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Estimation of Crop Water Requirement and Yield Observation of Safflower Cultivated under Drip and Flood Irrigation

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A B S T R A C T

Crop water requirement is the water required by the crop in a given period of time to meet its normal growth. PENMEN MONTEITH formula was chosen to calculate crop ET_o for safflower crop from which crop water requirement is obtained. The period of 30 years meteorological data (i.e. from 1983 -2017) was collected from WALAMTARI (Water and Land Management Training and Research Institute) meteorological station and computerized. Solar radiation, crop duration, crop coefficient (k_c) values for safflower crop and also sunshine hours was taken from a standard values available from FAO-56 tables, CRIDA, Hyderabad and standard textbooks. Then irrigation scheduling is done for safflower crop. GPS was used to calculate the field area of safflower and it was 0.24 ha. The total cropped area of safflower was divided into 6 plots, out of which 3 were irrigated by drip and 3 were by flood irrigation and each plot size was 1×1 m². The growth parameters like plant height, number of branches were noted to know the difference in growth between drip and flood irrigation. The study was concluded that the crop water requirement for safflower crop when estimated by Penman Monteith method was 365mm (Standard value is 250 to 300mm) for its entire crop period of 120-140 days in Rabi season. It was concluded that the yield of safflower under drip irrigation was 12.56 quintal and whereas in flood irrigation was 8.18 quintal. Thus 35% of yield was more in drip irrigation than flood irrigation.

Introduction

Crop water requirement is the water required by the crop in a given period of time to meet its normal growth. The major climatic factors which influence the crop water needs are sunshine, temperature, humidity and wind speed. Water requirement depends on four crop growth stages i.e. initial, development, mid and late season. PENMEN MONTEITH formula was chosen to calculate crop ET_o. Irrigation scheduling is the process of determining the time to irrigate and how much water is applied in each irrigations. Safflower is a source of oil and eatable purpose. This oil is also used as cooking oil.

Drip irrigation is a type of micro-irrigation system that is to place water directly into the root zone and minimize evaporation. Flood irrigation is water is delivered to the field by ditch, pipe and simply flows over the ground through the crop.

Krishna Rao Battu (2005) reported a paper on Decision support system for canal water releases (CWREDSS) was developed to provide demand-based optimal canal water releases for reducing the gap between canal supplies and demands for increasing the water-use efficiency in canal command areas. CWREDSS is capable of developing releases under different scenarios of varying cropping patterns, groundwater use situations and different rainfall probability levels of the study area, and reduced the gap between demands and supplies considerably.

Doorenbos and Pruitt (1997) reported a paper on obtaining accuracy of estimating evapotranspiration (ET) using the FAO-56 Penman-Monteith (FAO-56-PM) model, with measured and estimated net radiation (R_n measured and R_n estimated, respectively). They used meteorological data collected, on a daily basis and on a seasonal basis (wet vs. dry seasons). They collected following data: temperature; relative humidity; global solar radiation (R_s); wind speed and soil heat flux.

Richard G. Allen *et al.,* (1998) reported a paper on updated procedure for calculating reference and crop evapotranspiration from meteorological data and crop coefficients. The procedure, first presented in the FAO Irrigation and Drainage Paper No. 24 'Crop Water Requirements', is termed the 'k_c ET_o' approach, whereby the effect of the climate on crop water requirements is given by the reference evapotranspiration ET_o and the effect of the crop by the crop coefficient k_c. Other procedures developed in FAO Irrigation and Drainage Paper No. 24 such as the estimation of dependable and effective rainfall, the calculation of irrigation requirements and the design of irrigation schedules. The panel of experts recommended the adoption of the Penman-Monteith combination method as a new standard for reference evapotranspiration and advised on procedures for calculating the various parameters. The FAO Penman-Monteith method uses standard climatic data that can be easily measured or derived from commonly measured data.

Michael (1978) introduced a book involves Water Resources Development and Irrigation Management. Topics added were Requirement of Crops and Irrigation Management', and 'Economic Evaluation of Irrigation Projects and Water Pricing Policy'. The chapter on Water Conveyance and Control has been expanded and split into two: 'Open Channel Distribution in Command Areas', and 'Underground Pipeline System'. Similarly, the chapter on Water Application Methods has been split into three, namely, 'Surface Methods of Water Application', 'Sprinkler Irrigation' and 'Drip Irrigation' for a focused study of these techniques.

Materials and Methods

Crop water requirement

Water required by the crop in a given period of time to meet its normal growth is called Crop water requirement. It depends upon the cropping pattern (i.e., area under different crops), Evapotranspiration of each crop, special water needs of individual crop or soil and the effective rainfall occurring during that period. The major climatic factors which influence the crop water needs are: sunshine, temperature, humidity and wind speed. Water requirement also depends on crop growing stages.

Initial stage: From sowing to about 10% ground cover
Development stage: From 10% to 70% ground cover
Mid-season stage: Including flowering and grain setting and yield formation stage
Late season stage: Including ripening and harvest

The particular crop growing stages for safflower crop were shown in Figure 1 the vertical axis was represented kc (Crop coefficient) values ranging from 0 to 1.4.

Methods of estimation of crop water requirement

Water required by crop is mainly due to evaporation loss and water required by plants for their metabolic activity. There are several methods to estimate crop water requirement but they all related to mainly estimation of Evapotranspiration (ET_o). The methods are mainly divided as:

Direct method

The principal methods for direct measurement of Evapotranspiration are:

Lysimeter experiment
Field experimental plots
Soil moisture depletion studies
Water balance method

Indirect methods

Owing to the difficulty in obtaining accurate direct measurement of pan evaporation under field conditions, evaporation is often predicted on the basis of climatologically data. The approaches followed are to relate the magnitude and variation of Evapotranspiration to one or more climatic factors (temperature, day length, humidity, wind, sunshine etc.). The more commonly used empirical formulae in estimating Evapotranspiration are:

Blaney-Criddle method
Thornthwaite method
Hargreaves method
Penman monteith equation

FAO Penman Monteith method

We have chosen Penman Monteith formula for calculating evapotranspiration.

$$ET_o = \frac{0.408\Delta\left(R_n - G\right) + \gamma \frac{900}{T+273} u_2 \left(e_s - e_a\right)}{\Delta + \gamma\left(1 + 0.34u_2\right)}$$

ET_o = reference evapotranspiration (mm/day)
R_n= net radiation at the crop surface (MJ/m²/day)
G= soil heat flux density (MJ/m²/day)
T= mean daily air temperature at 2 m height (^oc)
U_2= wind speed at 2m height (m/s)
e_s= saturation vapor pressure(kPa)
e_a= actual vapor pressure(kPa)
Δ= slope of vapor pressure curve (kPa/°c)
γ = psychometric constant (kPa/°c)
e°=saturation vapor pressure at the air temperature(kPa)

$$\Delta = \frac{4098\left[0.6108exp\left(\frac{17.27 * T_{mean}}{T_{mean} + 237.3}\right)\right]}{(T_{mean} + 237.3)^2}$$

$G = 0.14(T_{monthn} - T_{monthn-1})$
γ=0.665×10^-3×P
P= atmospheric pressure (kPa)
P = 101.3 $(\frac{293 - 0.0065z}{293})$^5.26

$$e_a = \frac{e^o(Tmin)\frac{RHmax}{100} + e^o(Tmax)\frac{RHmin}{100}}{2}$$

$$e_s = \frac{e^o(Tmax) + e^o(Tmin)}{2}$$

$e^o = 0.6108\exp\left(\frac{17.27T}{T+237.3}\right)$

$R_n = R_{ns} - R_{nl}$

$R_{nl} = \sigma\left[\frac{Tmax,K4 + Tmin,K4}{2}\right](0.34 - 0.14\sqrt{ea})\left(1.35\frac{Rs}{Rso} - 0.35\right)$

$R_{ns} = (1-\alpha)R_s$

$R_{so} = (0.75+2*10\text{^}-5*z)R_a$

$R_s = \left[(as + bs)\frac{n}{N}\right]Ra$

R_{nl} =Net outgoing long wave radiation (MJ/m²/day)

R_{ns} =Net solar or shortwave radiation (MJ/m²/day)

R_{so} =clear-sky solar radiation (MJ/m²/day)

R_s =solar or shortwave radiation (MJ/m²/day)

Crop Water Requirement for safflower crop

The period of 30 years meteorological data (i.e. from 1983 -2017) was collected from WALAMTARI (Water and Land Management Training and Research Institute) meteorological station and computerized. The data comprised of temperature, relative humidity, sunshine hours, wind velocity, evaporation and amount of rainfall. The entire meteorological data was used for calculating evapotranspiration (ET_o) in the region. Every day average of all the climatic parameters was calculated for the entire data available for study. Solar radiation, crop duration, crop coefficient (k_c)values for safflower crop, and also sunshine hours was taken from a standard values available from FAO-56 tables, CRIDA, Hyderabad and standard textbooks.

From the standard k_c values, graph is drawn from which crop coefficient of every day is known. Penman monteith formula was placed in excel sheet to calculate ET_o, with the help of meteorological data available. According to the crop duration, every day average of different climatic parameters from the date of sowing is substituted in the excel sheet to get ET_o as shown in Figure 2. By using this excel sheet evapotranspiration was estimated. GPS was used to calculate the field area of safflower and it was 0.24ha. The total cropped area of safflower (Plate 1) was divided into 6 plots, out of which 3 were irrigated by drip and 3 were by flood irrigation and each plot size was 1×1 m². The three plots (plot A, B and C) were at starting, middle and end of the field.

The growth parameters like plant height, number of branches were noted to know the difference in growth between drip and flood irrigation. Penman monteith formula was placed in excel sheet to calculate ET_o, with the help of meteorological data. The computerized meteorological data was shown in (Table 1). The Average of 30 years meteorological data was shown in (Table 2). The Standard meteorological weeks of crop years were shown in (Table 3). Average monthly effective rainfall as related to mean monthly consumptive use was shown in (Table 4). The irrigation schedule for safflower crop was shown in (Table 5).

Results and Discussion

Branches and heights

The average number of plants in every plot of safflower under drip irrigation and flood irrigation were grown same as 8 and the maximum number of branches were developed for safflower under drip irrigation in plot- A was 18, plot-B was 17 and plot -C was 18as shown in (Table 6) whereas in flood irrigation the branches developed for every plant in plot- A was 15, plot-B was 16 and plot -C was 15 as shown in (Table 7). The maximum height of plants in every plot of safflower under drip irrigation and flood irrigation in plot- A was 81cm, plot-B was

81cm and plot -C was 81cm as shown in (Table 8) whereas in flood irrigation the maximum height was s developed for every plant in plot- A was 70cm, plot-B was 70cm and plot -C was 69 cm as shown in Table 9.

Table.1 Computerized meteorological data

Date	Max T(°C)	Min T(°C)	RH1 (%)	RH2 (%)	Sun shine (hr)	R (mm)	WV (km/h)	E (mm/day)
12/1/1983	27.3	11.6	93	35	8.6	0	3.1	3.3
12/2/1983	26.3	11.5	89	41	10.3	0	2.9	3.3
12/3/1983	27.3	16.5	88	56	9.2	0	3.1	3.1
12/4/1983	26.9	14.1	92	57	9.4	0	4.7	3.6
12/5/1983	26.5	11.4	93	36	6.4	0	4.2	3.1
12/6/1983	26	10.6	93	42	9.1	0	4.2	3.2
12/7/1983	25.7	9.9	93	36	9.2	0	3.9	3.4
12/8/1983	25.1	9.7	90	31	10.2	0	3.9	3.9
12/9/1983	25.1	10.9	91	47	10	0	3.7	3
12/10/1983	26.7	14.5	94	55	8.6	0	3.5	2.7
12/11/1983	27	15.1	90	56	8.6	0	3.9	2.7
12/12/1983	27	15	89	51	9.1	0	4	3.1
12/13/1983	27.5	13.9	92	50	9.2	0	3.9	3.2
12/14/1983	27.1	13.4	94	50	9.6	0	3.7	3.4
12/15/1983	27.3	13.7	90	45	8.8	0	3.1	2.6
12/16/1983	27.9	13.9	98	48	7.3	0	2.7	3
12/17/1983	27.9	13.7	98	35	9.4	0	3.5	3.4
12/18/1983	28.7	15.1	98	59	10	0	3.9	3.6
12/19/1983	26.9	14.1	98	51	10.1	0	3.7	3
12/20/1983	27.1	13.5	96	50	8.4	0	3.7	2.7
12/21/1983	27.1	13.4	96	43	7.9	0	2.6	3.4
12/22/1983	25.6	13.1	96	42	4.1	0	4.2	2.2
12/23/1983	26.7	16.1	82	26	9.1	0	3.7	3.3
12/24/1983	26.6	18.7	82	48	3.2	0	9	3.6
12/25/1983	27	19.5	94	66	1.5	0.1	6.9	3.2
12/26/1983	25.1	16	98	86	0	1.2	3.2	1.6
12/27/1983	22.1	8.5	97	60	0	3.6	4	0.5
12/28/1983	24.4	9.6	77	42	5.7	0	2.1	2.8
12/29/1983	27.5	13.6	96	42	10.4	0	4.3	3
12/30/1983	28.5	16.1	96	36	10.2	0	6	3.2
12/31/1983	30.1	16.1	94	58	6.8	0	6	3.5
Total	801.5	419.8	2867	1480	239		123.3	93.6
Mean	25.8	13.5	92.2	47.7	7.7		4	3

Table.2 Average of meteorological data of a day from 30 year data

Date	Max T(°C)	Min T(°C)	RH1 (%)	RH2 (%)	Sunshine (h)	E (mm/day)	WV (km/h)	R (mm)
1/2/1984	29.5	16.1	98	32	9.3	4.8	6.1	0
1/2/1985	31.1	14.6	98	20	10.6	5.3	5	0
1/2/1986	30.6	16.2	98	20	9.3	-	-	0
1/2/1987	30.6	12	84	98	10	6.4	-	0
1/2/1988	31.6	14.4	84	36	10.1	5.7	-	0
1/2/1989	31	11.2	57	28	9.6	4	-	0
1/2/1990	32.1	13.5	55	45	11.4	5.9	-	0
1/2/1991	30.5	14.8	56	33	10.2	6.9	-	0
1/2/1992	29.3	13.8	60	31	9.9	3.9	-	0
1/2/1993	30.1	19.1	83	37	9.2	5.4	-	0
1/2/1994	30.6	12.3	75	39	9.7	6.3	-	0
1/2/1995	27.3	14.3	66	45	7.9	3	4.7	0
1/2/1996	31.7	20.4	67	36	10	4.7	1.5	0
1/2/1997	31	13.1	67	34	9.6	5.8	0.07	0
1/2/1998	30.8	16.3	81	38	9.9	4	1.8	0
1/2/1999	31.6	15.2	73	28	10.6	5.5	4.1	0
1/2/2000	31.6	11.8	76	28	9.7	4	10	0
1/2/2001	31.4	8.8	57	28	10	5.1	2.5	0
1/2/2002	32.9	17	94	43	7.9	3.8	4.5	0
1/2/2003	34.6	12.3	67	27	10	3.8	2.3	0
1/2/2004	29.1	19.3	80	35	8	4.1	3.6	0
1/2/2005	30.3	11.8	70	63	8.6	3.4	4.7	13.8
1/2/2006	29.4	11.8	90	45	9.4	4.5	4.4	0
1/2/2007	32.9	12.8	74	30	9.6	6	3.1	0
1/2/2008	31.1	14	92	45	9.3	4	3.4	0
Avg	30.91	14.28	76.08	37.76	9.59	4.85	3.86	0.55

Table.3 Standard meteorological weeks

Week No.	Dates	Week No.	Dates
1	01 Jan – 07 Jan	27	02 Jul – 08 Jul
2	08 Jan – 14 Jan	28	09 Jul – 15 Jul
3	15 Jan – 21 Jan	29	16 Jul – 22 Jul
4	22 Jan – 28 Jan	30	23 Jul – 29 Jul
5	29 Jan – 04 Feb	31	30 Jul – 05 Aug
6	05 Feb – 11 Feb	32	06 Aug – 12 Aug
7	12 Feb – 18 Feb	33	13 Aug – 19 Aug
8	19 Feb – 25 Feb	34	20 Aug – 26 Aug
9*	26 Feb – 04 Mar	35	27 Aug – 02 Sep
10	05 Mar – 11 Mar	36	03 Sep – 09 Sep
11	12 Mar – 18 Mar	37	10 Sep – 16 Sep
12	19 Mar – 25 Mar	38	17 Sep – 23 Sep
13	26 Mar – 01 Apr	39	24 Sep – 30 Sep
14	02 Apr – 08 Apr	40	01 Oct – 07 Oct
15	09 Apr – 15 Apr	41	08 Oct – 14 Oct
16	16 Apr – 22 Apr	42	15 Oct – 21 Oct
17	23 Apr – 29 Apr	43	22 Oct – 28 Oct
18	30 Apr – 06 May	44	29 Oct – 04 Nov
19	07 May – 13 May	45	05 Nov – 11 Nov
20	14 May – 20 May	46	12 Nov – 18 Nov
21	21 May – 27 May	47	19 Nov – 25 Nov
22	28 May – 03 June	48	26 Nov – 02 Dec
23	04 June – 10 June	49	03 Dec – 09 Dec
24	11 June – 17 June	50	10 Dec – 16 Dec
25	18 June – 24 June	51	17 Dec – 23 Dec
26	25 June – 01 June	52**	24 Dec – 31 Dec

(Source: CRIDA, Hyderabad, website); *Week No.9 will be 8 days during leap year; * Week No.52 will always have 8 days

Standard Weeks	Week	Rainfall(mm)	ET_o (mm)	Kc	ETc mm)	WR (mm)
20 Oct-21 Oct	42	6.44	5.63	0.35	1.97	1.97
22 Oct-28 Oct	43	26.32	20.58	0.35	7.20	7.20
29 to 31 Oct,1 to 4 Nov	44	26.24	19.91	0.35	6.97	6.97
5 to 11 Nov	45	9.98	19.78	0.36	7.05	7.05
12 to 18 Nov	46	26.38	18.84	0.50	9.35	9.35
19 to 25 Nov	47	10.47	65.72	0.69	42.43	42.43
26 to 30 Nov,1&2 Dec	48	3.86	19.43	0.88	17.00	17.00
3 to 9 Dec	49	6.37	16.59	1.06	17.65	17.65
10 to 16 Dec	50	2.92	17.41	1.15	20.02	20.02
17 to 23 Dec	51	1.91	16.36	1.15	18.82	18.82
24 to 31 Dec	52	1.85	19.22	1.15	22.10	22.10
1 to 7 Jan	1	0.00	22.68	1.15	26.09	26.09
8 to 14 Jan	2	0.00	23.10	1.15	26.56	26.56
15 to 21 Jan	3	9.14	21.35	1.15	24.56	24.56
22 to 28 Jan	4	0.00	24.04	1.14	27.34	27.34
29 to 31 Jan,1 to 4 Feb	5	1.09	28.78	1.05	30.21	30.21
5 to 11 Feb	6	0.00	30.64	0.96	29.30	29.30
12 to 18 Feb	7	1.10	30.90	0.86	26.65	26.65
19 Feb to 25 Feb	8	0.00	8.23	0.53	4.41	4.41

Table.4 Average monthly effective rainfall as related to mean monthly consumptive use

Monthly mean rainfall mm	Mean monthly consumptive use mm													
	25	50	75	100	125	150	175	200	225	250	275	300	325	350
	Mean monthly effective rainfall mm													
12.5	7.5	8.0	8.7	9.0	9.2	10.0	10.5	11.2	11.7	12.5	12.5	12.5	12.5	12.5
25.0	15.0	16.2	17.5	18.0	18.5	19.7	20.5	22.0	24.5	25.0	25.0	25.0	25.0	25.0
37.5	22.5	24.0	26.2	27.5	28.2	29.2	30.5	33.0	35.2	37.5	37.5	37.5	37.5	37.5
50.0	25	32.2	34.5	35.7	36.7	39.0	40.5	43.7	47.0	50.0	50.0	50.0	50.0	50.0
62.5	at 41.7	39.7	42.5	44.5	46.0	48.5	50.5	53.7	57.5	62.5	62.5	62.5	62.5	62.5
75.0		46.2	49.7	52.7	55.0	57.5	60.2	63.7	67.5	73.7	75.0	75.0	75.0	75.0
87.5		50.0	56.7	60.2	63.7	66.0	69.7	73.7	77.7	84.5	87.5	87.5	87.5	87.5
100.0		at 80.7	63.7	67.7	72.0	74.2	78.7	83.0	87.7	95.0	100	100	100	100
112.5			70.5	75.0	80.2	82.5	87.2	92.7	98.0	105	111	112	112	112
125.0			75.0	81.5	87.7	90.5	95.7	102	108	115	121	125	125	125
137.5			at 122	88.7	95.2	98.7	104	111	118	126	132	137	137	137
150.0				95.2	102	106	112	120	127	136	143	150	150	150
162.5				100	109	113	120	128	135	145	153	160	162	162
175.0				at 160	115	120	127	135	143	154	164	170	175	175
187.5					121	126	134	142	151	161	170	179	185	187
200.0					125	133	140	148	158	168	178	188	196	200
225					at 197	144	151	160	171	182				
250						150	161	170	183	194				
275						at 240	171	181	194	205				
300							175	190	203	215				
325							at 287	198	213	224				
350								200	220	232				
375								at 331	225	240				
400									at 337	247				
425										250				
										at 412				
450	25	50	75	100	125	150	175	200	225	250				

(Source: Decision support system for canal water utilization by WALAMTARI)

Table.5 Irrigation schedule for safflower

SW	W	R (mm)	ET_o (mm)	Kc	ET_c (mm)	WR (mm)	ER (mm)	NIR (mm)	GIR (mm)	GIR (m^3)	Min/ week	Min/ day	DOI	Remarks
20 oct-21 oct	42	6.4	5.6	0.4	2.0	2.0	2.4	-0.4	-0.5	-5.1	0.0	0.0	0	No Irrigation
22 oct-28 oct	43	26.3	20.6	0.4	7.2	7.2	1.1	6.1	7.6	76.0	0.0	0.0	0	No Irrigation
29 to 31 oct,1 to 4 nov	44	26.2	19.9	0.4	7.0	7.0	3.7	3.2	4.0	40.3	0.0	0.0	0	No Irrigation
5 to 11 nov	45	10.0	19.8	0.4	7.0	7.0	1.4	5.6	7.0	70.3	0.0	0.0	0	No Irrigation
12 to 18 nov	46	26.4	18.8	0.5	9.4	9.4	3.8	5.6	7.0	69.8	0.0	0.0	0	No Irrigation
19 to 25 nov	47	10.5	65.7	0.7	42.4	42.4	1.5	40.9	51.2	511.6	0.0	0.0	0	No Irrigation
26 to 30 nov,1&2 dec	48	3.9	19.4	0.9	17.0	17.0	0.6	16.4	20.6	205.6	14.3	14.3	1	once in a week
3 to 9 dec	49	6.4	16.6	1.1	17.6	17.6	0.9	16.7	20.9	209.2	10.3	10.3	1	once in a week
10 to 16 dec	50	2.9	17.4	1.2	20.0	20.0	0.4	19.6	24.5	245.1	19.3	9.5	2	Twice in a week
17 to 23 dec	51	1.9	16.4	1.2	18.8	18.8	0.3	18.5	23.2	231.8	19.3	9.5	2	Twice in a week
24 to 31 dec	52	1.8	19.2	1.2	22.1	22.1	0.2	21.9	27.3	273.3	20.3	10.3	2	Twice in a week
1 to 7 jan	1	0.0	22.7	1.2	26.1	26.1	0.1	26.0	32.4	324.4	31.0	10.2	3	Alternate days in a week
8 to 14 jan	2	0.0	23.1	1.2	26.6	26.6	0.0	26.5	33.2	331.6	32.3	10.5	3	Alternate days in a week
15 to 21 jan	3	9.1	21.4	1.2	24.6	24.6	1.3	23.3	29.1	290.6	16.0	8.0	2	Twice in a week
22 to 28 jan	4	0.0	24.0	1.1	27.3	27.3	0.1	27.3	34.1	341.0	37.0	12.3	3	Alternate days in a week
29 to 31 jan,1 to 4 feb	5	1.1	28.8	1.1	30.2	30.2	0.2	30.1	37.6	375.7	47.0	11.5	4	Alternate days in a week
5 to 11 feb	6	0.0	30.6	1.0	29.3	29.3	0.1	29.2	36.5	365.4	46.3	11.4	4	Alternate days in a week
12 to 18 feb	7	1.1	30.9	0.9	26.6	26.6	0.2	26.5	33.1	331.2	41.0	10.3	4	Alternate days in a week
19 feb to25 feb	8	0.0	8.2	0.5	4.4	4.4	0.1	4.3	5.4	54.2	24.0	12.0	2	Twice in a week
Sum						365.67		347.76	434.70	4347.04				

Table.6 Number of branches in drip Irrigation

Plant No.	Plot-A	Plot-B	Plot -C
1	18	14	13
2	11	13	11
3	14	17	14
4	15	15	15
5	16	16	18
6	17	16	12
7	14	17	13
8	13	No plant	17

Table.7 Number of branches in flood irrigation

Plant No.	Plot- A	Plot -B	Plot- C
1	15	7	14
2	14	8	13
3	11	6	14
4	15	5	15
5	13	16	6
6	15	15	6
7	No plant	12	4
8	No plant	13	8
9	15	7	14

Table.8 Plant height in drip irrigation

Plant No.	Plot-A (cm)	Plot-B (cm)	Plot -C (cm)
1	80	80	79
2	69	81	80
3	79	72	74
4	69	75	79
5	70	79	81
6	65	68	72
7	80	69	69
8	81	No plant	69

Table.9 Plant height in flood irrigation

Plant No.	Plot- A(cm)	Plot –B(cm)	Plot- C(cm)
1	70	70	69
2	69	69	45
3	75	75	30
4	71	73	54
5	69	69	39
6	70	72	47
7	No plant	70	53
8	No plant	69	60
9	No plant	No plant	52

Table.10 Number of capsules in one plant in drip irrigation

Plant No.	Plot-A	Plot-B	Plot -C
1	45	89	83
2	67	58	44
3	49	75	28
4	85	48	31
5	26	98	97
6	78	114	88
7	77	45	75
8	102	No plant	64

Table.11 No of capsules in one plant in flood irrigation

Plant No.	Plot- A	Plot -B	Plot- C
1	43	24	88
2	59	71	75
3	92	88	46
4	66	26	23
5	90	42	89
6	37	78	77
7	63	38	44
8	62	87	38
9	No plant	No plant	65

Table.12 No of grains in one plant in drip irrigation

Plant No.	Plot-A	Plot-B	Plot –C
1	2025	1428	**3589**
2	2950	2568	2257
3	**3589**	**3697**	2499
4	2982	2012	1548
5	4268	2258	2478
6	1668	2589	3574
7	2885	2579	1178
8	2687	No plant	2874

Table.13 No of grains in one plant in flood irrigation

Plant No.	Plot-A	Plot-B	Plot –C
1	1158	1265	1897
2	1489	1587	1854
3	1678	1987	1745
4	1825	2036	2574
5	2021	2654	1689
6	**2678**	2258	2298
7	No plant	**2697**	2598
8	No plant	2657	2456
9	No plant	No plant	**2684**

Table.14 Yield of one plant under drip irrigation

	Plot A	Weight(g)	Plot B	Weight(g)	Plot C	Weight(g)
	2025	105.705	1428	74.54	**3589**	**187.34**
	2950	153.99	2568	134.05	2257	117.81
	3589	187.34	**3697**	**192.98**	2499	130.44
	2982	155.66	2012	105.02	1548	80.80
	4268	**222.79**	2258	117.86	2478	129.35
	1668	87.069	2589	135.14	3574	186.56
	2885	150.59	2579	134.62	1178	61.49
	2687	140.26			2874	150.02
Sum		1203.42		894.23		1043.84

Table.15 Yield of one plant under flood irrigation

	Plot A	Weight(g)	Plot B	Weight(g)	Plot C	Weight(g)
	1158	45.741	1265	49.968	1897	74.932
	1489	58.816	1587	62.687	1854	73.233
	1678	66.281	1987	78.487	1745	68.928
	1825	72.088	2036	80.422	2574	101.67
	2021	79.83	3654	144.33	1689	66.716
	2678	**105.78**	2258	89.191	2298	90.771
			3697	**146.03**	2598	102.62
			3657	144.45	**3456**	**136.51**
					2684	106.02
Sum		428.54		795.57		821.4

Fig.1 kc graph for safflower crop

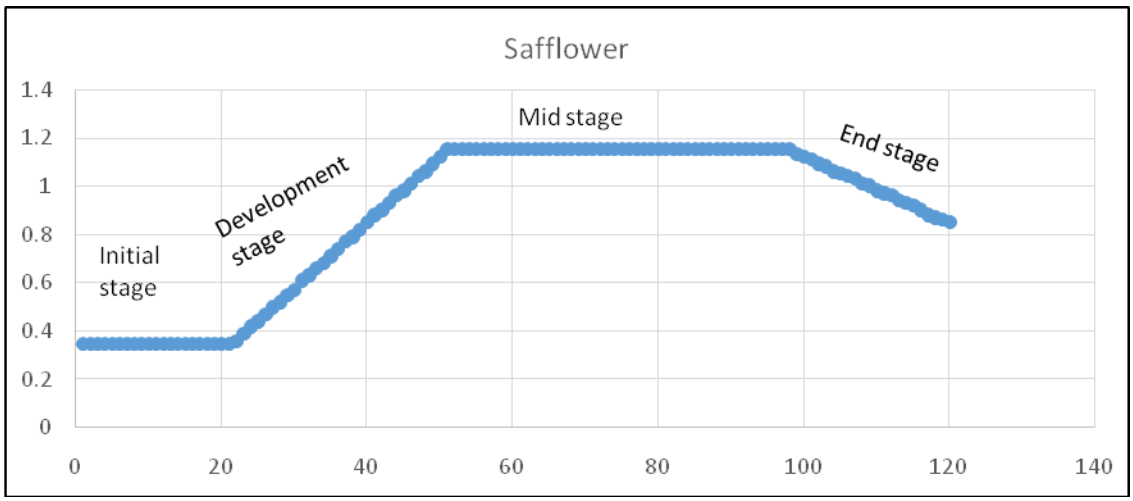

Fig.2 Excel sheet in which formula to calculate ETo is inserted

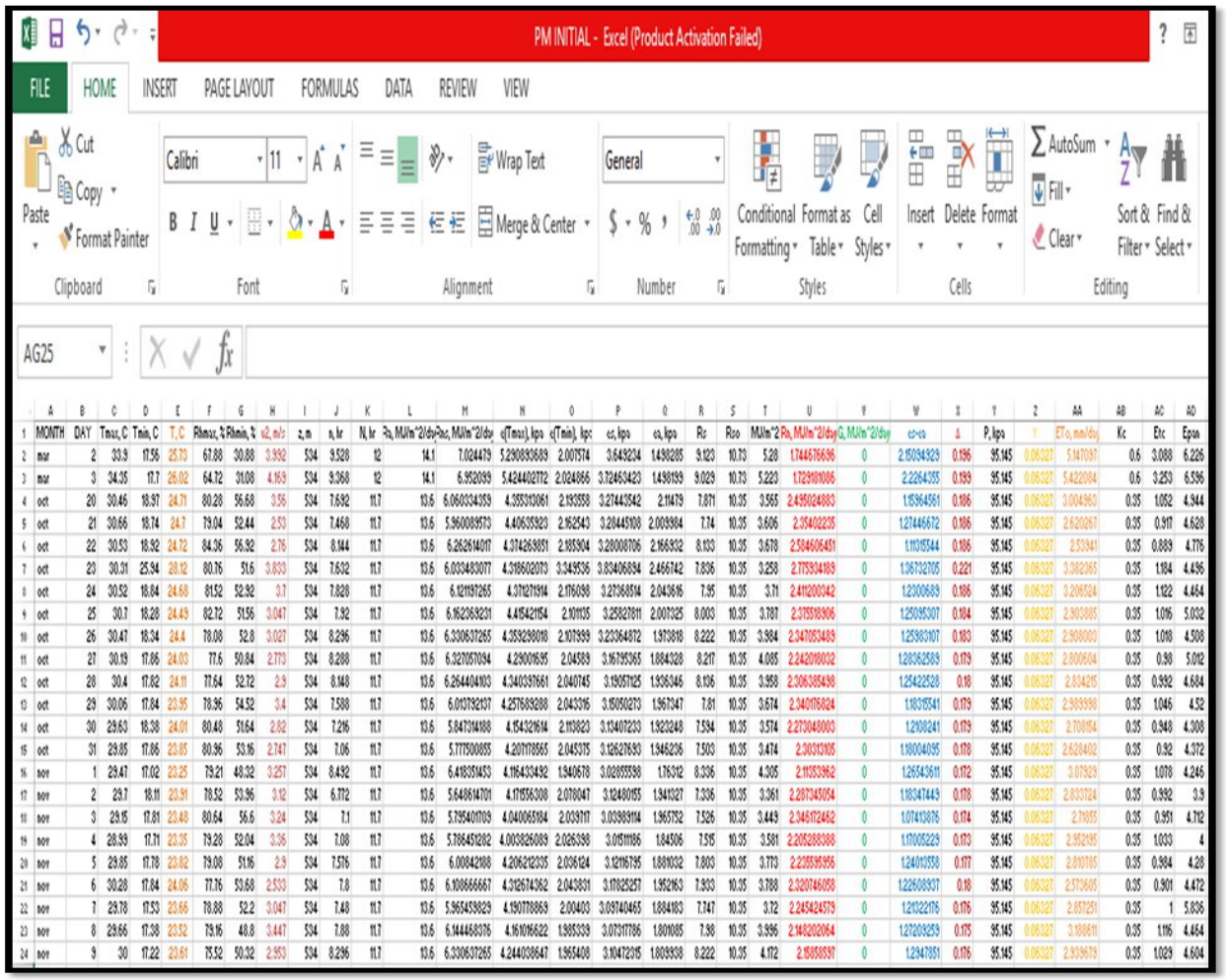

Plate.1 Safflower crop

Capsules and grains

The maximum number of capsules were developed for safflower under drip irrigation in plot- A were102, plot-B were114 and plot - C were97as shown in (Table 10) whereas in flood irrigation the branches developed for every plant in plot- A were92, plot-B were88 and plot -C were89as shown in (Table 11). The maximum number of grains in one plant of safflower under drip irrigation in plot- A were3589, plot-B were3697 and plot -C were3589as shown in (Table 12) whereas in flood irrigation, the maximum grains in one plant from plot- A were2678, plot-B were2697 and plot - C were 2684as shown in (Table 13).

Yield

The maximum yield produced for one safflower plant under drip irrigation in plot- A was 4268 grains and the weight was 222.79 g, in plot-B was 3697 grains and the weight was 192.98 g and in plot -C was 3589 grains and the weight was 187.34 gas shown in (Table 14) whereas in flood irrigation, the maximum yield produced for one safflower plant under flood irrigation in plot- A was 2678 grains and the weight was 105.78 g, in plot-B was 3697 grains and the weight was 146.03g and in plot -C was 3456 grains and the weight was 136.51 g as shown in (Table 15).

The study was concluded that the crop water requirement for safflower crop estimated by Penman Monteith method was 365mm (Standard value is 250 to 300mm) for its entire crop period of 120-140 days in Rabi season.

The study was concluded that the yield of safflower under drip irrigation was 12.56 quintal and where as in flood irrigation, it was 8.18 quintal. Thus 35% of yield was more in drip irrigation than flood irrigation.

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