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The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; SP-12(7): 1167-1174

www.thepharmajournal.com
Received: 03-05-2023
Accepted: 13-06-2023

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Response of cucumber to different irrigation and fertigation levels in summer under polyhouse condition

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Abstract
There is need to increase nutritionally rich vegetable production and productivity of seasonal and non-season crops in our country. Productivity of vegetable crops can be increased by 3 to 5 times in protected cultivation as compared to open environment. Considering the importance of timely application of fertilizers and irrigation in protected cultivation the research project entitled "Response of cucumber to different irrigation and fertigation levels in summer season under polyhouse conditions" was conducted to know the optimum irrigation, fertigation requirement of parthenocarpic cucumber at the Research-cum-Demonstration Farm of Precision Farming Development Centre, Department of Irrigation and Drainage Engineering, Dr. Annasaheb Shinde College of Agril. Engg. & Tech., MPKV, Rahuri (M.S.) during the period from March 2021 to July 2021. This experiment involved growing of cucumber in a polyhouse condition with three irrigation regimes (100, 80, and 60% of evapo-transpiration of crop i.e. Etc.) and three fertigation regimes (150, 125 and 100% of recommended dose of fertilizer i.e. RDF) treatments. The experiment was carried out in factorial randomized block design with three replications. The RDF for cucumber in open field was 100:50:50 NPK Kg ha^{-1} and 20 t ha^{-1} farm yard manure. The crop was irrigated daily and fertigated twice in a week with 27 equal splits as per treatments. The area under experiment was 336.00 m^2. ENZA ZADEN Fadia best quality parthenocarpic, beit alpha hybrid cucumber seeds were selected for protected cultivation. The results revealed that drip irrigation scheduled daily with 100% ETc. recorded highest cucumber yield (117.46 q/1008 m^2) and fertigation @ 150% RDF twice in a week with 27 equal splits recorded maximum cucumber yield (122.48 q/1008 m^2) under polyhouse condition. It is concluded that the irrigation scheduled daily with drip @ 100% ET_c and fertigated @ 150% RDF twice in a week with 27 equal splits resulted maximum B:C ratio of 3.46 and net monetary returns of Rs. 399568/1008 m^2 from cucumber grown in summer season under polyhouse condition.

Keywords: Cucumber, fertigation levels, irrigation levels, polyhouse, summer

Introduction
Cucumber (*Cucumis sativus* L.) is one of the most important cucurbitaceous vegetable crops grown extensively in tropical and sub-tropical parts of the country. It is considered as 4th most important vegetable crop after tomato, cabbage and onion. Cucumber is a thermophilic and frost susceptible crop species, growing best at a temperature above 20 °C. Cucumber is very sensitive to fluctuations of light and temperature. The productivity and quality of cucumber grown under open field conditions is generally low. Cucumber under open fields is grown in two seasons; one in summer and second in rainy season. The quality and efficiency of water management determines the yield and quality of crop produce. The optimum frequency and amount of applied water is a function of climate and weather conditions, crop species, variety, stage of growth and rooting characteristics, soil water retention capacity and texture, irrigation system and management factor. Too much or too little water causes abnormal plant growth, predisposes plants to infection by pathogens, and causes nutritional disorders. If water is scarce and supplies are erratic or variable, then timely irrigation and conservation of soil moisture reserves are the most important agronomic interventions to maintain yields during drought stress. There are several methods of applying irrigation water and the choice depends on the crop, water supply, soil characteristics and topography. Application of irrigation water could be through overhead, surface, drip, or sub-irrigation systems. Surface irrigation methods are utilized in more than 80% of the world's irrigated lands yet its field level application efficiency is often 40-50%. Drip irrigation delivers water directly to plants through small plastic tubes and it saves water up to 50% compare to furrow system of irrigation, fertigation via drip is 30% more effective coupled with higher productivity and quality than traditional irrigation systems.

Crop production per unit of water consumed by plant evapo-transpiration is typically increased by 10-50%. Thus, more plants can be irrigated per unit of water by drip irrigation and with less labour (Bharadwaj *et al.*, 2012) [2]. This system also saves the energy, reduces the weed growth, reduces the incidence and transmission of pests and diseases (Manda and Avinash, 2019) [5]. Further, this drip irrigation system is highly suitable for crops with wider spacing such as vegetables, soft fruits, vines and trees.

There is need to increase nutritionally rich vegetable production and productivity of seasonal and non-season crops in our country. If the climatic conditions are not suitable for crop cultivation then one has an option of choosing polyhouses or shade nets. Keeping in view of the abiotic stresses in changing climatic condition under open field, production technology of cucumber need to be developed and standardized for cultivation under two types of protected structures namely, naturally ventilated greenhouse and insect-proof net house. Greenhouse is the most practical method of achieving the objectives of protected agriculture, where natural environment is modified by using sound engineering principles to achieve optimum plant growth and yield. Besides, protected technology has potential to produce more produce per unit area with increased input use efficiency. Research results have shown that by adopting protected cultivation; productivity of vegetable crops can be increased by 3 to 5 times as compared to open environment (Bharadwaj *et al.*, 2012) [2]. Production of cucumber in greenhouse or net house has led to the minimum use of pesticides, which is not possible under open field cultivation. The demand of fresh salad varieties of cucumber is increasing day by day and growing this crop under protected conditions is becoming profitable proposition. Vegetable growers, for getting higher prices from their off-season produce, often try to send their produce to the market early in the season and also try to extend the growing season for selected vegetable crops for the purpose of obtaining marketing advantage of their off-season produce.

The standardization irrigation, fertigation and other production practices of parthenocarpic cucumber is needed under naturally ventilated greenhouse conditions. Three crops of parthenocarpic cucumber can be grown over duration of 10-11 months under naturally ventilated greenhouse conditions with productivity ranging between 120-130 t/ha with very high quality fruits. This technology eliminates stresses due to biotic and abiotic factors and the use of pesticides can be minimized (Kumar *et al.*, 2020) [4]. Considering the importance of timely application of fertilizers dose, irrigation, protected cultivation and well management practices for the growth of cucumber as an important vegetable crop, the research project entitled, "Response of Cucumber to Different Irrigation and Fertigation Levels in Summer Under Polyhouse Condition" has been undertaken to study the yield response of cucumber to different drip irrigation and fertigation levels; and work out the economics of cucumber cultivation in polyhouse condition.

Materials and Methods

Experimental details: The field experiment on "Response of cucumber to different irrigation and fertigation levels in summer season under polyhouse conditions" was conducted at the Research-cum-Demonstration Farm of Precision Farming Development Centre, Department of Irrigation and Drainage Engineering, Dr. Annasaheb Shinde College of Agricultural Engineering and Technology, Mahatma Phule Krishi Vidyapeeth, Rahuri (M.S.) during the period from March 2021 to July 2021. Geographically, the farm lies at 19^0 18'00'' N latitude and 74^0 39'00'' E longitudes at 657 m above mean sea level, in the central campus of Mahatma Phule Krishi Vidyapeeth, Rahuri. The experiment was carried out in factorial randomized block design with two main factors as irrigation levels and fertigation levels with three replications. This formed the nine treatments combinations of irrigation and fertigation levels (Table 1).

Table 1: Details of treatments and symbols used

Symbol used	Treatments
T_1: I_1 x F_1	100% ETc. x 150% RDF
T_2: I_1 x F_2	100% ETc. x 125% RDF
T_3: I_1 x F_3	100% ETc. x 100% RDF
T_4: I_2 x F_1	80% ETc. x 150% RDF
T_5: I_2 x F_2	80% ETc. x 125% RDF
T_6: I_2 x F_3	80% ETc. x 100% RDF
T_7: I_3 x F_1	60% ETc. x 150% RDF
T_8: I_3 x F_2	60% ETc. x 125% RDF
T_9: I_3 x F_3	60% ETc. x 100% RDF

The experimental set up consisted of different treatments in polyhouse of 500 m^2 along with drip irrigation system. The topography of the experimental field was uniform and levelled. The soil was well drained with 45 cm depth. The soil media in polyhouse consisted of red soil, Farm Yard Manure (FYM) and sand mixed with wheat husk in the proportion of 3:3:3:1. The media was then well sterilized (fumigated) by using formalin acid in the proportion of 1:10 in water. The schematic layout of an experimental set-up is shown in Fig.1. The field experiment was laid out with nine treatments and three replications. Beds were prepared manually with available soil on field. The size of each bed was 5 m × 0.7 m (Fig. 2). A buffer strip of 0.5 m was provided between two beds to avoid lateral movement of water from one bed to another and to enable easy cultural operations like weeding, spraying and harvesting etc. Gator pump was used for injecting the fertilizers into the drip irrigation system. The water soluble fertilizers were applied through inline drip irrigation system with irrigation water at 3 days interval to cucumber as per the treatments. Fertilizers were not given for first 10 days after sowing and last 5 days before harvesting. The grades of solid water soluble fertilizers 19:19:19 and Urea were used for meeting the fertilizer requirement as per treatments.

Drip irrigation was used to irrigate the cucumber crop on a daily basis throughout the entire crop period. Cucumber was irrigated at a depth determined by crop evapotranspiration. Daily maximum and minimum temperatures, daily maximum and minimum relative humidity, wind speed at 2 m height, pan evaporation, actual sunshine hour and rainfall were collected from India Meteorological Department, Pune for MPKV, Rahuri on daily basis.

The daily crop evapotranspiration was estimated using equation 1 as shown below:

$$ETc = ETr \times Kc \quad \ldots (1)$$

Where,

ETc = Crop evapotranspiration (mm day^{-1})

ETr = Reference evapotranspiration (mm day^{-1}) estimated by using FAO based Penman-Monteith method.

Kc = Crop coefficient

The daily crop coefficient required for computing the daily crop evapotranspiration were estimated using the following four degree polynomial equation (Gadge, 2010) [3].

$$Kc_t = 2.7429\left\{\frac{t}{T}\right\}^4 - 10.583\left\{\frac{t}{T}\right\}^3 + 8.5733\left\{\frac{t}{T}\right\}^2 - 0.5305\left\{\frac{t}{T}\right\}^1 + 0.2471 \quad \ldots (2)$$

Where,
Kc = Crop coefficient of t^{th} day.
t = Number of days since sowing
T = Total period of crop growth from sowing to harvesting (days).

Once the depth of irrigation calculated as above, the total amount of water applied to cucumber was calculated by the following equation.

Total amount of water to be applied (V), lit per plot = (A x d) / EU … (3)

Where,
A = Total area of treatment plot, m^2
d = Net depth of water, mm
EU = Emission uniformity of inline drip system, %

Time of water application (T) in each plot will be calculated as below.

$T = V / (q \times n)$ … (4)

Where,
V = Total amount of water to be applied, lit.
q = Average discharge rate of emitter, lit h^{-1}
n = Number of emitters per plot

The experimental size was 25 m x 20 m. The cucumber variety Fadia (Parthenocarpic, beit alpha hybrid) planted at a spacing of 0.5 m x 1.0 m on 19 March, 2021. This variety is suitable for protected cultivation. It bears 2-3 fruits per node - Fadia brings in average 3 fruits per internode, the setting is strong and all together it results into high production. The irrigation applications and fertilizer applications were as per treatment details. The agronomic practices and plant protection practices were common to all treatments. The following growth, fruit, yield and economic parameters of cucumber under different irrigation and fertigation combinations were recorded during the investigation.

Growth dynamics of cucumber
Following growth parameters of cucumber vine were recorded for each treatment.

Germination count
The seeds of cucumber which fails to geminate after sowing were again transplanted with plants grown in trays for gap filling. The plant count was taken after sowing by counting the number of plants germinated over the total number of plants in each plot and final count was taken before harvesting.

Days to 50% flowering
The number of days required for flower initiation was recorded from the sowing to the date at which 50% flowers were visible from each treatment plot.

Length of vine: The length of main shoot of vine was measured from the collar of stem up to the growing tip with the help of a metallic tape for labeled plants at 30, 60 DAS and at the harvest and average length of vine was worked out for each treatment plot.

Fruit characteristics: Four fruits from each plot were randomly selected for recording observations as given below.

Number of fruits per plant: The number of fruits harvested from each plant at each harvesting was counted and recorded.

Length of fruit
The length of four randomly selected fruits from each treatment plot from stalk end to end was measured by scale in cm and average length of fruits was worked out.

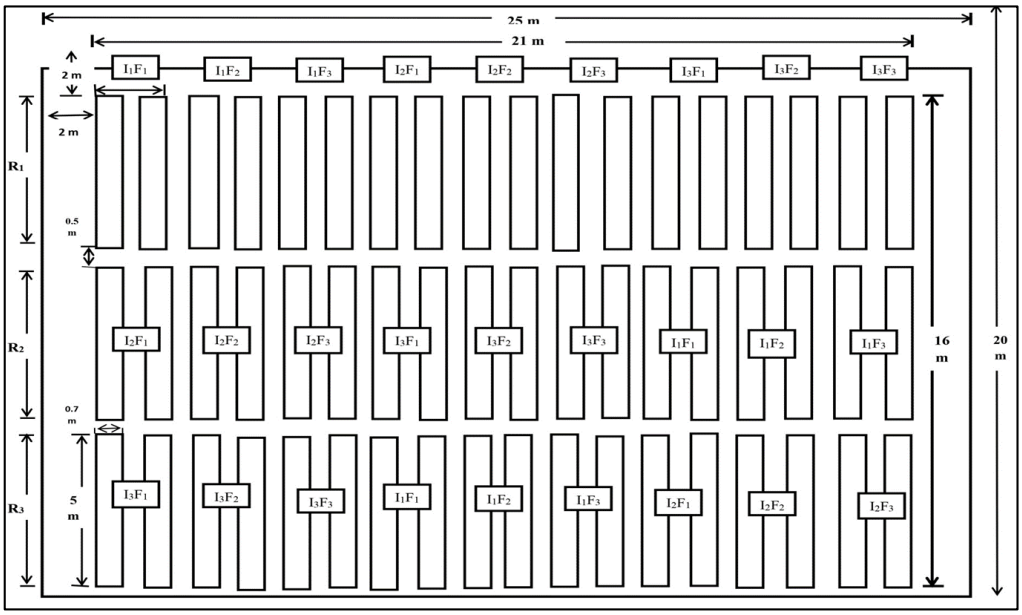

Fig 1: Experimental layout

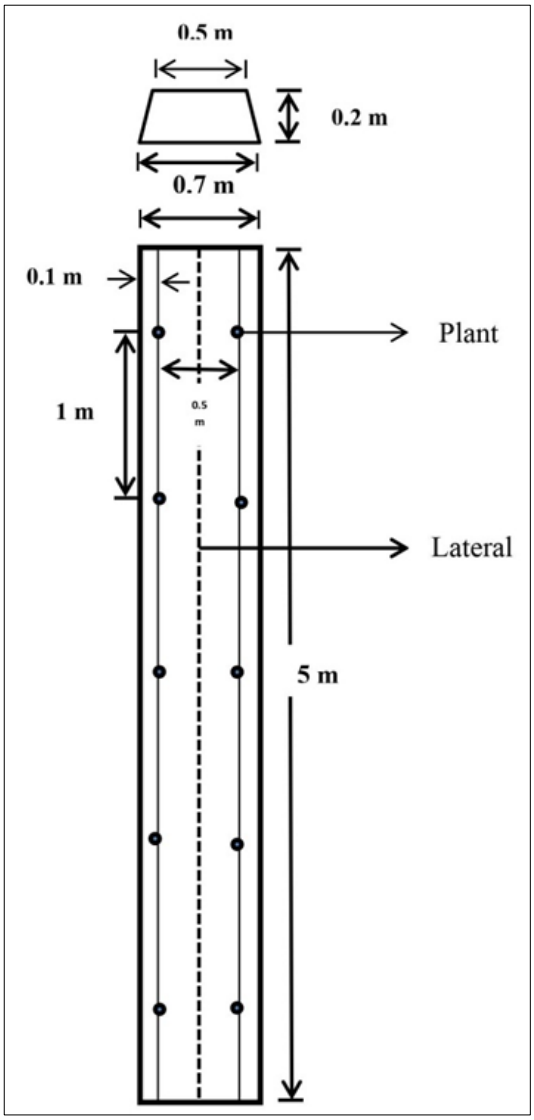

Fig 2: Specification of bed and planting details

Diameter of fruit: The diameter of four randomly selected fruits from each plot was measured at middle portion of the fruit in cm and average diameter of fruit was worked out.

Weight of fruit: Immediate after the harvest, the four randomly selected fruits from each plot were weighed on electronic balance and average weight was determined and recorded.

Yield contributing parameters: Following yield contributing parameters of cucumber were recorded for each treatment.

Yield of cucumber fruits per plant: The overall yield of cucumber fruits in kg per plant was recorded for each treatment.

Yield of cucumber fruits per square metre: The overall yield of cucumber in kg m^{-2} was recorded for each treatment.

Yield of cucumber fruits per 1008 m^2: The overall yield of cucumber in kg per 1008 m^2 was recorded for each treatment.

Cost economics: The economics of cucumber production was worked out for different treatments.

Cost of production: The cost of production was worked out for each treatment. The variable cost includes paid out cost on hired human labour, machine labour, seeds, fertilizers, water charges, supervision charges and interest on working capital, interest on fixed capital, depreciation, repair and maintenance for drip irrigation system and polyhouse.

Gross monetary returns: The gross monetary returns per 1008 m^2 were worked out by considering the cucumber yield obtained from different treatments and the prevailing market prices of commodities.

Net monetary returns: The net returns per 1008 m^2 were worked out by subtracting the cost of production from the gross returns, in each treatment.

Benefit cost ratio: The benefit cost ratio (B:C ratio) was worked out by dividing the cost of production to the gross returns in each treatment.

Statistical analysis: The data pertaining to growth, fruit and yield characters as well as economic feasibility parameters were tabulated treatment-wise and replication-wise. The statistical analysis of data was done by statistical method known as "Analysis of variance" (ANOVA) appropriate for the "Factorial randomized block design". The data regarding each character were statistically computed. The standard error (S.Em. ±) for each factor and their interaction was worked out. Wherever the results vary significant, critical difference (C.D.) at 5% level of significance of corresponding degree of freedom was worked out.

Results and Discussion

Effect of irrigation and fertigation levels on growth characteristics of cucumber under polyhouse condition

Plant count (initial and final plant population): The seeds of cucumber which fails to germinate after sowing were again sown for gap filling. The data regarding initial and final plant count as influenced by different treatments are recorded. The initial plant population at 30 DAS was 100% and final plant population at harvest was also 100%, which indicated that the plant population was uniform in the experimental plot throughout the experimental period.

Days to 50% flowering: The data regarding number of days required to 50% flowering influenced by different irrigation and fertigation levels are shown in Table 2. Among the different irrigation levels, 60% ETc. exhibited early flowering as the days required for 50% flowering were observed significantly minimum (21.19 days) in 60% ETc. irrigation level followed by 80% ETc. i.e., 22.57 days. The irrigation level 100% ETc. recorded significantly highest days (24.59 days) for 50% flowering over rest of the irrigation levels. This might be due to good vegetative growth of cucumber vines flowered late under optimum irrigation level (100% ETc.) and vice-versa. Whereas, minimum days required for 50% flowering were observed in fertigation level 100% RDF (21.33 days) which were significantly superior over rest of the fertigation levels. The significantly highest days for 50% flowering were observed under fertigation level 150% of RDF (24.11 days) followed by 125% of RDF (22.92 days). The days required for 50% flowering were non-significantly influenced by the interaction effect of irrigation and fertigation levels.

Table 2: Effect of irrigation and fertigation levels on growth characteristics of cucumber under polyhouse condition

Treatments	Days to 50% flowering	Vine length of cucumber, m		
		30 DAS	60 DAS	At harvest
A. Irrigation level (I)				
I1: 100% ETc.	24.59	1.18	2.34	3.23
I2: 80% ETc.	22.57	1.15	2.26	3.16
I3: 60% ETc.	21.19	1.09	2.21	3.14
S.Em±	0.31	0.02	0.02	0.01
C.D. at 5%	0.93	0.06	0.08	0.05
B. Fertigation level (F)				
F1: 150% RDF	24.11	1.23	2.32	3.24
F2: 125% RDF	22.92	1.20	2.30	3.18
F3: 100% RDF	21.33	1.00	2.19	3.11
S.Em±	0.31	0.02	0.02	0.01
C.D. at 5%	0.93	0.06	0.08	0.05
C. Interaction (I x F)				
S.Em±	0.53	0.03	0.04	0.03
C.D. at 5%	NS	NS	NS	NS

Vine length of cucumber

The statistically analyzed data for vine length of cucumber at 30, 60 days after sowing (DAS) and at harvest influenced by different irrigation and fertigation regimes are presented in Table 2. It is observed from Table 2 that significantly maximum average vine length of cucumber at harvest was observed in irrigation level 100% ETc. (3.23 m) followed by 80% ETc. (3.16 m). The irrigation level 60% ETc. (3.14 m) was at par with 80% ETc. (3.16 m). Anita *et al.* (2019) [1] also recorded highest length of cucumber vine at 30, 60 DAS and at harvest under 100% ETc. in naturally ventilated polyhouse. Rolaniya *et al.* (2018) [8] also recorded similar type of results under 100% ETc. to cucumber grown in polyhouse. Whereas, the maximum average vine length of cucumber at harvest was observed in 150% RDF (3.24 m) which was significantly superior over level 125% RDF (3.18 m) and level 100% RDF (3.11 m). The interaction effect of irrigation and fertigation levels on average vine length of cucumber was non-significant.

Effect of irrigation and fertigation levels on fruit characteristics of cucumber under polyhouse condition

Number of cucumber fruits per plant: The number of fruits per vine is the most important yield attributing character which ultimately determines the productivity of the crop. It is observed from Table 3 that the maximum average number of cucumber fruits were observed in irrigation level 100% ETc. (31.11) which was significantly superior over irrigation level 80% ETc. (28.89) and irrigation level 60% ETc. (28.22). However, the irrigation levels 80% ETc. and 60% ETc. were at par with each other. Rolaniya *et al.* (2018) [8] also recorded highest number of fruits per plant in 100% ETc. Whereas, the fertigation level 150% RDF recorded significantly highest number of cucumber fruits per plant (31.44) followed by 125% RDF (29.89) and 100% RDF (26.89). Patil and Gadge (2016) [7] recorded highest number of fruits per plant with application of 125% NPK RDF through drip irrigation system.

Table 3: Effect of irrigation and fertigation levels on fruit characteristics of cucumber under polyhouse condition.

Treatments	Number of fruits per cucumber plant	Average length of cucumber fruit (cm)	Average diameter of cucumber fruit (cm)	Average weight of cucumber fruit, g
A. Irrigation level (I)				
I1: 100% ETc.	31.11	16.84	4.59	200.40
I2: 80% ETc.	28.89	16.70	4.32	188.49
I3: 60% ETc.	28.22	15.69	3.70	180.29
S.Em±	0.39	0.14	0.09	1.91
C.D. at 5%	1.18	0.43	0.28	5.75
B. Fertigation level (F)				
F_1:150% RDF	31.44	17.44	4.45	194.37
F_2:125% RDF	29.89	17.04	4.42	191.64
F_3:100% RDF	26.89	14.75	3.75	183.17
S.Em±	0.39	0.14	0.09	1.91
C.D. at 5%	1.18	0.43	0.28	5.75
C. Interaction (I x F)				
S.Em±	0.68	0.25	0.16	3.32
C.D. at 5%	2.06	0.75	0.48	9.96

The average number of cucumber fruits per plant was significantly influenced by interaction effect of irrigation and fertigation levels (Table 4). The significantly highest average number of cucumber fruits per plant (33.33) was observed under treatment combination 100% ETc x 150% RDF. Whereas, the minimum average number of a cucumber fruits per plant were (25.00) under 60% ETc x 100% RDF treatment.

Table 4: Interaction effect of irrigation and fertigation levels on fruit characteristics of cucumber under polyhouse condition.

Treatment combinations	No. of fruits per plant	Average length of cucumber fruit	Average diameter of cucumber fruit	Average weight of cucumber fruit
$I_{100\%ETc}$ x $F_{150\%\ RDF}$	33.33	18.15	4.99	209.02
$I_{100\%ETc}$ x $F_{125\%\ RDF}$	30.33	17.82	4.94	206.00
$I_{100\%ETc}$ x $F_{100\%\ RDF}$	30.33	14.55	3.86	186.18
$I_{80\%ETc}$ x $F_{150\%\ RDF}$	31.33	17.48	4.55	191.53
$I_{80\%ETc}$ x $F_{125\%\ RDF}$	30.00	17.31	4.64	188.93
$I_{80\%ETc}$ x $F_{100\%\ RDF}$	25.33	15.31	3.76	185.00
$I_{60\%ETc}$ x $F_{150\%\ RDF}$	30.33	16.70	3.80	182.55
$I_{60\%ETc}$ x $F_{125\%\ RDF}$	29.33	15.98	3.68	180.00

$I_{60\%ETc}$ x $F_{100\%\ RDF}$	25.00	14.39	3.62	178.33
S.Em±	0.68	0.25	0.16	3.32
C.D. at 5%	2.06	0.75	0.48	9.96

Length of cucumber fruit: The fruit length is the most important desired marketable and commercial character in parthenocarpic cucumber. The irrigation and fertigation levels had significant effect on the average length of cucumber fruit (Table 3). The maximum average length of cucumber fruit was observed in irrigation level 100% ETc. (16.84 cm) which was at par with irrigation level 80% ETc. (16.70 cm) and significantly superior than level 60% ETc. (15.69 cm). The irrigation level 80% ETc. was significantly superior over level 60% ETc. Rolaniya *et al.* (2018) [8] found maximum length of fruit (13.04 cm) in 100% ETc. irrigation treatment. In case of fertigation, the fertigation with 150% RDF recorded maximum average length of cucumber fruit (17.44 cm) which was at par with fertigation level 125% RDF (17.04 cm) and significantly superior over 100% RDF (14.75 cm). Whereas, the fertigation level 125% RDF was significantly superior to 100% RDF. The values of parthenocarpic cucumber fruit length ranged from 11.07 cm to 22.00 cm under shade net house (Nagamani *et al.*, 2019) [6].

The average length of cucumber fruit was significantly influenced by interaction effect of irrigation and fertigation levels (Table 4). The treatment combination 100% ETc. x 150% RDF recorded higher average length of a cucumber fruit (18.15 cm) which was at par with 100% ETc. x 125% RDF (17.82 cm) and 80% ETc. x 150% RDF (17.48 cm). Whereas, interaction effect of 60% ETc. x 100% RDF found significantly lower average length of a cucumber fruit (14.39 cm) which was at par with 100% ETc. x 100% RDF (14.55 cm).

Diameter of cucumber fruits: The average diameter of cucumber fruits were significantly affected by different irrigation and fertigation levels (Table 3). It is observed from Table 3 that the maximum average diameter of cucumber fruit was observed in irrigation level 100% ETc. (4.59 cm) which was at par with irrigation level 80% ETc. (4.32 cm) and significantly superior than level 60% ETc. (3.70 cm). The irrigation level 80% ETc. was significantly superior to level 60% ETc. Rolaniya *et al.* (2018) [8] found maximum fruit girth (3.67 cm) in 100% ETc. irrigated treatment. Whereas, the maximum average diameter of cucumber fruit was observed in fertigation level of 150% RDF (4.45 cm) which was at par with fertigation level 125% RDF (4.42 cm) and significantly superior than level 100% RDF (3.75 cm). Further, the fertigation level 125% RDF was significantly superior than fertigation level 100% RDF.

The average diameter of cucumber fruit was significantly influenced by interaction effect of irrigation and fertigation levels (Table 4). The interaction effect of 100% ETc. x 150% RDF recorded significantly higher average diameter of a cucumber fruit (4.99 cm) which were at par with 100% ETc. x 125% RDF (4.94 cm), 80% ETc. x 150% RDF (4.55 cm) and 80% ETc. x 125% RDF (4.64 cm). Whereas, 60% ETc. x 100% RDF treatment combination found significantly lower average diameter of a cucumber fruit was (3.62 cm) which were at par with 60% ETc. x 150% RDF (3.80 cm), 60% ETc. x 125% RDF (3.68 cm), 80% ETc. x 100% RDF (3.76 cm) and 100% ETc. x 100% RDF (3.86 cm).

Weight of cucumber fruit: Fruit weight is one of the key yield components which are positively associated with yield. The average weight of cucumber fruits influenced by different irrigation and fertigation regimes are presented in Table 3. The irrigation levels and fertigation levels had significant effect on the average weight of cucumber. The average weight of cucumber fruit was observed significantly highest in irrigation level 100% ETc. (200.40 g) followed by 80% ETc. (188.49 g) and 60% ETc. (180.29 g). Rolaniya *et al.* (2018) [8] found maximum average fruit weight in 100% ETc. irrigated treatment. In case of fertigation effect, the maximum average weight of cucumber fruit was observed in fertigation level 150% RDF (194.37 g) which was at par with fertigation level 125% RDF (191.64 g) and significantly superior than level 100% RDF (183.17 g). Whereas, the fertigation level 125% RDF was significantly superior to 100% RDF.

It is found from Table 4 that the average weight of cucumber fruit was significantly influenced by interaction effect of irrigation and fertigation levels. The treatment 100% ETc. x 150% RDF recorded significantly higher average weight of a cucumber fruit (209.02 g) which was at par with 100% ETc. x 125% RDF (206.00 g). The treatment combination 60% ETc. x 100% RDF found significantly lower value of average weight of a cucumber fruit (178.33 g) which were at par with 100% ETc. x 100% RDF (186.18 g), 80% ETc. x 100% RDF (185.00 g), 60% ETc. x 150% RDF (182.55 g) and 60% ETc. x 125% RDF (180.00 g).

Effect of irrigation and fertigation levels on yield characteristics of cucumber under polyhouse condition

Yield of cucumber fruits per plant: The statistically analysed data on yield of cucumber fruits per plant influenced by different irrigation and fertigation levels are presented in Table 5. The irrigation levels and fertigation levels had significant effect on the yield of cucumber fruits per plant. It is revealed from Table 5 that the irrigation level 100% ETc. recorded significantly highest yield of cucumber fruits per plant (6.29 kg/plant) followed by level 80% ETc. (5.45 kg/plant). Whereas, the significantly minimum yield of cucumber per plant (5.45 kg/plant) was observed under 60% ETc. Rolaniya *et al.* (2018) [8] also recorded highest yield of cucumber per plant in 100% ETc. In case of fertigation, significantly maximum yield of cucumber per plant was observed in fertigation level 150% RDF (6.17 kg/plant) followed by 125% RDF (5.73 kg/plant). The fertigation level 100% RDF recorded significantly lowest yield of cucumber per plant (4.93 kg/plant). The yield of cucumber fruits per plant was non-significantly influenced by interaction effect of irrigation and fertigation levels. The values of parthenocarpic cucumbers fruit yield per plant ranged from 4.24 Kg/plant to 7.70 Kg/plant under shade net house (Nagamani *et al.* 2019) [6].

Yield of cucumber fruits per square metre: The average yield of cucumber fruits per square meter influenced by different irrigation and fertigation levels are presented in Table 5. It is revealed from Table 5 that the irrigation level 100% ETc. recorded significantly highest yield of cucumber per square meter (12.58 kg/m^2) followed by level 80% ETc. (10.90 kg/m^2) and 60% ETc. (10.18 kg/m^2). The significantly minimum yield of cucumber per square meter was observed under I_3 (60% ETc.). The significantly maximum yield of

cucumber per plant was observed in fertigation level F_1 (12.34 kg/m^2) followed by F_2 (11.46 kg/m^2) and level F3 (9.86 kg/m^2). The fertigation level F_2 was significantly superior to F_3. The yield of cucumber fruits per square meter was non-significantly influenced by interaction effect of irrigation and fertigation levels. Nagamani *et al.* (2019) [6] found that the fruit yield of parthenocarpic cucumbers per plant ranged from 8.23 kg/m^2 to 21.33 kg/m^2 under shade net house.

Table 5: Effect of irrigation and fertigation levels on yield characteristics of cucumber under polyhouse condition.

Treatments	Yield of cucumber per plant (kg/plant)	Yield of cucumber per square meter (kg m^{-2})	Yield of cucumber q per 1008 m^2
A. Irrigation level (I)			
I1: 100% ETc.	6.29	12.58	126.76
I2: 80% ETc.	5.45	10.90	109.90
I3: 60% ETc.	5.09	10.18	102.66
S.Em±	0.09	0.18	1.86
C.D. at 5%	0.27	0.55	5.60
B. Fertigation level (F)			
F1: 150% RDF	6.17	12.34	124.35
F2: 125% RDF	5.73	11.46	115.56
F3: 100% RDF	4.93	9.86	99.42
S.Em±	0.09	0.18	1.86
C.D. at 5%	0.27	0.55	5.60
C. Interaction (IxF)			
S.Em±	0.16	0.32	3.23
C.D. at 5%	NS	NS	NS

Yield of cucumber fruits per 1008 square metre: The yield of a cucumber fruits per 1008 square meter were influenced by irrigation and fertigation levels are shown in Table 5. It is observed that maximum yield of cucumber per 1008 square meter was observed in irrigation level 100% ETc. (126.76 kg/1008 m^2) which was significantly superior over 80% ETc. (109.90 kg/1008 m^2) and 60% ETc. (102.66 kg/1008 m^2). Whereas, irrigation level 80% ETc. was significantly superior to 60% ETc. This might be due to optimum water applied under 100% ETc. treatment for cucumber plant growth. It is further observed that the cucumber yield increased with increased application irrigation water amount. Hence, the irrigation with 100% ETc. is suggested to irrigate cucumber grown in summer under polyhouse condition.

The fertigation effect showed that 150% RDF recorded significantly maximum yield of cucumber per 1008 square meter (124.35 q/1008 m^2) followed by 125% RDF (115.56 q/1008 m^2) and level 100% RDF (99.42 q/1008 m^2). The fertilizer (150% RDF) applied was found more effective towards yield improvement as parthenocarpic cucumber variety Fadiya grown well and yielded more in polyhouse as compare with other fertigation levels. Whereas, the significantly lowest yield of cucumber per 1008 square meter (99.42 q/1008 m^2) was observed under fertigation level 100% RDF). Patil and Gadge (2016) [7] recorded maximum yield of cucumber under fertigation with 125% RDF in shade net house. It is observed that the cucumber yield increased with increased application fertilizer amount. Hence, the fertigation with 150% RDF is suggested for better growth and yield of cucumber in summer under polyhouse condition. Whereas, interaction effect of irrigation and fertigation levels on yield of cucumber fruits per 1008 meter square was non-significant. The fruit yield of parthenocarpic cucumbers per ha (variety Fadiya) was found to be 144.43 t/ha under shade net house (Nagamani *et al.*, 2019) [6]. The yield of cucumber fruits per 1008 meter square was non-significantly influenced by interaction effect of irrigation and fertigation levels (Table 5).

Effect of irrigation and fertigation levels on cost economics of Cucumber cultivation under polyhouse condition

The data on cost of cultivation, gross and net monetary returns, benefit: cost ratio of cucumber as influenced by different treatments are presented in Table 6.

Cost of cultivation: It is observed from Table 6 that the cost of cultivation per 1008 m^2 was highest (₹162466/-) in treatments 100% ETc. x 150% RDF, 80% ETc. x 150% RDF and 60% ETc. x 150% RDF. The lowest cost of cultivation per 1008 m^2 (₹161236/-) was found in 100% ETc. x 100% RDF, 80% ETc. x 100% RDF and 60% ETc. x 100% RDF.

Gross monetary returns: The differences in respect of gross monetary returns were found due to the various treatments under study. The gross monetary returns obtained under different treatments varied from ₹ 359789/- to ₹ 562034/-. The maximum gross monetary returns per 1008 m2 of ₹ 562034/- was obtained under the treatment of 100% ETc. x 150% RDF. The minimum gross monetary returns (₹359789/) was obtained by treatment combination 60% ETc. x 100% RDF.

Net monetary returns: The net monetary returns obtained under different treatments varied from ₹ 198553/- to ₹ 399568/- (Table 6). The maximum net monetary returns of (₹ 399568/-) was obtained under the treatment combination 100% ETc. x 150% RDF and the minimum net monetary returns of (₹ 198553/-) was under 60% ETc. x 100% RDF.

Table 6: Economics of cucumber cultivation as affected by different treatments of different environmental condition, irrigation and fertigation regimes.

Treatments	Cost of cultivation, ₹/1008 m2	Gross income, ₹/1008 m2	Net Income, ₹ /1008 m2	B:C Ratio
$I_{100\%ETc}$ x $F_{150\%\ RDF}$	162466	562034	399568	3.46
$I_{100\%ETc}$ x $F_{125\%\ RDF}$	161731	483679	321948	2.99
$I_{100\%ETc}$ x $F_{100\%\ RDF}$	161236	446463	285227	2.77
$I_{80\%ETc}$ x $F_{150\%\ RDF}$	162466	503812	341346	3.10
$I_{80\%ETc}$ x $F_{125\%\ RDF}$	161731	457162	295431	2.83
$I_{80\%ETc}$ x $F_{100\%\ RDF}$	161236	425698	264462	2.63
$I_{60\%ETc}$ x $F_{150\%\ RDF}$	162466	455320	292854	2.80
$I_{60\%ETc}$ x $F_{125\%\ RDF}$	161731	377933	216202	2.34
$I_{60\%ETc}$ x $F_{100\%\ RDF}$	161236	359789	198553	2.23

Benefit: Cost Ratio

It is found from Table 6 that the B: C ratio obtained under different treatments varied from 2.23 to 3.46. The maximum B:C ratio of 3.45 was obtained under the treatment combination 100% ETc. x 150% RDF. Whereas, the minimum B: C ratio of 2.23 was recorded in 60% ETc. x 100% RDF.

Conclusions

Irrigation scheduled daily with drip @ 100% ETc. and fertigation @ 150% RDF twice in a week with 27 equal splits is suggested for maximum cucumber yield, net monetary returns and B:C ratio grown in summer season under polyhouse condition.

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