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Effect of drip irrigation uniformity and soil moisture on growth and yield of chilli (*Capsicum annum* L.)

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Abstract
The present study was conducted at All India Coordinated Research Project on Vegetable Crops, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar during summer and *late kharif* 2018-19.
The experiment was laid out in split plot design with three replications and sixteen treatment combinations, which comprises four levels of irrigation *viz.*, I_1-0.7ETc, I_2-0.8 ET_C, I_3-0.9 ET_C and I_4-1.0ETc by drip irrigation as main plot treatments and four levels of fertigation *viz.*, F_1-125, F_2-100, F_3-75 and F_4-50% of RDF through WSF as sub-plot treatments. The control treatment (I_5) i.e. surface irrigation with 100% RDF through conventional fertilizers.
The results indicated that higher drip irrigation uniformity significantly improved soil moisture distribution, resulting in better vegetative growth and increased yield. Application of irrigation at 0.8 ETc level coupled with fertigation level F_2-100% RDF through WSF recorded significantly maximum yield plant^{-1}(444.49, 953.67 and 699.08 g, respectively), yield plot^{-1}(14.22, 30.52 and 22.37 kg, respectively) and total yield hectare^{-1}(123.47, 264.91 and 194.19 q, respectively).The study highlighting the importance of maintaining high irrigation system efficiency and appropriate moisture level to enhance water use efficiency and crop productivity in chilli cultivation.

Keywords: Chilli, drip discharge, emission uniformity, soil moisture, growth and yield

1. Introduction

Chilli (*Capsicum annuum* L.) is a member of Solanaceae family, extensively cultivated throughout tropical Asia and equatorial America for their edible, pungent fruits. India is the largest producer and exporter of chillies, the major chillies producing states are Andhra Pradesh, Karnataka, Maharashtra, Orissa, Tamil Nadu, West Bengal, Madhya Pradesh, Rajastan, Gujarat and Assam, Annual production of Andhra Pradesh is 5, 26, 171 tonnes.
Drip irrigation uniformity and its impact on soil moisture distribution are crucial for efficient water management and crop production. This introduction explores the importance of achieving high uniformity in drip irrigation systems and how this affects soil moisture patterns, ultimately influencing crop yield and water use efficiency. The way water spreads within the soil is crucial for plant water uptake. Uniformity in water application ensures that a larger portion of the soil volume is adequately moistened, supporting healthy root development and nutrient uptake.
This system uses less water and can be worked with low pressure. There is high availability of water in the root zone, minimum foliage wetting and possibility of using low quality water. It can deliver liquid fertilizers and pesticides mixed with irrigation water effectively and are not subjected to water loss through seepage and evaporation. There is saving of about 50 to 75 per cent water in drip method of irrigation with an increase in yield upto 50 per cent (Sivanappan, 1979) [11].

2. Materials and Methods

The experiment was conducted at All India Coordinated Research Project on Vegetable Crops, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar during summer and *late kharif* 2018-19.
The experiment was laid out in split plot design with three replications and sixteen treatment combinations, which comprises of four levels of irrigation *viz.*, I_1-0.7 ETc, I_2-0.8 ET_C, I_3-0.9 ET_C and I_4-1.0 ETc by drip irrigation as main plot treatments and four levels of fertigation

viz., F_1-125, F_2-100, F_3-75 and F_4-50% of RDF through WSF as sub plot treatments. The control treatment (I_5) i.e. surface irrigation with 100% RDF through conventional fertilizers.

2.1 Drip irrigation
In drip irrigation method, scheduling of irrigation was done at every alternate days on the basis of reference crop evapotranspiration (ETr) and crop coefficients (Kc). The reference crop evapotranspiration (ETr) was estimated by using FAO based Penman-Monteith method (Allen *et al.*, 1998) [1]. The daily data of reference crop evapotranspiration (ETr, mm day^{-1}) was available from Department of Irrigation and Drainage Engineering MPKV., Rahuri. They estimated ETr values from the daily data *viz.*, maximum and minimum temperature (^{0}C), maximum and minimum relative humidity (RH%), wind speed and sunshine hours obtained from Automatic weather Station (AWS) installed at farm and Phule Jal Software. The details of scheduling of drip irrigation are given in Appendix-II.

2.2 Daily crop coefficient (Kc)
The daily crop coefficient required for computing the daily crop evapotranspiration was estimated using the fifth degree polynomial equation. This equation was developed from the stage wise crop coefficient value obtained from FAO for chilli crop (Allen *et al.*, 1998) [1].
The quantity of water applied per plot on every alternate day was estimated by the following formula.

The crop evapotranspiration was estimated using equation

$$ETc = ETr \times Kc$$

Where,
ETc - Crop evapotranspiration (mm day^{-1})
ETr - Reference crop evapotranspiration (mm day^{-1})
Kc - Crop coefficient.

The volume of water to be applied was computed as

$$V = ETc \times A \times Wa$$

Where,
V - Volume of water to be applied (lit. alternate day^{-1} plot^{-1})
ETc - Crop evapotranspiration (mm)
A - Area of one plot (m^2)
Wa - Wetted area of chilli (0.6)

The time of operation (hr) was computed as,

$$T = \frac{V}{Q \times N \times Eu} \times 60$$

Where,
V - Volume of water to be applied (lit. alternate day^{-1} plot^{-1})
Q - Emitter discharge (lph)
N - Number of emitters per plot
Eu - Field emission uniformity (%)

2.3 Surface irrigation
Irrigations were applied at 50 mm cumulative ETr with 5 cm depth at each irrigation turn. Total volume of water to the applied to surface irrigation plot was estimated by the following equation (Michael, 1978) [4] and details are given in Appendix-II

$$V = \frac{(A \times D)}{Ea}$$

Where,
V - Volume of water to be applied (lit.)
A - Area of plot (m^2)
D - Depth of irrigation to be applied (mm)
Ea - Application efficiency (fraction)

Application efficiency was considered as 100% as the water was applied to the surface irrigation plot directly with the help of pipe. Time of application was calculated by following equation.

$$\text{Time of application (min.)} = \frac{\text{Amount of water to be applied (lit.)}}{\text{Discharge of pipe (lit. min}^{-1}\text{) x Numbers of pipes}}$$

2.4 Average discharge (lph) and emission uniformity (%)
The average discharge of each plot of drip irrigation system was measured at monthly interval and emission uniformity was estimated by the procedure suggested by Nakayama and Bucks (1986) [6]. For this purpose from each treatment and each replication discharge was measured by collecting the water from specified emitters in the catch can for three min. The specified emitters were from head, middle and tail end of laterals. The constant operating pressure of 1 kg/cm^2 was maintained throughout the period of application. The same pressure was maintained during the application of irrigation water also. The emitter discharge was used for evaluation of emission uniformity. The formula used for estimation of field emission uniformity is presented below,

$$Eu = \frac{q_{min}}{q_{avg}} \times 100$$

Where,
Eu - Emission uniformity (%)
q_{min} - Average discharge of minimum quarter of emitter (lit. min^{-1})
q_{avg} - Average discharge of all emitter (lit. min^{-1})

2.5 Soil moisture content (%)
The soil moisture content was measured at 20 cm depth from 25 cm away from emitter point and parallel to the lateral (M_1). Similarly, at 25 cm horizontal distance from emitter point and perpendicular to the lateral (M_2), it was measured. The measurements were made with the help of portable soil moisture probe instrument at 15 days interval from days after transplanting.

3. Results and Discussion
3.1 Average drip discharge (lph)
Data regarding to average drip discharge influenced by the different levels of drip irrigation during summer and late *kharif*-2018 and presented in Table 1.
The average drip discharge for I_1-0.7 ETc, I_2-0.8 ETc, I_3-0.9 ETc and I_4-1.0 ETc were recorded higher before transplanting of chilli seedling in March 2018 (3.878,

3.880,3.879 and 3.877, respectively) and September 2018 (3.862, 3.864, 3.860 and 3.866 respectively) were as the minimum average drip discharge were observed at the end of investigation in August (3.854, 3.861, 3.851 and 3.849) and February 2019 (3.843, 3.848, 3.849 and 3.845, respectively).

3.2 Average emission uniformity (%)

Scrupulous study of data revealed that different levels of drip irrigation influenced average emission uniformity during summer and late *kharif*-2018 and presented in Table 2.

The data regarding to average emission uniformity for I_1-0.7 ETc and I_2 -0.8 ETc, I_3-0.9 ETc and I_4-1.0 ETc were observed maximum before transplanting of chilli seedling in March 2018 (94.92, 95.09, 95.01 and 94.72, respectively) and September 2018 (93.85, 93.89, 93.88 and 93.83, respectively) were as the minimum average drip discharge were observed at the end of investigation in August (93.18, 94.05, 93.02 and 92.54) and February, 2019 (92.08, 93.02, 92.12 and 92.12, respectively).

It indicates the excellent performance of drip irrigation system in supplying water uniformly through the laterals. The average discharge and emission uniformity were almost constant throughout the season. This may due to the fact that irrigation water quality was good and effective filtration system was used. Similar results were also reported by Patil (2006) [7], Gupta *et al.* (2010b) [3] and Mirjat *et al* (2010) [5].

3.3 Soil moisture content (%)

The observations of soil moisture content were recorded from different levels of drip irrigation at before and after irrigation during summer and late *kharif*-2018 and presented in Table 3 and 4.

It is apparent from data that the average values of for soil moisture content before irrigation were recorded maximum in I_4-1.0 ETc level of irrigation and it was observed in the range of 36.67 to 34.25 and 39.68 to 37.07 At M_1 (25 cm away from emitter point and parallel to the lateral),

whereas, 36.72 to 34.29 and 39.97 to 37.11 at M_2 (25 cm horizontal distance from emitter point and perpendicular to the lateral), while soil moisture content after irrigation it was found in the range of 37.81 to 35.48 and 42.52 to 38.11 at M_1 (25 cm away from emitter point and parallel to the lateral) 37.83 to 35.52 and 42.74 to 38.57 at M_2 (25 cm horizontal distance from emitter point and perpendicular to the lateral) during summer and late *kharif* season 2018-19, respectively.

However the minimum values for soil moisture content before irrigation was noticed in I_1- 0.7 ETc level of irrigation, which was recorded in the range of 31.45 to 28.15 and 35.62 to 31.62 at M_1 (25 cm away from emitter point and parallel to the lateral), whereas 31.52 to 28.19 and 35.81 to 31.92 at M_2 (25 cm horizontal distance from emitter point and perpendicular to the lateral), while soil moisture content after irrigation it was found in the range of 32.49 to 29.38 and 37.35 to 32.72 at M_1 (25 cm away from emitter point and parallel to the lateral) 32.56 to 29.45 and 37.85 to 32.78 at M_2 (25 cm horizontal distance from emitter point and perpendicular to the lateral) during summer and late *kharif* season 2018-19.

The moisture content at M_2 slightly higher than the M_1 indicates that the horizontal spread of water was more. It was also observed that the moisture content in I_4-1.0 ETc level of irrigation fairly maintained nearer to field capacity which indeed must had congenial condition in the root zone of crop during the growth and development period, which leads to higher uptake of nutrients and yield.

The moisture content at the early and late stage was less than mid stage of the chilli crop, during both the summer and late *kharif* season of investigation. This might be due to the quantity of applied water as per the water requirement of the chilli crop considering crop coefficient (Kc) and the evapotranspiration demand. These results are in conformity with the findings of Singandhupe *et al.* (2003) [10], El-Abedin (2006) [2], Patil (2006) [7], Shrivastava *et al.* (2011) [8] and Shrivastava *et al.* (2012) [9].

Table 1: Average drip discharge (lph) of chilli as influenced by different levels of irrigation and fertigation

Summer-2018				
Irrigation levels	**I_1-0.7 ETc**	**I_2-0.8 Etc**	**I_3-0.9 ETc**	**I_4-1.0 Etc**
March	3.878	3.880	3.879	3.877
April	3.876	3.878	3.874	3.873
May	3.872	3.872	3.871	3.871
June	3.869	3.870	3.868	3.865
July	3.858	3.868	3.854	3.852
August	3.854	3.861	3.851	3.849
Late *Kharif* -2018-19				
Irrigation levels	**I_1-0.7 ETc**	**I_2-0.8 Etc**	**I_3-0.9 ETc**	**I_4-1.0 Etc**
September	3.862	3.864	3.860	3.866
October	3.858	3.862	3.859	3.863
November	3.850	3.861	3.856	3.861
December	3.848	3.856	3.852	3.858
January	3.846	3.850	3.850	3.852
February	3.843	3.848	3.849	3.845

Table 2: Average emission uniformity (%) of chilli as influenced by different level of irrigation & fertigation

Summer-2018				
Irrigation levels	**I_1-0.7 ETc**	**I_2-0.8 ETc**	**I_3-0.9 ETc**	**I_4-1.0 ETc**
March	94.92	95.09	95.01	94.72
April	94.62	94.85	94.55	94.48
May	94.36	94.36	94.32	94.12
June	94.01	94.25	94.12	93.85
July	93.28	94.12	93.10	92.95
August	93.18	94.05	93.02	92.54
Late *Kharif* -2018-19				
Irrigation levels	**I_1-0.7 ETc**	**I_2-0.8 ETc**	**I_3-0.9 ETc**	**I_4-1.0 ETc**
September	93.85	93.89	93.88	93.83
October	93.14	93.74	93.68	93.76
November	93.11	93.58	93.42	93.56
December	92.58	93.44	92.58	92.95
January	92.28	93.12	92.36	92.48
February	92.08	93.02	92.12	92.12

Table 3: Soil moisture content (%) influenced by the different levels of drip irrigation summer -2018

Irrigation levels	Before irrigation							
	I_1-0.7 ETc		I_2-0.8 ETc		I_3-0.9 ETc		I_4-1.0 ETc	
DAT	M_1	M_2	M_1	M_2	M_1	M_2	M_1	M_2
15	28.34	28.33	30.25	30.31	32.19	32.65	34.39	34.48
30	28.56	28.63	30.48	30.51	32.61	32.74	34.62	34.69
45	29.56	29.67	31.16	31.58	33.85	33.81	35.21	35.24
60	29.73	29.91	31.64	31.62	33.34	33.41	35.47	35.58
75	31.39	31.34	32.79	32.65	34.52	34.69	36.27	36.61
90	31.45	31.52	33.16	33.21	34.85	34.73	36.67	36.72
105	30.22	30.12	33.05	33.18	34.03	34.09	36.31	36.37
120	29.44	29.48	32.35	32.56	33.13	33.14	35.74	35.81
135	28.24	28.31	32.14	32.18	32.91	32.86	34.98	35.13
150	28.15	28.19	31.56	31.68	33.82	32.42	34.25	34.29
After irrigation								
DAT	M_1	M_2	M_1	M_2	M_1	M_2	M_1	M_2
15	29.38	29.45	31.38	31.42	33.79	33.82	35.48	35.52
30	29.72	29.76	31.57	31.64	33.63	33.69	35.70	35.74
45	30.75	30.79	32.06	32.14	34.46	34.51	36.02	36.11
60	30.77	30.91	32.86	32.71	34.79	34.84	36.69	36.76
75	32.13	32.11	33.75	33.83	35.86	35.78	37.48	37.55
90	32.49	32.56	34.41	34.45	35.92	35.89	37.81	37.83
105	32.38	32.43	33.97	34.11	35.26	35.51	37.57	37.45
120	31.46	31.35	33.42	33.36	34.15	34.27	37.01	37.17
135	31.13	31.15	33.20	33.16	34.02	34.18	36.44	36.52
150	30.59	30.64	32.95	32.88	33.19	33.11	36.08	36.21

Table 4: Soil moisture content (%) influenced by the different levels of drip irrigation late *Kharif* -2018-19

Irrigation levels	Before irrigation							
	I_1-0.7 ETc		I_2-0.8 ETc		I_3-0.9 ETc		I_4-1.0 ETc	
DAT	M_1	M_2	M_1	M_2	M_1	M_2	M_1	M_2
15	31.62	31.71	33.49	33.54	35.53	35.68	37.07	37.11
30	31.85	31.92	33.79	34.82	35.78	35.87	37.35	37.39
45	32.15	32.26	34.58	34.69	36.21	36.16	37.53	37.80
60	34.29	33.38	34.64	34.74	36.35	36.47	38.12	38.29
75	34.38	33.43	34.92	35.15	36.62	36.59	38.21	38.29
90	34.58	33.62	35.15	35.29	37.07	37.11	38.51	38.71
105	34.68	33.73	35.69	35.78	37.35	37.39	39.18	38.26
120	35.22	35.35	35.57	35.64	37.53	37.59	39.53	38.62
135	35.58	35.68	35.66	35.84	37.64	37.74	39.68	38.76
150	35.62	35.81	35.60	35.99	37.81	37.99	39.81	39.97
After irrigation								
DAT	M_1	M_2	M_1	M_2	M_1	M_2	M_1	M_2
15	32.72	32.78	34.58	34.91	36.58	36.71	38.11	38.57
30	32.95	34.12	35.11	35.21	36.81	36.91	38.63	38.78
45	33.28	33.53	35.58	35.96	37.15	37.29	39.15	39.32
60	34.48	34.58	36.12	36.29	37.43	37.61	39.51	39.68
75	34.61	34.86	36.51	36.68	37.71	37.93	40.11	40.39
90	35.72	36.15	36.71	36.91	38.15	38.51	40.51	40.81
105	34.32	34.79	37.18	3751	38.56	38.75	41.18	41.39
120	34.85	34.99	37.68	37.98	38.81	38.99	41.53	41.86
135	35.07	37.21	38.04	38.44	39.06	39.45	41.95	42.16
150	37.35	37.85	38.67	38.82	39.51	39.77	42.52	42.74

4. Conclusion

The performance of chilli was assessed under different levels of irrigation during the period of investigation the overall average discharge was found to be 3.8 lit. h^{-1} and emission uniformity of drip irrigation system greater than 92.08 per cent during summer and late *kharif* 2018-19, respectively. Also the average values of for soil moisture content before and after irrigation were recorded maximum in I_4-1.0 ETc level of irrigation at M_1 (25 cm away from emitter point and parallel to the lateral) and M_2 (25 cm horizontal distance from emitter point and perpendicular to the lateral), during both the season of investigation.

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