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A Study on the Optimum Water Use in Drip Irrigation System

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This study was undertaken to determine the optimum water use in drip irrigation system. Drip irrigation is the practice where water is applied at a rate almost equal to the consumptive use of the plant. In an average irrigation system, the losses of water take place in the form of deep percolation, conveyance and evaporation. The monthly average evapo-transpiration of bananas was found 3.969 mm/day at Kalyani, district Nadia. The average monthly evaporation obtained for Kalyani, Nadia was found 1.9775 mm/day. It was also observed that the lowest (0.99 mm/day) and highest (3.68 mm/day) values of evaporation occurred at Kalyani in December and May, respectively. For banana (Musa spp.) spacing 2m x 2m, actual water used by the plant for a crop season was found to be 4686.287 l/plant. It was found that dripper with discharge rate of 0.5 l/hr is most suitable for banana cultivation at Kalyani, Nadia. The final water saving upto 45.62 % is possible with the proper management of the system we adopted. In our present research, we have observed some dissimilarity in values of soil evaporation that occurred when pan evaporation exceeded 4.5

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mm/day. So it can further study for more efficient procedures to calculate the evaporation from the soil surface.

Keywords: Drip; evaporation; spacing; water saving; pan.

1. INTRODUCTION

Though irrigation is as old as civilization, it is considered as modern science – the science of survival. Many changes have taken place in all walks of life, but the age-old practice of flood irrigation is still practised in many parts of the country. Although some steps have been taken to improve water management in surface irrigation, the water use efficiency is not to the desired extent, which has resulted in water logging and salinity in some areas. In view of the urgent need to maximize the use of available resources, it is imperative to affect utmost economy in water use by adopting the advanced method of irrigation like drip, sprinkler and piped system. Drip irrigation is the practice where water is applied at a rate almost equal to the consumptive use of the plant. In an average irrigation system, the losses of water take place in the form of deep percolation, conveyance and evaporation [1,2]. Deep percolation and conveyance losses are entirely avoided and evaporation loss is greatly minimized in drip irrigation system. However, avoiding the deep percolation and reducing evaporation loss requires the knowledge of water spreading in soils at different rate and volume of application, crop root development at a different stage of growth and other fundamentals to evaporation process [3,4]. A large outlay was provided in the successive five-year plans to expand the irrigation potential [5-7]. As a result, presently irrigated land has increased to 90 M ha for the production of food and non- food crop from 22.4 mha at the time of independence. From the world view, about 70% of the world's water is used in agriculture to grow food and fibre. In developing and under-developed countries, it could go up to 90%, while in India, it is about 80%. About 30% average for the world's water is used in municipal water supplies, for households and for industries [8-10]. In India it would be about 7% for industries and about 13% for domestic and municipal supplies. So the time has come when efficient management of water resources is essential to meet the increasing competition for agricultural and non- agricultural sectors [11-13]. For proper scientific management of water resource in agriculture, modern irrigation technique like drip, sprinkler has already been adopted, all over the world as well as in India. But considering the future worst condition, we must try to have a further reduction in irrigation water without affecting plant growth [14,15]. In consideration to the available literature, it appears that perfection in choosing the proper drip system play very important role in proper water-saving management. Unlikely this information is limited or lacking in our country, with these in view the present research work has been purposed with the objective to determine the optimization of water requirement of the selected plant by selecting the proper dripper discharge

2. EXPERIMENTAL DETAILS

Study Area: The present study of estimating evapo-transpiration was carried out for the station Kalyani, district Nadia, West Bengal. The area comes under the tropical zone and is situated at Latitude 23.5^0 N, Longitude 89^0 E, at an altitude of 9.75 m above MSL. Long term data of all meteorological parameters of Kalyani station was used for the study, which was obtained from Meteorological Department of Bidhan Chandra Krishi Viswavidylaya, Mohanpur, Nadia and Kalyani Meteorological Observatory, Kalyani, Nadia, West Bengal.

Evapo-transpiration Calculation: Evapo-transpiration ET_c, which includes evaporation of water from land and water surfaces, and transpiration by vegetation continue to be of foremost importance in water resources planning and management. Thus, present study was undertaken with the main objective of estimating the evapo-transpiration by based on banana using the universally accepted Modified Penman Method tropical condition of Kalyani, Nadia, West Bengal, India. Evapotranspiration is estimated on weekly basis for Kalyani situated in Nadia district.

Reference crop Evapo-transpiration was calculated with the following

2.1 Modified Penman Method

$$ETo^* = W * Rn + (1- W) * f(u) * (e_a - e_b) \quad (1)$$

Where,

ETo* = reference crop evapo-transpiration, mm/day
W = temperature related weighting factor
Rn = the net radiation in equivalent evaporation in mm/day
f (u) = the wind related factor
(e_a - e_b) = the difference between the saturated vapour pressure at mean air temperature and mean actual pressure of the air, both in m-bar. The wind related function is directly related to wind velocity through the following relation: f (u) = 0.27 * (1 + u_2 / 100) Where,u_2 = wind speed at 2 metre height, km/hour.The unadjusted ETo* values were adjusted with the help of the Fig. 1.

To obtained the crop Evapo-transpiration (ETc), reference crop Evapo-transpiration has to be multiplied with crop coefficient (K_c). For our present study we have selected the crop banana (Musa *spp*.) and its crop coefficient in different month is given in the Table 1.

2.2 Evaporation Calculation from the Soil

Evaporation from the bare soil of the banana field was calculated with the help of the following equations—

$$E = a_1 * (Ø_W)^{b1} \quad \text{for } Ø_W <= Ø_P \qquad (2)$$
$$= a_2 * (Ø_W)^{b2} \quad \text{for } Ø_W >= Ø_P \qquad (3)$$

Where,

E = evaporation of soil (mm/day)
$Ø_W$ = moisture content in the soil
$Ø_P$ = point of inflection
a_1 ,a_2 , b_1, b_2 = Function of pan evaporation.
a_1 or a_2 = K_1* $(e)^{K2 * E_P}$
b_1 or b_2 = K_3*a + K_4 , a = a_1 or a_2

Where

K_1, K_2, K_3 and K_4 are empirical constants. Ep = Pan evaporation (mm/day) .

For our present station (Kalyani) different soil parameters are as follows :

Saturated soil moisture ($Ø_s$) = 31.92 % (w.b.)
Point of inflection ($Ø_p$) = 13.90 %.
Soil texture = Sandy loam.

Value of a_1, b_1 and a_2, b_2 for Kalyani sandy loam soil :

$Ø_W <= Ø_P$: $a_1 = 1.6704 \times 10^{-3} \times e^{1.64224 \times Ep}$
$b_1 = 2.053579 \times a_1 + 1.2663$

$Ø_W >= Ø_P$: $a_2 = 0.431661 \times e^{0.208982 \times Ep}$
$b_2 = 0.408732 \times a_2 – 0.034625$

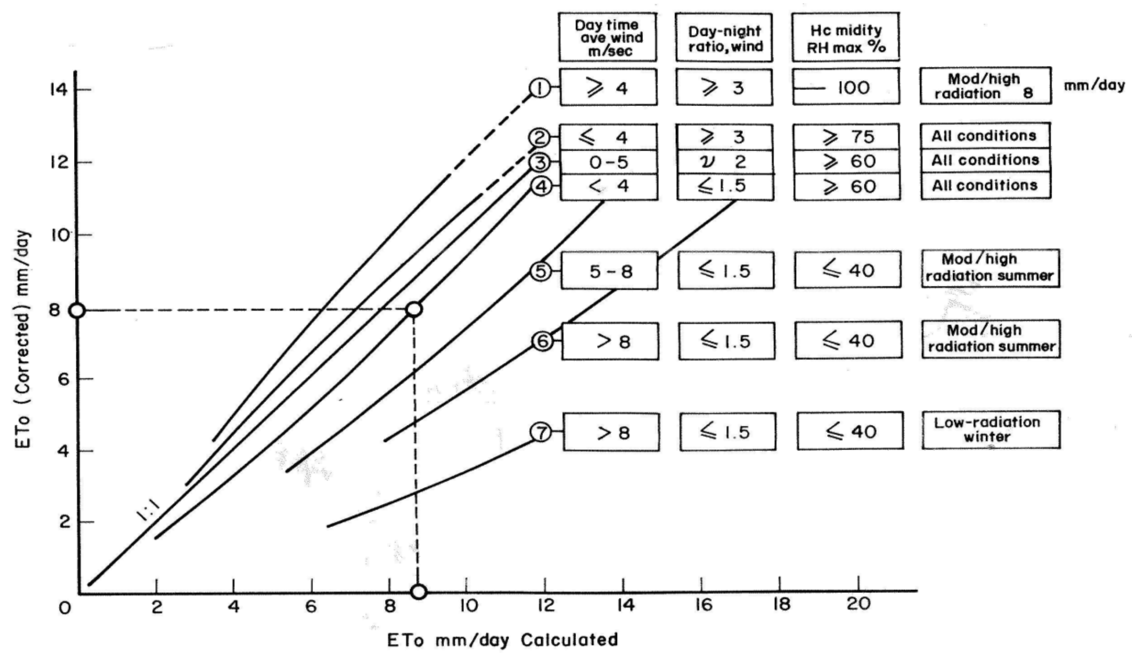

Fig. 1. Diagram for modified penman method

Table 1. Crop coefficient (Kc) for banana at different month for tropical climate

Month following planting	1	2	3	4	5	6	7	8	9	10	11	12	13	14
K_c	.4	.4	.45	.5	.6	.7	.85	1.0	1.1	1.1	.9	.8	.8	.95

2.3 Actual Water Requirement of the Plant

Major component of the water used by the plant is transpiration. The transpiration requirement of the plant is obtained by subtracting the evaporation loss (from the plant projected soil surface) from the evapo-transpiration requirement of the plant. Transpiration = (Evapo-transpiration) – (Evaporation).

Optimization of water use by the plant: The actual water required by the plant is the sum of water consumed by the plant for it's physiological requirement and the minimum water that must be evaporated from the root zone area. By using the equation of Schwartzman and Zur we can determine the water front distribution (Vertical and Horizontal) of the applied water to the plant .So the actual water requirement that can't be reduced further is the sum of the transpiration and evaporation loss from the wetted root zone area as per the above equation. With the selection of proper drip system (particularly drippers' discharge rate) the probable wetting of the root zone area may be tried to keep minimum .Thus it is proposed to ensure the transpiration requirement of plant and the requirement for evaporation to minimum level.

3. RESULT AND DISCUSSION

3.1 Estimation of Weekly Reference crop Evpo-transpiration

The estimated weekly ETo values obtained from Modified Penman Method for Kalyani, district Nadia, West Bengal are given in Fig. 2. There is variability of ET_o values obtained from Modified Penman Method for different weeks over Kalyani.

3.2 Estimation of Monthly Reference Evapo-transpiration

The average monthly reference evapo-transpiration obtained from Modified Penman Method for Kalyani is 5.91 mm/ day. It was also observed that the lowest (3.15 mm/day) and height (9.31 mm/day) values of reference evapo-transpiration occurred at Kalyani in December and May, respectively. Table 2 gives the estimated monthly ET_o values obtained from Modified Penman Method for Kalyani.

3.3 Crop Evapo-transpiration

Banana (*Musa spp.)* is propagated in March in tropical conditions. With the crop coefficient (Kc) value of banana from Table 2, we calculated the crop evapo-transpiration for a banana at Kalyani. The Crop Evapo-transpiration of the different month is shown at Fig. 3. It is quite clears from the figure that water requirement for Banana at Kalyani increase with age net water requirement is quite higher at the harvesting stages.

3.4 Evaporation Calculation from Soil Surface

The estimated weekly average water evaporated (E in mm/day) calculated from the equation 3.3 is given at Fig. 4 for Kalyani, Nadia. It was seen that the value of evaporation is in the week of 17, 18, 20, 21 and 22 were not consistent. So we have manipulated these data to have a consistency with other data. There is variability of E values obtain from equation 3.3 for different weeks for Kalyani, Nadia. It was observed that the lowest (0.938 mm/day) weekly value obtained from equation 3.3 occurred in the meteorology week of 47, 50 and 51. It was also observed that the pan evaporation (E_p) for the weeks of 47, 50 and 51 were minimum (0.9 mm/day) among the all 52 weeks. Hence, the result was accordance with the meteorological parameter, which was quite favourable for the record of lowest E in the week of 47, 50 and 51. Similarly, the highest (4.59 mm/day) weekly value of E occurred in the meteorological week of 22. The observed value of E_p in the week of 22 was 5.8 mm/day. This was highest among the values of 52 weeks. Thus the result was in total agreement with the variation of the meteorological parameters, which was quite favourable for the occurrence of the highest evaporation in the week number 22 over Kalyani, Nadia.

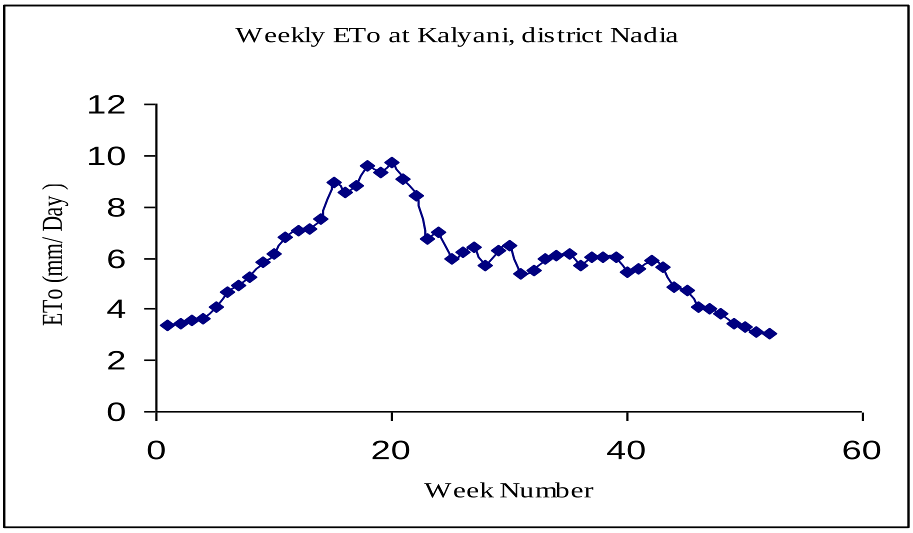

Fig. 2. Weekly reference crop evapo-transpiration values (mm/ day)

Table 2. Monthly ET_o values

Month	ET_o (mm/day)
March	6.65
April	8.45
May	9.31
June	6.71
July	6.17
Aug	5.83
Sept	5.96
Oct	5.56
Nov	4.27
Dec	3.15
Jan	3.55
Feb	5.33

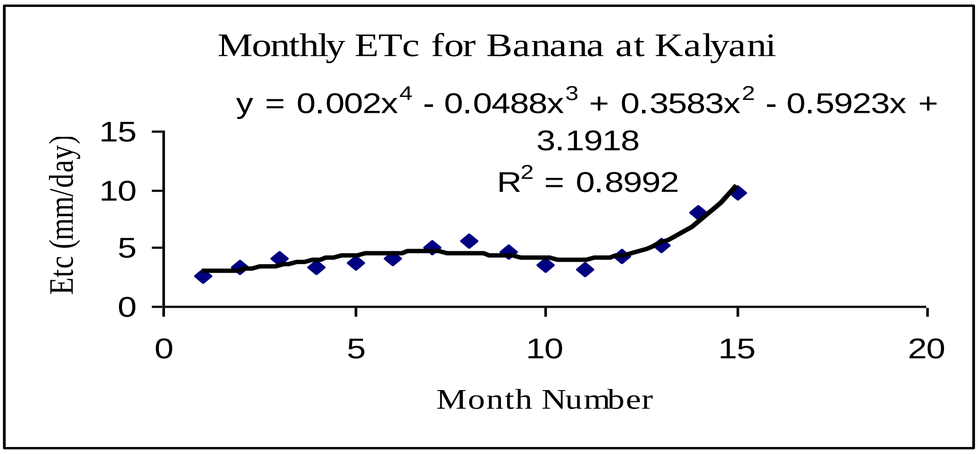

Fig. 3. Monthly ETc for banana at Kalyani

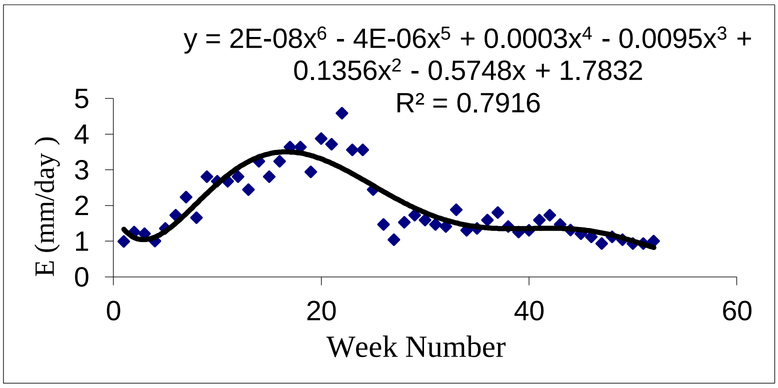

Fig. 4. Weekly evaporation from soil at Kalyani, Nadia

Table 3. Monthly evaporation (mm/day) for Kalyani station, District Nadia

Month	Evaporation (mm/day)
March	2.62
April	3.22
May	3.68
June	2.99
July	1.48
Aug	1.5
Sept	1.51
Oct	1.51
Nov	1.13
Dec	0.99
Jan	1.14
Feb	1.9

Table 4. Monthly actual water consumed by a plant

Month	ETc (mm/d)	Soil Evaporation (mm/d)	Actual water used (mm/d/p)	Actual water used (l/day/plant)
March	2.68	2.62	0.06	0.24
April	3.38	3.22	0.16	0.64
May	4.19	3.68	0.51	2.04
June	3.36	2.99	0.37	1.48
July	3.7	1.48	2.22	8.88
Aug	4.08	1.5	2.58	10.32
Sept	5.07	1.51	3.56	14.24
Oct	5.56	1.51	4.05	16.20
Nov	4.7	1.13	3.57	14.28
Dec	3.47	0.99	2.48	9.92
Jan	3.2	1.14	2.06	8.24
Feb	4.26	1.9	2.36	9.44
March	5.32	2.68	2.64	10.56
April	8.03	3.22	4.81	19.24
May	9.78	3.68	6.1	24.4

3.5 Estimation of Monthly Evaporation

It was observed the lowest (0.99 mm/day) and highest (3.68 mm/day) values of evaporation occurred at Kalyani in December and May, respectively. The average monthly evaporation obtained from Table 3 for Kalyani is 1.9775 mm/day. Table 3 gives the estimated monthly E values obtained from the Eq. 3.

3.6 Estimation of Actual Water Consumed by the Plant

Loss of water from the wetted soil surface through evaporation is the portion of irrigated water that is not consumed by the plant. Actual water consumed by the plant is obtained after subtraction of evaporation loss from the evapo-transpiration for the selected crop. For banana (Musa spp.) spacing was 2m x 2m, the value of actual water used by plant is given in Table 4.

The minimum evaporation loss will be occurred from the wetted root zone area is given in the Table 5. Finally, the total water that must be produced to the plant is given in the Table 6.

Table 5. Evaporation from the minimum wetted root zone area

Months	Wetted diameter (m)	Wetted Area (sq. m)	Soil Evaporation (mm/day)	Volume of water (l/day)
March	0.18	0.025	2.68	0.067
April	0.23	0.042	3.22	0.135
May	0.28	0.062	3.68	0.228
June	0.26	0.053	2.99	0.158
July	0.4	0.126	1.48	0.186
Aug	0.41	0.132	1.5	0.198
Sept	0.44	0.152	1.51	0.23
Oct	0.45	0.159	1.51	0.24
Nov	0.44	0.152	1.13	0.172
Dec	0.4	0.126	0.99	0.125
Jan	0.39	0.12	1.14	0.137
Feb	0.4	0.126	1.9	0.239
March	0.41	0.132	2.68	0.354
April	0.46	0.166	3.22	0.535
May	0.49	0.188	3.68	0.692

Table 6. Total water required to the plant

Months	Soil Water Evaporated (l/day)	Actual Plant water required (l/day)	Total water Required (l/day)	Total water per plant for whole planting season (litre)
March	0.067	0.24	0.307	9.517
April	0.135	0.64	0.775	23.25
May	0.228	2.04	2.268	70.308
June	0.158	1.48	1.638	49.14
July	0.186	8.88	9.006	279.186
Aug	0.198	10.32	10.518	326.056
Sept	0.23	14.24	14.47	434.1
Oct	0.24	16.2	16.44	509.64
Nov	0.172	14.28	14.452	433.56
Dec	0.125	9.92	10.045	311.395
Jan	0.137	8.24	8.377	259.687
Feb	0.239	9.44	9.679	271.012
March	0.354	10.56	10.914	338.334
April	0.535	19.24	19.775	593.25
May	0.692	24.4	25.092	777.852
	Total water			4686.287

Table 7. Total water require with full area wetting of the root zone under drip system

Months	ETc (mm/day)	Water required (l/day/plant)	Total water required in whole planting season (l/plant)
March	2.66	10.64	329.84
April	3.38	13.52	405.6
May	4.19	16.76	519.56
June	3.36	13.44	403.2
July	3.7	14.8	458.8
Aug	4.08	16.32	505.92
Sept	5.07	20.04	601.2
Oct	5.56	22.24	689.44
Nov	4.7	18.8	564
Dec	3.47	13.88	430.28
Jan	3.2	12.8	396.8
Feb	4.26	17.04	477.12
March	5.32	21.28	659.68
April	8.03	32.12	963.6
May	9.78	39.12	1212.72
Total water			8617.76

Final Water Save = 45.62 %

If water front distribution was not considered then total water that could be required is given in the Table 7.

The above finding similar to the findings of Bashour and Nimah [16] where they reported that the trickle irrigation saved about 50% of the water used in surface irrigation.Similar observation was also find out by Sharma and Kispotta [17] & Pramanik and Biswas [18].

4. CONCLUSIONS

I. This study was undertaken to determine the optimum water use in drip irrigation system. The outcome of this study can be summarized as below:
II. Determination of the evapo-transpiration of the banana (Musa spp.): The monthly average evapo-transpiration of banana was found 3.969 mm/day at Kalyani, district Nadia.
III. Determination of the evaporation loss from the projected soil surface of the plant: The average monthly evaporation obtained for Kalyani, Nadia was found to be 1.9775 mm/day. It was also observed that the lowest (0.99 mm/day) and highest (3.68 mm/day) values of evaporation occurred at Kalyani in December and May, respectively.
IV. Determination of the actual water requirement of the plant: For banana (Musa sp.) spacing 2m x 2m, actual water used by plant for a crop season was found to be 4686.287 l/plant.
V. Optimization of the water requirement of the plant by proper selection of suitable drippers: It was found that dripper with discharge rate of 0.5 l/hr is most suitable for banana cultivation at Kalyani, Nadia. The final water saving upto 45.62 % is possible with the proper management of the system we adopted.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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