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Effect of different irrigation and fertigation levels on water use efficiency, fertilizer use efficiency and biometric parameter of strawberry crop under coastal climatic condition of Konkan region

SM Bhagwat, PM Ingle, US Kadam, ST Patil and PB Bansode

Abstract
The present research entitled, "Effect of different irrigation and fertigation levels on water use efficiency, fertilizer use efficiency and biometric parameter of Strawberry crop under coastal climatic condition of Konkan region" during the 2022-23 growing season was carried out at the instructional Farm of Department of Irrigation and Drainage Engineering, college of Agricultural Engineering and technology, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli. The experiment involved nine treatment combinations with four replication. The experiment was arranged in split plot design with three irrigation levels in the main plots and three fertigation levels in the sub plots. The study results revealed for maximum water use efficiency and fertilizer use efficiency (6.71 q/ha.cm) and (10.10) was found in treatment combination I_2F_3 (0.8 ETc and 105% RD) and I_3F_1 (1.0 ETc and 75% RD). Three irrigation levels includes I_1 (60% ETc), I_2 (80% ETc) and I_3 (100% ETc) and fertigation levels includes F_1 (75% RDF), F_2 (90% RDF) and F_3 (105% RDF). The irrigation was scheduled on daily basis and fertigation was weekly basis. The study results revealed for treatment combination I_3F_3 was found better in obtaining maximum number of leaves, plant height and leaf area and % canopy over the treatment combination I_1F_2.

Keywords: Strawberry, irrigation, fertigation, treatments, water use efficiency and fertilizer use efficiency

1. Introduction
Strawberry is favorite fruit among with on all the age of the community member. The fruit is famous for is flavor, taste and sweetness. The climatic condition / soil condition of the Konkan region the favorable congnernce growing of strawberry crop. The soil is highly drainable on provides condition for growth of strawberry crop. The both climatic and soil provides an opportunity for cultivation of strawberry in this region. As the Konkan is famous for the tourist destination and strawberry fruit and its process products for tourists are favorite provides a commercial demand as well as market for the cultivation of strawberry crop. The successful cultivation for strawberry crop provides extra income to the local farmer and business opportunity to the youth of the region. But the successful and commercial cultivation of strawberry need proper scientific information regarding cultivation, water management, fertigation, plant protection, harvesting and packaging and a need of standard management practices.

Strawberries are very good sources of natural antioxidants including vitamins, carotenoids, flavonoids, phenols, dietary glutathionine and endogenous metabolites. (Singh *et al*. 2001) [12]. In winter, the plants does not show any growth and remain undeveloped. When days grow to be longer and temperature rises in spring, the plants continue grow and flowering begins. Due to drought stress during flowering and fruit maturing stages, the yield and size are significantly reduced (Bhatt, 1984) [2]. The characteristics of best irrigation are to supply sufficient water according to plant requirements in the rooting area and to avoid the leaching of nutrients into the deeper soil levels (Kruger *et al*. 1999) [5]. Drip irrigation reduces the conveyance losses like runoff, deep percolation and evaporation. Maximum 30 to 70% water saves depending on crop and its growth condition and it enhances the crop yield up to 66% (Singh *et al*., 2001) [12]. In soil with high infiltration rate and land with steep slope, drip irrigation is found to be more advantageous.

When planting and manufacturing take place during warm weather, the silver-black mulch is applied. Slayer stops the growth of weeds. According to Olson 2011 [8], the reflecting silver colour has advantages such as a 50% reduction in fumigant rates and a reduction in the incidence of some diseases. In subtropical and tropical climates, strawberries can effectively mature. The fruit should be consumed quickly after being picked because it matures in just 30 to 40 days and is perishable. The temperature needs to be between 13 and 28 degrees centigrade on a daily average for strawberry growth to be at its best. It is a crop with shallow roots that is highly susceptible to water shortages in the soil. The majority of roots are found in the top 7 to 15 cm of soil, although in lighter soil they can extend 30 cm or more below the surface. It is a short-day plant that needs about 10 days of daylight for less than 8 hours to begin flowering (Rahudkar, 2010) [10].

The Konkan region is somewhat blessed with soil and climatic conditions. The temperature in Konkan not crosses 35ºC to 36ºC with an average humidity of 50% around the year. The average rainfall is ranging from 2500 to 4000 mm and soils are high percolative. Therefore, considering the climatic and soil conditions of the Konkan were favorable for most of the high valued vegetable crops like strawberries which can be grown even in open fields. Also, in Konkan, mostly the farmers grow mango and cashew as perennial crops and paddy during the Kharif. Therefore, after paddy, the costly commodity and high-valued land are kept unattended most of the time. The youth from the Konkan region are migrated and migrating to metropolitan cities like Mumbai, and Pune to get a job as they don't find any means of their income from agriculture at present. In Maharashtra, India, and particularly in the Konkan region, very rare as well scientific research/work was carried out on the cultivation of strawberries in the open field.

2. Materials and Methods

2.1 Materials

Soil condition

The topography of the experimental site is level. The soil type is lateritic. The soil properties such bulk density, Infiltration rate texture class etc. was determine.

2.2 Methodology

2.1 Experimental details

The experiment consists of total nine treatment combinations including three irrigation levels (0.6 ETc, 0.8 ETc, 1.0 ETc) and three fertigation levels (75% RD, 90% RD, 105% RD) with three replications. In the present study strawberry crop variety (R1) was transplanted at spacing 0.3 m × 0.3 m in split plot design with three irrigation levels (main plot) and three fertigation levels (Sub plot) with four replications. For application of recommended dose of 100-70-85 NPK kg ha^{-1}, water soluble fertilizers (WSF) were used. (Mane *et al* 2015) [7].

2.2 Irrigation scheduling

The irrigation schedule was prepared on the basis of daily climatic data. Three irrigation levels were fixed as 60% ETc, 80% ETc, 100% ETc. The reference evapotranspiration was calculated by using formula as given in

$$ETo = Epan \times Pan\ factor$$

Where,
ETo = Reference evapotranspiration, mm/day
Epan = Pan evapotranspiration, mm/day
Pan factor = 0.7

2.3 Fertilizer scheduling

The water soluble fertilizers applied through drip according to different levels of fertilizers i.e., 75%, 90% and 105% of recommended dose of fertilizer. Fertilizers were applied in equal split and induced immediately 10 days after transplanting of the crop. Fertilizers were applied at the interval of 7 days through drip irrigation system.

2.4 Water use efficiency (WUE)

The water use efficiency was determined from the total yield and total depth of water applied.

$$WUE = \frac{\text{Total Yield, q/ha}}{\text{Depth of water applied, cm}}$$

Where,
WUE = Water use efficiency, q/ha-cm**.**

2.5 Fertilizer use efficiency (FUE)

The fertilizer use efficiency was determined from the total yield and total quantity of fertilizer applied.

$$FUE = \frac{\text{Total Yield, q/ha}}{\text{Total quantity of fertilizer applied, q/ha}}$$

Where,
FUE =Fertilizer use efficiency.

2.6 Biometric parameter

Five randomly selected observation plants from each treatment were subjected to various observations over the duration of the entire crop period. At intervals of 15 days, observations of growth parameter like the number of leaves, plant height, percentage of canopy area, and leaf area were made.

2.6.1 Number of leaves

The number of leaves of randomly selected observation plants were recorded at 15 days interval from 15DAT and its statistical analysis.

2.6.2 Plant height (cm)

The plant height of randomly selected observation plants was recorded by measuring scale from the ground level up to the top of completely open leaf at 15 days interval after DAT and its statistical analysis.

2.6.3 % canopy over

The spread diameter of randomly selected observation plants was measured across the center of the plant at 15 days interval after DAT and its statistical analysis.

2.6.4 Leaf area (cm^2)

The length of leaves of randomly selected observation plants was recorded by measuring scale at 15 days interval after DAT and its statistical analysis.

3. Results and Discussion

3.1 Physical and Chemical properties of soil

It necessary to know the physical properties of soil i.e., type of soil, field capacity, permanent wilting point etc. for consideration of different parameters like emitter discharge, spacing, irrigation scheduling etc. It was also necessary to know the chemical properties and their present status like EC, pH values along with NPK.

3.1.1 Physical properties of soil

The necessary data collected and the results of physical properties of soil are reported in it is observed that soil sample contains sand 73.17%, silt 15.2% and clay 11.63% results in textural class of sandy loam. It also revealed that the bulk density is 1.63g/cm^3 and infiltration rate of soil is 6.5 cm/hr clearly indicated that the soil is highly porous and less water holding capacity. As soil water holding capacity is less and due lateritic type of soil needs frequent irrigation to maintain the desired soil moisture.

3.1.2 Chemical properties of soil

It observed that, the pH of soil is 6.5 with EC of 0.45 dS/m. The soil is slightly acidic and soil contains lower nitrogen and potash and average in phosphorus. The available N Kg/ha, P Kg/ha and K Kg/ha is 175.25, 15.50 and 170.50.

3.2 Crop water requirement and Irrigation scheduling

It is revealed that the total depth of irrigation water applied in I_1 (0.6 ETc), I_2 (0.8 ETc) and I_3 (1.0 ETc) was observed to be 210.77 mm, 281.03 mm and 351.29 mm. The maximum irrigation water (351.29 mm) was applied in I_3 (1.0 ETc) i.e., 100% of evapotranspiration, while it was found to be lowest (210.77 mm) in I_1 (0.6 ETc). The irrigation levels were imposed from 1st December 2022 and terminated on 20th March 2023.

The depth of irrigation water applied and volume of water needed by plant also determined for strawberry crop. It observed that for initial stage of crop (i.e. 30 days period) it ranged from 23.36 mm to 66.11mm for different irrigation levels. The peak water demand was observed during the crop development and mid-season stage for different irrigation levels i.e. 61.53 mm and 88.15 mm; 76.92 mm and 110.19mm and 125.23 mm for irrigation levels 0.6 ETc, 0.8 ETc and 1.0 ETc respectively. The maximum water saving 38.57% was achieved in irrigation level I_1 (0.6 ETc) followed by 19.27% water saving In I_2 (0.8 ETc) over the irrigation level I_3.

Table 1: Depth of water applied to strawberry under different irrigation levels (mm)

Months	ETo	ETc	I_1=0.6ETc	I_2=0.8ETc	I_3=1.0ETc	Remarks
19th Nov-22	==	==	50	50	50	For transplanting of seedlings
20thNov-22 to 30 Nov-22th(12 days)	63.08	14.92	8.95	11.93	14.92	Establishment of seedlings
1st Dec-22 to 31st Dec-22 (31 days)	106.53	44.11	26.46	35.28	44.11	Irrigation treatments were imposed
1st Jan-23 to 31st Jan-23 (31 days)	122.67	104.26	62.55	83.40	104.26	
1 Feb-23 to 28 Feb-23 (28 days)	131.45	111.23	66.73	88.98	111.23	
1 March-23 to 20 March-23 (20 days)	102.41	76.80	46.08	61.44	76.80	
Total	500.25	351.29	210.77	281.03	351.29	
Water saving (%) over I_3	==	==	38.57	19.27	==	
*	General irrigation for establishment of the crop					
**	Treatments were imposed on 1th December, 2022					
***	Last irrigation on 20th March, 2023					

Table 2: Stage wise depth of water applied and water requirement

Stages	0.6 ETC	0.8 ETc	1.0 ETc
Initial Stage (30 days)	23.36 mm (1.05 lit/day/plant)	46.15 mm (2.08 lit/day/plant)	66.11 mm (2.98 lit/day/plant)
Crop development (30 days)	31.15 mm (1.40 lit/day/plant)	61.53 mm (2.77 lit/day/plant)	88.15 mm (3.98 lit/day/plant)
Mid- Stage (30 days)	38.94 mm (1.75 lit/day/plant)	76.92 mm (3.47 lit/day/plant)	110.19 mm (4.97 lit/day/plant)
End Stage (32 days)	75.14 mm (3.18 lit/day/plant)	100.18 mm (4.52 lit/day/plant)	125.23 mm (5.65 lit/day/plant)
Total	210.77 mm	281.03 mm	351.29 mm

3.3 Water Use Efficiency

From Table 3, it is observed that the maximum water use efficiency was found in treatment combination I_2F_3 (6.71 gm/lit) followed by I_1F_3 (6.62 gm/lit), I_1F_2 (6.36 gm/lit), I_1F_1 (5.90 gm/lit), I_2F_2 (4.87 gm/lit), I_2F_1 (4.64 gm/lit), I_3F_3 (4.48 gm/lit), I_3F_2 (4.31 gm/lit) and I_3F_1 (4.17 gm/lit), respectively.

It is very interesting to note that though the maximum WUE is found to be in I_2F_3 (6.71) however the treatment combination I_1F_3 (6.62) gave very close WUE with I_2F_3. The minimum water use efficiency (4.17gm/lit) was observed in treatment combination I_3F_1, due to very low yields in relation to the amount of water applied.

Table 3: Water use efficiency under different treatment combination

Treatments Combinations	Depth of water applied (cm)	Yield (q/ha)	Water use efficiency (gm/lit)
I_1F_1	21.35	125.88	5.90
I_1F_2	21.35	135.87	6.36
I_1F_3	21.35	141.33	6.62
I_2F_1	28.06	130.09	4.64
I_2F_2	28.06	136.76	4.87
I_2F_3	28.06	188.19	6.71
I_3F_1	34.76	144.92	4.17
I_3F_2	34.76	149.79	4.31
I_3F_3	34.76	155.85	4.48

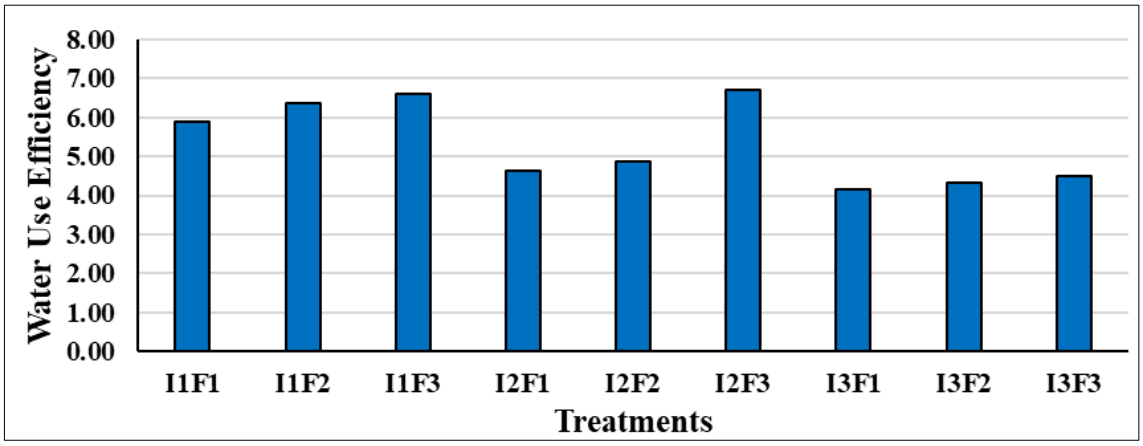

Fig 1: Water use efficiency under different treatment combinations

3.4 Fertilizer Use Efficiency

From Table 4, it is observed that the maximum fertilizer use efficiency is found in treatment combination I_3F_1 (10.10) followed by I_2F_3 (9.41), I_2F_1 (9.07), I_1F_1 (8.77), I_3F_2 (8.74), I_2F_2 (7.98), I_1F_2 (7.93), I_3F_3 (7.79) and I_1F_3 (7.07), respectively. The minimum fertilizer use efficiency (7.07) is observed in treatment combination I_1F_3, due to very low yields in relation to the amount of fertilizer applied.

Table 4: Fertilizer use efficiency under different treatment combination

Treatments Combinations	Fertilizer applied (q/ha)	Yield (q/ha)	Fertilizer use efficiency
I_1F_1	14.35	125.88	8.77
I_1F_2	17.14	135.87	7.93
I_1F_3	20.00	141.33	7.07
I_2F_1	14.35	130.09	9.07
I_2F_2	17.14	136.76	7.98
I_2F_3	20.00	188.19	9.41
I_3F_1	14.35	144.92	10.10
I_3F_2	17.14	149.79	8.74
I_3F_3	20.00	155.85	7.79

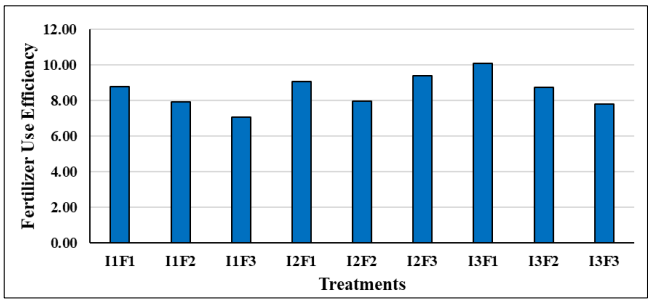

Fig 2: Fertilizer use efficiency under different treatment combinations

3.5 Biometric parameters

The different biometric parameters were recorded periodically with the 15 days interval and discussed in the following sections.

3.5.1 Effect of irrigation and fertigation levels on growth parameters

The interaction effects of irrigation and fertigation levels as well as the individual effect of irrigation and fertigation on growth parameters i.e., number of leaves, leaf area, plant height, % canopy cover were recorded.

3.5.1.1 Interaction effect of irrigation and fertigation levels on number of leaves

The terms of number of leaves per plant, treatment combination I_3F_3 was found to be superior over the rest of the treatment combination at 30 DAT, 45 DAT, 60 DAT and 105 DAT. Based upon above analysis the maximum number of leaves were noted in treatment combination I_3F_3 (1.0 ETc, 105% of RDF). For individual irrigation and fertigation levels, number of leaves.

Table 5: Interaction effect of irrigation and fertigation levels on number of leaves

Treatment	No. of leaves (DAT)						
	15	30	45	60	75	90	105
I_1F_1	6	9	13	19	26	25	25
I_1F_2	6	7	12	19	30	26	24
I_1F_3	5	6	13	22	29	30	27
I_2F_1	6	7	13	22	28	29	26
I_2F_2	5	7	12	22	26	24	25
I_2F_3	5	7	13	24	29	31	30
I_3F_1	5	7	13	24	32	31	29
I_3F_2	5	8	15	26	33	29	30
I_3F_3	5	8	15	25	31	36	33
S.E(m)±	0.34	0.38	0.36	0.52	0.75	2.62	1.45
C.D. at 5%	1.04	1.18	1.11	1.59	2.30	8.07	4.46

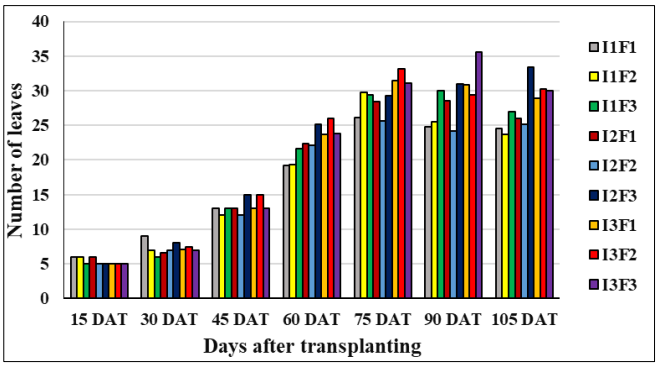

Fig 3: Effect of irrigation and fertigation levels on number of leaves

3.5.1.2 Interaction effect of irrigation and fertigation levels on Plant height

It is revealed that the maximum and minimum plant height was observed in treatment combination of I_3F_3 and I_3F_1 respectively at 15 DAT to 105 DAT. Based upon above analysis the maximum plant height were noted in treatment combination I_3F_3 (1.0 ETc, 105% of RDF).

Table 6: Interaction effect of irrigation and fertigation levels on Plant height

Treatment combinations	Plant height (DAT)						
	15	30	45	60	75	90	105
I_1F_1	12.98	16.75	19.71	24.01	26.23	27.31	26.72
I_1F_2	14.08	17.35	19.67	23.03	25.15	26.27	26.29
I_1F_3	13.38	15.73	19.25	21.87	23.77	24.83	25.05
I_2F_1	13.18	15.45	18.81	21.53	24.15	25.25	25.55
I_2F_2	13.85	15.67	17.94	20.75	24.00	25.29	25.33
I_2F_3	13.95	16.19	17.78	21.05	25.33	25.88	25.47
I_3F_1	12.40	15.40	16.99	19.83	23.89	25.04	25.26
I_3F_2	12.38	15.77	17.12	20.83	24.91	26.01	26.25
I_3F_3	14.58	16.89	18.74	21.89	25.45	26.47	27.40
S.E(m)±	0.37	0.32	0.23	0.59	0.18	0.54	0.52
C.D. at 5%	1.15	0.99	0.70	1.82	0.57	1.66	1.62

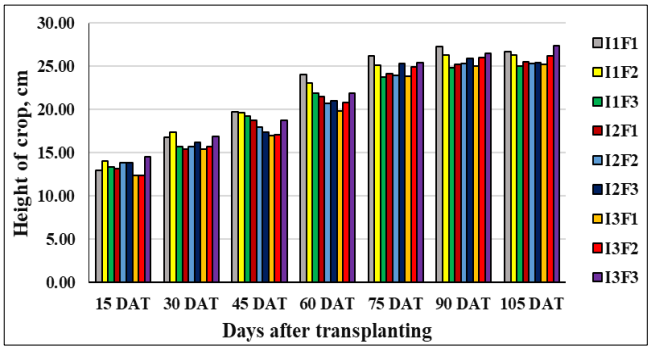

Fig 4: Effect of irrigation and fertigation levels on Plant height

3.5.1.3 Interaction effect of irrigation and fertigation levels on % canopy over

From the data it is revealed that the treatment combination I_2F_1 was found to be significantly superior as compared to the rest of treatment combination at 15 DAT to 45 DAT. It is very interesting to note that the % canopy over was maximum treatment I_1 and then all other treatment to be reduced. It means the maximum excess of irrigation to the reduce % canopy over. Based upon above analysis the maximum % canopy over were noted in treatment combination I_1F_2 (0.6 ETc, 90% of RDF).

Table 7: Interaction effect of irrigation and fertigation levels on % canopy over

Treatment Combinations	% Canopy over (DAT)		
	15	30	45
I_1F_1	42.64	97.94	107.81
I_1F_2	52.08	83.72	110.81
I_1F_3	39.69	49.98	101.87
I_2F_1	44.93	98.87	109.20
I_2F_2	28.66	65.50	91.843
I_2F_3	42.25	86.18	79.21
I_3F_1	40.07	67.79	75.28
I_3F_2	41.99	84.82	79.50
I_3F_3	31.02	77.73	76.27
S.E(m)±	0.97	1.38	0.39
C.D. at 5%	2.99	4.26	1.19

3.5.1.4 Interaction effect of irrigation and fertigation levels on leaf area (cm^2)

It is also revealed that the maximum and minimum leaf area was observed in treatment combination of I_3F_3 and I_1F_1 respectively at 15 DAT to 105 DAT. Based upon above analysis the maximum leaf area were noted in treatment combination I_3F_3 (1.0 ETc, 105% of RDF).

Table 8: Interaction effect of irrigation and fertigation levels on leaf area (cm^2)

Treatment combinations	Leaf area (DAT)						
	15	30	45	60	75	90	105
I_1F_1	271.50	427.84	499.95	524.15	536.37	571.32	611.15
I_1F_2	264.02	383.23	515.99	526.39	533.54	536.60	604.92
I_1F_3	236.54	455.81	546.98	560.44	563.85	580.57	625.85
I_2F_1	225.90	444.76	577.37	590.68	609.61	627.27	662.28
I_2F_2	173.31	329.57	510.04	545.42	556.75	571.07	621.58
I_2F_3	231.89	381.82	478.66	552.57	555.40	614.20	653.10
I_3F_1	244.90	378.60	421.54	555.21	567.74	622.17	663.14
I_3F_2	227.30	365.69	477.56	569.40	592.26	604.29	628.17
I_3F_3	193.45	366.90	480.58	531.63	587.97	593.82	610.29
S.E(m)±	6.71	12.95	30.59	14.17	12.55	8.90	5.27
C.D. at 5%	20.68	39.91	94.26	43.65	38.67	27.42	16.25

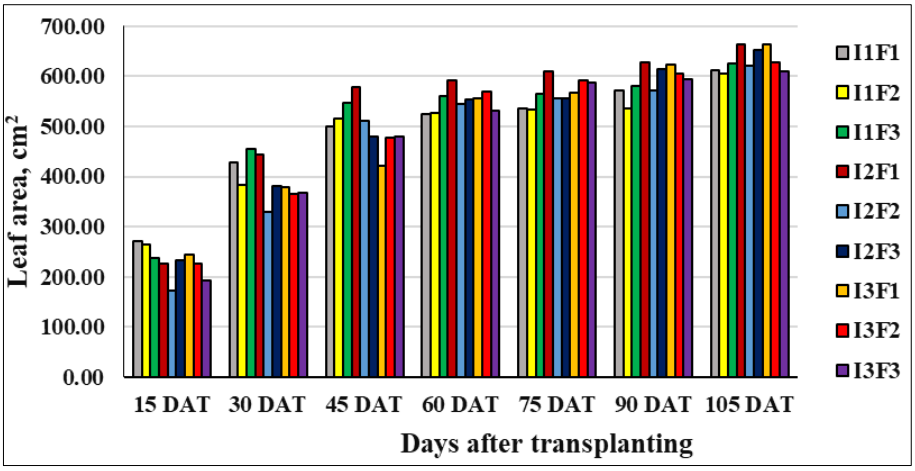

Fig 5: Effect of irrigation and fertigation levels on Leaf area

4. Conclusions

1 The Crop water requirement of Strawberry was 0.8 ETc (I_2) for attaining maximum yield.
2 The maximum water saving 38.57% was achieved in irrigation level I_1 (0.6 ETc) followed by 19.27% water saving In I_2 (0.8 ETc) over the irrigation level I_3.
3 The maximum water use efficiency (6.71q/ha.cm) was found in treatment combination I_2F_3 (0.8 ETc and 105% RD).
4 The maximum fertilizer use efficiency (10.10) was found in treatment combination I_3F_1 (1.0 ETc and 75% RD).
5 It was observed that the growth parameters such as number of leaves, height of crop and leaf area was maximum in treatment combination I_3F_3 (1.0 ETc and 105% RD) and % canopy over was maximum in treatment combination I_1F_2 (0.6 ETc and 90% RD).

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