	27.102	14.091	1.996	0.5638	13.033
	29.899	15.533	1.655	0.6595	14.578
	23.673	17.486	2.644	0.7653	4.427
	29.906	14.524	1.603	0.6112	17.861
	29.046	16.111	1.446	0.5236	16.170
	29.601	17.625	1.656	0.4570	16.197
	27.489	17.783	1.761	0.5934	4.738
	30.478	17.406	1.442	0.5779	14.735
	29.291	12.273	2.457	0.4041	18.690

Methodology

A case study of Niphad, Nashik district, Maharashtra India was considered for improving the irrigation water allocation and its use for different crops. The application of the CROPWAT model was implemented to estimate crop water requirement (CWR), and irrigation water requirement (IWR), and to identify the impact of irrigation efficiency on gross irrigation water requirement. Monthly irrigation water demand for practiced crops is estimated by using CROPWAT 8. Software. The Food and Agriculture Organization (FAO) agency of the United nation developed CROPWAT 8.0 software. Decision-making the computer program is based upon numerous equations. Figure 2 represents the systematic working of software and data required for CROPWAT software such as climatic conditions, maximum and minimum temperature, evaporation, humidity, the intensity of sunshine and its duration, wind speed and its direction, and precipitation details, etc. With the help of systematic design steps, it can be possible to find out the crop water requirements (CWR), and irrigation water requirements (IWR). The working and performance of the software are based upon the four basic parameters such as data related to crop, characteristics of soil, meteorological data of the region, and climatic condition [16].

3.1. Description of Irrigation system

The drip irrigation systems were installed and implemented for the tomato crop. In the field, the tomato plant is placed in rows by planting 135 plants in one row with a plant interval of 0.6 m. The distance between two rows is 1.2 m. Furrow irrigation was also given to the tomato having the same spacing soil properties as the experimental plot. The mean values of recorded soil moisture data of 30 cm depth for drip and furrow irrigation system. and also measure height and yield of drip and furrow irrigation system. Drip irrigation has a regular 16mm lateral attached to the submain pipeline of size 65 mm. Each tomato plant has two emitters with a capacity of 4lit/hr. The moisture meter is used to measure the moisture of two irrigation systems having a depth of 30 cm. The soil moisture was recorded on an experimental plot of drip irrigation and furrow irrigation system respectively. The weekly efficiency of drip irrigation required for the tomato is represented in fig 3

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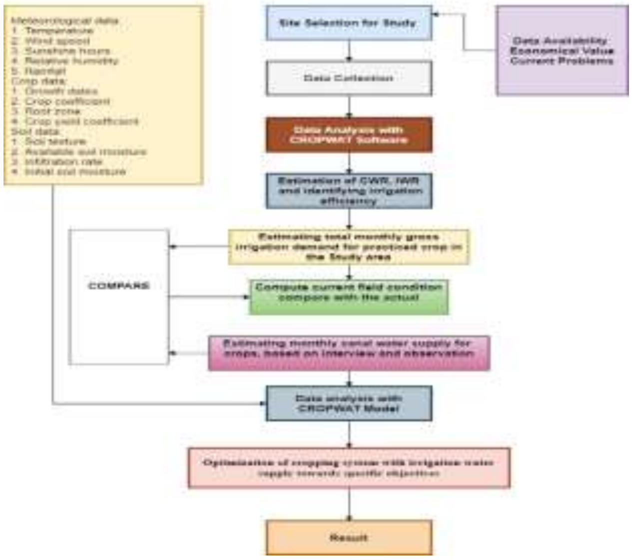

Fig.2 Schematic Diagram of the CROPWAT Model

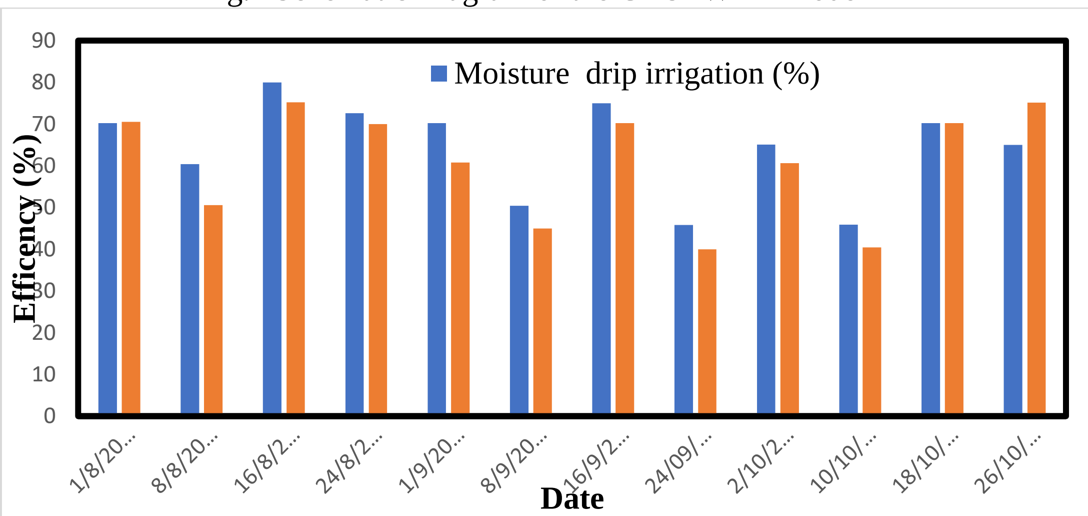

Fig. 3. Weekly Efficiency of drip irrigation

4. Results and Discussion

It is essential to define the terms such as Crop water requirements (CWR), irrigation water requirement, evapotranspiration, and irrigation schedule (Nam et al., 2016; Pereira et al., 2015). Crop water requirement means the amount of water required for crops to consume the transpiration and evaporation. Crop water requirement depends upon various factors such as the method of irrigation, climatic condition, the intensity of irrigation, types of soil, its characteristics, and condition of groundwater table, etc. Generally, the evapotranspiration equation had given by using the Penman-Monteith equation.

$$\boldsymbol{ETO} = \frac{0.408\Delta(Rn-G)+\gamma\left(\frac{900}{T+273}\right)u2(es-ea)}{\Delta+\gamma(1+0.34u2)} \qquad (1)$$

ET0= evapotranspiration in mm/day, G= soil heat flux density MJ/ m^2 /day, Rn = net radiation at the crop surface MJ/m^2/ day, u^2 = wind speed at 2 m height m/s, T= mean daily air temperature at 2 m height °C, es= saturation vapour pressure kPa, (es – ea) = saturation vapour pressure deficit kPa, ea= actual vapour pressure kPa.

The crop coefficient (Kc) represents the type of crop and its growth it depends upon the ratio of crop evapotranspiration to reference evapotranspiration. The total irrigation requirement is depending upon

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the crop evapotranspiration and irrigation frequency. Fundamentally, the irrigation frequency depends upon the ratio of readily available moisture to crop evapotranspiration.

$$Kc = \frac{ETc}{ETo} \quad (2)$$

$$IF = \frac{RAM}{ETc} \quad (3)$$

Irrigation water requirement for crops depends upon the root zone depth in the soil, water present in the soil, and rainfall. For optimum growth of plant water required is supplied by rainfall then net irrigation is not essential. If less amount of rainfall and water is required for the crop for its nourishment then irrigation water required is crop water need.

$$\mathrm{IR} = \mathrm{WR} - (\mathrm{ER} + \text{shallow water table}) \quad (4)$$

IR= Irrigation water requirement in mm
WR= Water requirement in mm/day
ER= effective rainfall in mm

As per the United States Department of Agriculture (USDA) effective rainfall has been calculated as below

ER = Total R*(125-0.2 TR) / 125 …… ………………… (5)
(For Total Rainfall < 250mm)
ER = 125 +0.1 * Total Rainfall …………………… (6)
(For Total Rainfall > 250mm). Fig 4 represents the effective Rainfall distribution of Niphad command area

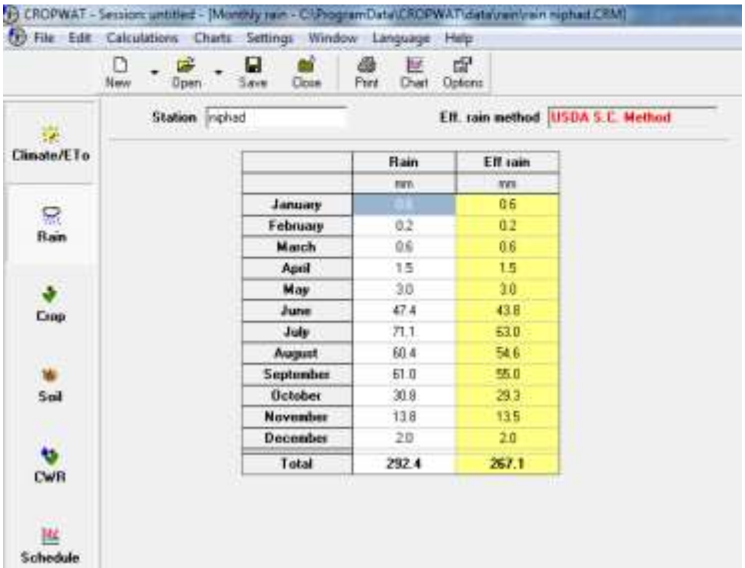

Fig. 4. Effective Rainfall distribution of Niphad command area

For CROPWAT software crop water requirement (CWR) and irrigation water requirement (IWR) were calculated by using eq. 7, and eq.8 respectively.

ETc=ETo*Kc...…………… (7)

IWR = (ET_o* Kc) – ER.… …… (8)

After feeding the data such as the name of crop, type of soil, and cultivation date to the CROPWAT software it automatically calculates the outcomes in the form of tables and graphs. The software can calculate the parameters such as the crop coefficient, maximum, and minimum temperature, humidity, evapotranspiration, effective rainfall, and total irrigation requirements for the tomato crop. Table 2, represents the meteorological characteristics such as rainfall, and evaporation of the Nashik region obtained from the CROPWAT software 8.0. table 2a represent the meteorological characteristics of the Niphad region obtained through the CROPWAT software 8.0.

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4.1. Crop water requirement for Tomato Crop

In the autumn-winter season tomato crop is ploughing in Maharashtra. Tomato is a fast-growing crop. The water requirement for tomato crops is the amount of water loss by actual evapotranspiration. Water requirement of the crop depends upon the area, methods of cultivation, groundwater table, characteristics of soil, effective precipitation, etc. Table 3, 4, Fig 5 represents the total water required for the Niphad region tomato crop. Water required for Niphad region tomato crop is 481.9 mm/dec respectively.

4.2. Irrigation Scheduling and net water requirement for the tomato crop

Water management in the agriculture sector is very essential as day by day there is a deficiency of water. Core knowledge about the irrigation schedule will be helpful for farmers to manage effective irrigation in the field. The irrigation requirement for tomato crops is 329.9 mm/ Dec. The tomato crop required a net water requirement of 313.1 mm.

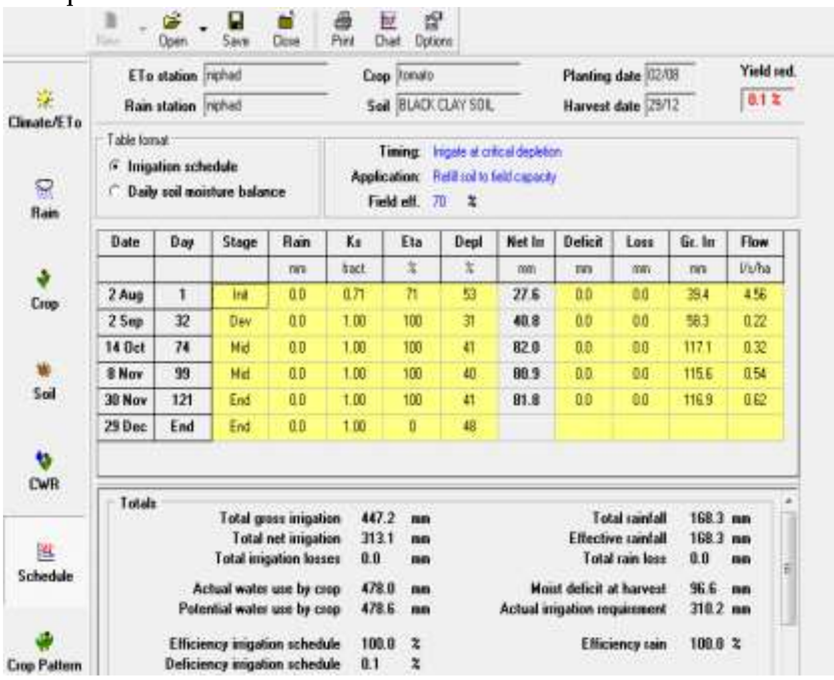

Fig. 5. Irrigation schedule for tomato at Niphad command area

Figure 6 represents the typical layout of drip irrigation system. It consists of various components such as lateral pipe, main pipe, sub main pipe, dripper, etc. Design of lateral, Design of Submain, Design of mainline, selection of pump and calculation of yield of furrow and drip irrigation are mentioned below

Table 2a. Meteorological characteristics of Niphad region obtained from the CROPWAT software 8.0

Month	Temp. (◦C) Max	Min	Rain (mm)	Eff. Rain	Humidity (%)	Wind (km/day)	Sun (hr.)	ET_0 (mm/day)	Rad. (MJ/m^2/day)
January	29.6	12.3	0.6	0.6	40	155	8.3	4.16	16.9
February	32.5	13.4	0.2	0.2	32	155	8.9	5.00	19.6
March	36.6	17.0	0.6	0.6	24	173	9.1	6.38	22.0
April	39.0	20.5	1.5	1.5	27	202	9.4	7.59	23.7
May	38.0	22.9	3.0	3.0	42	273	7.9	7.85	21.8
June	31.3	22.9	47.4	43.8	71	284	6.4	5.30	19.5
July	25.8	21.8	71.1	63.0	87	285	3.9	3.32	15.7
August	24.9	21.2	60.4	54.6	90	260	3.7	2.93	15.1
September	27.5	20.4	61.0	55.0	86	184	5.4	3.40	16.8

October	30.2	18.0	30.8	29.3	63	146	6.2	3.97	16.4
November	30.1	15.8	13.8	13.5	48	153	7.5	4.14	16.3
December	29.4	13.0	2.0	2.0	42	152	6.5	3.86	14.1
Total/Avg.	31.2	18.3	292.4	267.1	54	202	6.9	4.82	18.2

Table 3. Water requirement for Crop Tomato

Month	Decade	Stage	Kc (Coeff.)	ETc (mm/day)	ETc (mm/dec)	Eff. Rain (mm/dec)	Irr. Req. (mm/dec)
August	1	Init	0.60	1.84	16.5	17.0	0.0
August	2	Init	0.60	1.76	17.6	17.8	0.0
August	3	Init	0.60	1.85	20.4	18.0	2.4
September	1	Deve	0.67	2.18	21.8	19.1	2.7
September	2	Deve	0.80	2.73	27.3	19.5	7.8
September	3	Deve	0.93	3.35	33.5	16.3	17.2
October	1	Mid	0.99	3.75	37.5	12.3	25.2
October	2	Mid	0.99	3.94	39.4	9.3	30.1
October	3	Mid	0.99	4.00	44.0	7.7	36.3
November	1	Mid	0.99	4.06	40.6	6.2	34.4
November	2	Mid	0.99	4.11	41.1	4.3	36.8
November	3	Late	0.98	4.02	40.2	3.1	37.0
December	1	Late	0.95	3.77	37.7	1.6	36.1
December	2	Late	0.89	3.45	34.5	0.2	34.3
December	3	Late	0.84	3.32	29.9	0.2	29.6
					481.9	152.7	329.9

Table 4. Irrigation schedules for crops Tomato

Date	Day	Stage	Rain (mm)	Ks (Fract.)	ETo (%)	Depl (%)	Net Irrigation (mm)	Deficit (mm)	Loss (mm)
2nd Aug	1	Init	0.0	0.71	71	53	27.6	0.0	0.0
2nd Sept	32	Dev	0.0	1.00	100	31	40.8	0.0	0.0
14th Oct	74	Mid	0.0	1.00	100	41	82.0	0.0	0.0
8th Nov	99	Mid	0.0	1.00	100	40	80.9	0.0	0.0
30th Nov	121	End	0.0	1.00	0	41	81.8	0.0	0.0
29th Dec	End	End				48			

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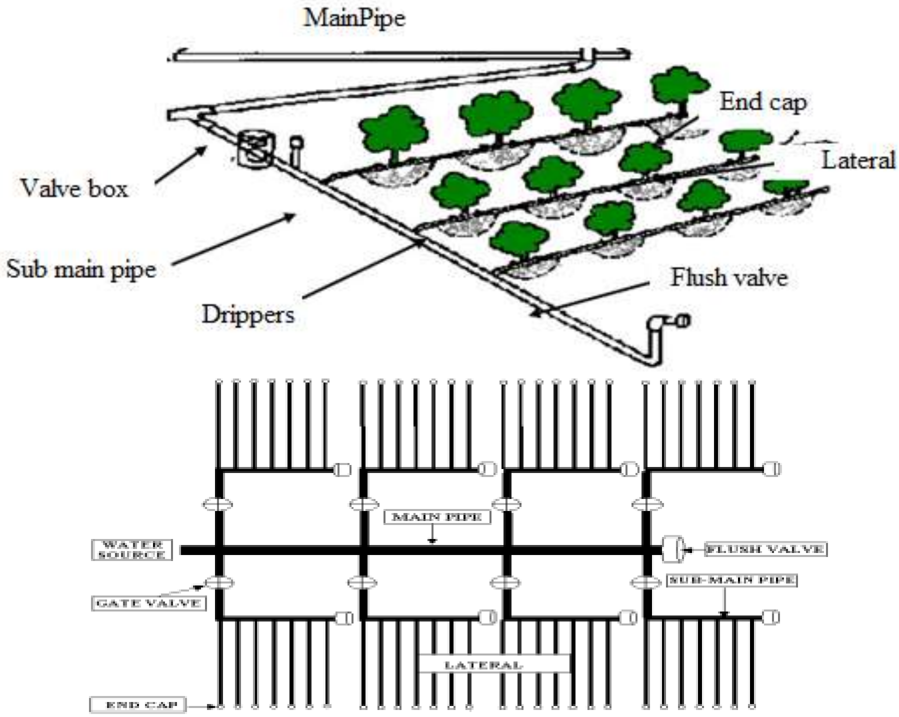

Fig 6. A typical layout of Drip Irrigation System

4.3. Design of Lateral

Total no of dripper = $\frac{\text{Total Area}}{\text{(Dripper spacing×lateral spacing}}$

$= \frac{10742}{(0.6\times1.2)} = 14919$

i. Length of lateral on one side of submain =41m
ii. No. of dripper on one lateral at a spacing of 0.6 m = 41/0.6 = 68.33
iii. Discharge rate of lateral = $68 \times 2 = 136\frac{l}{hr} = 0.037 l/sec$

Select 12mm diameter lateral. Using Hazen and William equation, head loss due to friction is,

$$\Delta Hl = K(Ql/C)1.852Dl - 4.871(L+Le)\ F$$

Were,

ΔHl = head loss in lateral K= constant, 1.21×10^{10}

Ql= flow rate in the lateral=0.037lit/sec

C = friction coefficient for continuous section of pipe and depends on the pipe material=140

Dl = inside diameter of lateral =9.8 mm

F = outlet factor = 0.36

For 83 Le = 0.36 × 83 = 29.88 m

$\Delta Hl = 1.21 \times 10^{10} (0.037/140)^{1.852}\ 9.8^{-4.871}(70.88)0.36$

$\Delta H1 = 1.12$

4.4. Design of Submain

Use two submains of 66m

a. Length of submain = 66m
b. No. of lateral on one side of submain =66/1.2=55
c. No of lateral on both side of submain=55×2=110
d. Discharge rate of one lateral = 136 l/hr. = 0.037lit/sec
e. Discharge rate of submain=110×136=14960 l/hr.= 4.15lit/sec

f. Outlet factor (for 84 outlet) for submain = 0.36

Select 63 mm diameter of submain, i.e., inside diameter of submain= 59 mm Using Hazen and William equation, head loss due to friction is, stated by equation below

$$\Delta Hl = K(Ql/C)1.852Dl - 4.871(L+Le)\ F$$

K= constant, 1.21 × 1010

Qsm = flow rate in the submain =4.15lit/sec

C = 150 for PVC material

F= outlet factor = 0.36

For 83 Le = 0.36 × 83=29.88m

$$\Delta Hl = 1.21 \times 1010\ (4.15/150)1.852 \times 59 - 4.871 \times (95088)\ 0.36$$

ΔHl=1.2851m

4.5. Design of mainline

1. Length of main line=213m
2. Discharge rate of mainline= discharge rate of one submain = 4.15lit/sec

Select 75mm diameter of main line Inside diameter of mainline =71mm Using Hazen and William equation, head loss due to friction is,

$$\Delta H\ m = K(Ql/C)1.852\ Dl - 4.871Lm$$

K= constant, 1.21×10^{10}

Qm=flow rate in the submain = 4.15lit/sec

C = 150 for PVC material

Dm= inside diameter of lateral =71mm

L_m = 213m

$$\Delta H\ m = 1.21 \times 1010\ (4.15/150)1.852\ 71 - 4.871 \times 213$$

ΔH_m = 3.22m

4.6. Selection of Pump

Total head = Suction head + Delivery head + Operating pressure of drip irrigation system + Main line head loss +Filter loss + Venture loss + Elevation difference in suction head + delivery head = 12m

Operating pressure of drip system = 10m (1 kg/cm^2)

Main line head loss =3.22 m

Filter loss = 2m

Fitting loss = 2m,

venturi loss = 5m

Total head $= 12 + 10 + 3.22 + 2 + 2 + 5 = 34.22$

Were,

Q= 4.15lit/sec,

H= 32.33m,

motor efficiency = 80%

pump efficiency = 75%

H.P = Q.H $/(75 n motor \times n\ pump)$

H.P = $(4.15 \times 34.22)/\ (75 \times 0.80 \times 0.75) = 3.15$

Add 10% unforeseen losses,

H.P = 3.15×1.1=3.465 H.P say 5 H.P

4.7. Furrow irrigation design consideration

Avg. depth of water applied, d=10cm

Duration of irrigation (t) =5hr

Furrow spacing (w) =1.2m

Furrow length (L) = 75m,

Depth of water applied $d = (q \times 360 \times t)/(w \times L)$

where, d = avg. depth of water applied in cm
q= stream size, lit/sec
t=duration of irrigation in hr.
w=furrow spacing in meter.
L= furrow length in meter.
10= (q×360×5)/ (1.2×75)
q= 0.5lit/sec

4.8. Calculation for Yield of Drip Irrigation

For drip irrigation 1 carat of tomato =20 kg 1700 carat for 1acre Therefore 34000 kg/acre. 1ha = 850 quintal = 93tone. For furrow irrigation 1 carat of tomato= 20 kg 900 carat for 1acre. Therefore 18000kg/acre. 1ha = 450 quintal= 50 ton

5. Conclusion

For the assessment of water requirements for the tomato crop contemporary technical tool is CROPWAT software. It is more precise, and effective to suggest cropping patterns and crop rotation. The farmer will become fond of CROPWAT software as it can predict and estimate the tomato water requirement, scheduling of irrigation, evapotranspiration, and meteorological data required for agricultural purposes. The crop water requirement for the Niphad region tomato crops is 481.9 mm/dec. The irrigation requirement for tomato crops is 329.9 mm/ Dec respectively. The tomato crop required a net water requirement of 313.1 mm. The yield achieved by drip irrigation is more, the reason behind this is that through drip irrigation water droplet directly reaches the root zone of the crop.

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