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Influence of infield variability in irrigation and fertigation levels on growth and yield of summer chilli (*Capsicum annuum* L.)

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Abstract
A field experiment entitled "Impact of Irrigation and Fertigation Levels on Growth, Yield and Quality of Summer Chilli (*Capsicum annuum* L.)" was carried out during summer season of 2018, in split plot design having main plot treatments as drip irrigation levels viz. I_1: at 0.7ETc, I_2: at0.8 ETc, I_3: at 0.9 ETc, I_4: at 1.0 ETc, and I_5: at 1.1 Etc and Sub-plot treatments as fertigation levels *viz.*F_1= 60 per cent of RDF, F_2= 80 per cent of RDF and F_3= 100 per cent of RDF with fifteen treatment combinations, replicated thrice. Results of the study indicates that the different drip irrigation levels on growth parameters and yield of chilli, drip irrigation levels between 80 to 100 per cent of crop evapotranspiration were found non -significant influence on the growth parameters and yield of chilli. Hence irrigation level of 80 per cent of crop evapotranspiration was found better among the all tested treatments. Whereas, application of different levels of fertigationin eleven had non-significant effect on plant height and plant spread of chilli at 30 and 60 DAT and found significant at 90 and 120 DAT. Yield of chilli was found highest in F_3(fertigation with 100% of RDF) treatment. Further fertigation levels with 100 per cent of RDF and 80 per cent of RDF was found statistically at par with each other for the above growth parameters at various stages of crop growth and yield of chilli. Therefore, fertigation with 80 per cent RDF in eleven splits was found optimum. Interaction effect of different irrigation and fertigation level was found non-significant.

Keywords: Drip irrigation, fertigation, chilli growth, yield

Introduction
In view of worsening water scarcity and raising water demand, the available water resources should be very effectively utilized through water saving irrigation technologies. The need of the hour is, therefore, to maximize the production per unit of water. Hence, further expansion of irrigation may depend upon the adoption of new systems such as pressurized irrigation methods with the limited water resources. Amongst those pressurized irrigation methods, drip irrigation has proved its superiority over other methods of irrigation due to high efficiency and the direct application of water and nutrients in the vicinity of root zone, matching the crop water needs. Because of reduced water loss and uniform water application in precise quantity drip system has higher irrigation efficiency of more than 90 per cent.

Fertilizer is the costliest input after water, in agriculture. Apart from the economics consideration it is also well known that the adverse effect of injudicious use of water and fertilizer on the environment can have far reaching implications. There is, therefore, a need for technological options, which will help in sustaining the precious resources and maximizing crop production without any detrimental impact on the environment. Fertigation opened up new possibilities for controlling water and nutrient supplies to the crops. By introducing fertigation, it is possible to save the water and fertilizers about 45-50 per cent and 30 per cent with increasing the productivity about 40 per cent respectively (Sivanappan and Ranghaswami, 2005) [15].

Chilli (*Capsicum annuum* L.) belongs to the *Solanaceae* family, has its unique place in the diet as a vegetable cum spice crop. Chilli is an indispensable spice due to its pungency, taste, appealing colour and flavor. It is the second largest commodity after black pepper (*Piper nigrum* L.) in the international spice trade. *Capsicum* spp. contain a range of essential nutrients and bioactive compounds which are known to exhibit antioxidant, antimicrobial, antiviral,

anti-inflammatory and anticancer properties (Khan *et al.*, 2014) [7]. It is predominantly popular for its green pungent fruits, which is used for culinary purpose. The nutritive value of chilli is excellent with different types of protein, vitamin and ascorbic acid contents and has of medicinal potential of especially anti-cancerous and instant pain relief.
India is the largest producer, consumer and exporter of chilli, which contribute to 25per cent of total world's production. In India, chilli is grown in almost all the states across the length and breadth of the country. Chilli being a long duration crop, it responds to split application of nutrients *i.e.,* nitrogen, phosphorus and potassium. It responds well to fertigation with 11 to 22 applications in terms of increased growth and yield properties besides, higher water and fertilizer use efficiencies compared to conventional methods of fertigation. Pungency and colour are two important characters liked by consumers. Some nutrients are known to play an important role in maintaining these characters. Nitrogen is an essential component of nucleic acid and has been suggested to improve the development of vegetative structures and thereby yield (Glass, 1989) [4]. Potassium is well known for its role in improving quality. Potassium improves colour, glossiness and dry matter accumulation in fruits (Subhani *et al.*, 1990) [16]. Since, chilli is a spice crop with tremendous export potential, the yield and quality are the important factors to be considered which can be achieved only through optimum nutrient application.

Materials and Methods

The field experiment entitled **"**Impact of Irrigation and Fertigation Levels on Growth, Yield and Quality of *Summer* Chilli (*Capsicum annuum* L.)" was undertaken during *summer* season of year 2017-18 at Experimental farm, College of Agriculture, Badnapur, VNMKV, Parbhani.

Experimental Details

The experimental field was laid out as per plan after preparatory operations. The layout consisted of fifteen treatments arranged randomly, in split plot design with three replications in a field of 40m x 36m size. The gross length and width of each main plot treatment *i.e.* drip irrigation level was 7x36m, divided into three sub plot treatment *i.e.* fertigation levels with each of size 7x12m. Net plot size for each treatment combination was 6x3.6m. A space of 1.0m was provided between two treatments as a buffer strip to avoid lateral movement of water from treatment to treatment.

Irrigation Scheduling

To assess the influence of infield variability irrigation levels on chilli, crop was irrigated with five drip irrigation levels as per the treatments. Irrigations were applied at an alternate day on the basis fraction of crop evapotranspiration (ETc) as per the treatments *i.e.* I_1: at 0.7ETc, I_2: at 0.8 ETc, I_3: at 0.9 ETc, I_4: at 1.0 Etc, and I_5: at 1.1 ETc, throughout the complete crop period of chilli.

The ETc was computed as given by equation (3.1)

$$ETc = ETr \times Kc.... \qquad (3.1)$$

Where,
ETc = Crop evapotranspiration (mm/day)
ETr = Reference crop evapotranspiration (mm/day)
Kc = Crop coefficient

The FAO Penman-Monteith method was used to estimate ETr as given by equation (3.2)

$$ETr = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u(e_s - e_a)}{\Delta + \gamma\,(1+0.34u_2)}........ \qquad (3.2)$$

Where,
ETr = Potential evapotranspiration (mm/day)
ssRn = Net radiation at the crop surface (MJ/m/day)
G = Soil heat flux density (MJ/m/day)
T = Mean daily air temperature at 2 m height (°C)
u2 = Wind speed at 2 m height (m/s)
es = Saturation vapours pressure (kPa)
ea = Actual vapour pressure (kPa)
es-ea = Saturation vapour pressure deficit (kPa)
Δ = Slope vapour pressure curve (kPa/°C)
γ = Psychometric constant (kPa/°C)

ETr values were computed by "Phule Jal App" developed by Gorantiwar and Palkar. It calculates the ETr values by different standard methods automatically by fetching the real time data from the weather service provider and estimate the evapotranspiration at the specified location. It has provision to fill up the input data manually also.

Fertigation

Water soluble 19:19:19 and Urea (46% N) was used as a source of NPK. The recommended dose of fertilizer (NPK) for chilli crop is 120:80:80 kg/ha. To assess the influence of different fertigation levels *i.e.*F_1 at 60 per cent, F_2 at 80 per cent and F_3 at 100 per cent of RDF fertilizers were applied in eleven splits during the critical growth stages of chilli (Establishment stage, Vegetative growth, Flowering and fruiting and Fruit maturity to harvest: 02, 03, 03 and 03 splits, respectively).

Growth parameters: Observations on the crop characteristics indicating growth of the crop i.e. plant height, number of branches per plant, plant spread were recorded in five randomly selected plants in each treatment were recorded at 30, 60, 90 days after transplanting and at final harvestby adopting standard procedure.

Yield: Yield of the total fruits of the chillies harvested in different pickings (Four potential) from the sample plants in each treatment was recorded and averages was worked out to estimate yield in tonnes per hectare.

Result and Discussion

Irrigation scheduling

Irrigations were scheduled at an alternate day on the basis of different treatments of chilli crop evapotranspiration over the whole crop period of chilli crop. Amount of irrigation water to be given was varied according to the treatment which is based on crop evapotranspiration.

Table 1: Number of irrigations and gross depth of irrigation water applied for different treatments during 2017-2018

Treatment	Number of irrigations	Total depth of irrigation water applied (mm)
		2018
I_1 = Drip irrigation at 0.7 ETc	55	417
I_2 = Drip irrigation at 0.8 ETc	55	477
I_3=Drip irrigation at 0.9 ETc	55	536
I_4=Drip irrigation at 1.0 ETc	55	596
I_5=Drip irrigation at 1.1 ETc	55	655

Influence of different irrigation and fertigation levels on growth parameters

Plant height

The data on plant height (cm) as influenced by Irrigation levels and fertigation levels and their interactions was recorded in different interval *i.e.* 30, 60, 90 and 120 DAT presented in Table 2. Data reveals that, the irrigation levels were significantly influenced the plant height at 30, 60, 90 and 120 days after transplanting (DAT) of chilli. Significantly highest plant height was recorded under the treatment I4 (38.56 cm, 55.24cm, 78.45cm and 98.31cm respectively) followed by I3 (37.84cm, 54.20cm, 77.71cm and 97.48cm respectively) and I2 (36.94cm, 53.53cm, 76.89 cm and 96.54 cm respectively) and these treatments were found at par with one another. However, except for 30 DAT, treatment I_5 (36.22cm) was found to be at par with I_4. The plant height was significantly lowest under the treatment I1 (30.63cm, 43.99cm, 63.09cm and 79.14cm respectively) at different DAT.

As the excess water supplied above its evapotranspiration needs does not found beneficial to increase the plant height of chilli. The results of present study are well supported by Nagalakshmi *et al.* (2002) [12]. She documented that among the different irrigation regimes, irrigation at 0.80 (IW/CPE) recorded significantly higher plant height, number of fruits, length and breadth of fresh fruit including yield per ha followed by I2 and I1. The higher amount of growth and yield might be due to increased availability of soil moisture with more frequent irrigations. Similar results are also documented by (Abou-Hussein *et al.* 1984, Ramamurthy 1988, Antony and Singandhupe 2004 and Gopala Reddy *et al*. 2018 for brinjal) [1, 14, 2, 5].

Whereas, application of different levels of fertigation had non-significant effect on plant height of chilli at 30 and 60 DAT and found significant at 90 and 120 DAT. Due to the effect of fertigation levels, significantly maximum plant height was observed in treatment F3 (76.53cm and 95.81cm) followed by the treatment F2 (74.36 and 93.55cm) at different dates *i.e.*, 90 and 120 DAT respectively and both the treatments were found at par with each other. The plant height was minimum in treatment F1 (71.76cm and 89.93cm respectively).

The increased plant height at 80per cent RDF through fertigation might be due to the optimum availability of moisture which facilitated for production of better root biomass resulting better nutrient uptake from the soil. Earlier similar results are reported by Nathulal and Pundrik (1971) [13] wherein the application of nitrogen at higher levels brought out a very large increase in plant height, due to rate of enhancement of chlorophyll synthesis, which causes an increase in carbohydrate synthesis responsible for higher vegetative growth. The results of present study are in conformity with the reports of (Takele *et al*. 2009 for green paperand Gopala Reddy *et al*. 2018 for brinjal) [17, 5].

The interaction effect of irrigation and fertigation levels was noticed non-significant on the plant height of chilli at 30, 60, 90 and 120 DAT.

Table 2: Effect of different irrigation and fertigation levels on chilli plant height (cm)

Treatments	Plant height (cm)			
	At 30 DAT	At 60 DAT	At 90 DAT	At 120 DAT
A) Main Plot (Irrigation levels)				
I_1= Drip irrigation at 0.7 ETc	30.63	43.99	63.09	79.14
I_2= Drip irrigation at 0.8 ETc	36.94	53.53	76.89	96.54
I_3= Drip irrigation at 0.9 ETc	37.84	54.20	77.71	97.48
I_4= Drip irrigation at 1.0 ETc	38.56	55.24	78.45	98.31
I_5= Drip irrigation at 1.1 ETc	36.22	52.39	74.96	94.03
S.E. ±	0.99	0.57	1.05	1.23
C.D. at (P=0.05)	2.93	1.7	3.10	3.64
B) Sub Plot (Fertigation levels)				
F_1= 60% of RDF	34.72	50.45	71.76	89.93
F_2= 80% of RDF	35.78	51.26	74.36	93.55
F_3= 100% of RDF	37.62	53.89	76.53	95.81
S.E. ±	1.33	1.33	1.20	1.58
C.D. at (P=0.05)	NS	NS	3.53	4.65
C) Interaction (I X F)				
S.E. ±	2.97	2.96	2.68	3.53
C.D. at (P=0.05)	NS	NS	NS	NS
General Mean	36.04	51.87	74.22	93.10

Number of branches per plant

The data pertaining to number of branches per plant as influenced by Irrigation and fertigation levels and their interactions recorded on different interval *i.e.* 30, 60, 90 and 120 DAT presented in Table 3.

The data indicates that, the irrigation and fertigation levels were significantly influenced the number of branches at 30, 60, 90 and 120 days after transplanting (DAT) of chilli. Significantly highest number of branches was recorded under the treatment I4 (5.50, 7.27, 9.35 and 11.30 respectively) followed by the treatment I3 (5.47, 7.24, 9.29 and 11.23 respectively) and treatment I2 (5.43, 7.18, 9.21 and 11.14 respectively) and these treatments were found at par with one another. However, except for 30 DAT treatment I_5 (5.39) was found to be at par with I_4. The number of branches was lowest under the treatment I1 (4.32, 5.80, 7.5 and 9.06 respectively) at different DAT.

It is concluded from the results of effect of drip irrigation levels on number of branched of chilli shows that the excess water supplied above its evapotranspiration needs does not found beneficial. Earlier the similar results were documented by Klickvenga and Siddiq (1985) [8] opined that chilli was sensitive to both water deficit and surplus, providing too much water results in anaerobic condition within root zone. While insufficient water inhibits leaf expansion and photosynthetic capacity. Similar results are documented earlier by (Ramamurthy 1988, Antony and Singandhupe 2004 and Gopala Reddy *et al*., 2018) [14, 2, 5].

The effect of application of different levels of fertigation had showed significant effect on number of branches of chilli at 30, 60, 90 and 120 DAT. Due to the effect of fertigation levels, significantly maximum number of branches were observed in treatment F3 (5.40, 7.18, 9.19 and 11.24 respectively) followed by treatment F2 (5.32, 7.06, 9.02 and 11.01 respectively) at different dates *i.e.* 30, 60, 90 and 120 DAT respectively and both the treatments were found at par with each other. The number of branches was found minimum in treatment F1 (4.94, 6.48, 8.38 and 9.88 respectively).

It might be due to greater Co_2 concentration and improved soil temperature enhancing the vegetative growth of plants. Favourable weather condition and soil moisture are the important parameters affect the number of branches per plant. Earlier similar findings have been also documented by (Takele *et al*., 2009 for green paper and Nadiya *et al.*, 2013 for chilli) [17, 11].

The interaction effect of irrigation and fertigation levels was noticed non-significant on the number of branches of chilli at 30, 60, 90 and 120 DAT.

Table 3: Influence of different irrigation and fertigation levels on number of branches of chilli.

Treatments	Number of branches per plant			
	At 30 DAT	At 60 DAT	At 90 DAT	At 120 DAT
A) Main Plot (Irrigation levels)				
I_1= Drip irrigation at 0.7 ETc	4.32	5.80	7.50	9.06
I_2= Drip irrigation at 0.8 ETc	5.43	7.18	9.21	11.14
I_3= Drip irrigation at 0.9 ETc	5.47	7.24	9.29	11.23
I_4= Drip irrigation at 1.0 ETc	5.50	7.27	9.35	11.30
I_5= Drip irrigation at 1.1 ETc	5.39	7.02	8.95	10.82
S.E. ±	0.04	0.042	0.078	0.082
C.D. at (P=0.05)	0.12	0.124	0.23	0.24
B) Sub Plot (Fertigation levels)				
F_1= 60% of RDF	4.94	6.48	8.38	9.88
F_2= 80% of RDF	5.32	7.06	9.02	11.01
F_3= 100% of RDF	5.40	7.18	9.19	11.24
S.E. ±	0.053	0.056	0.098	0.12
C.D. at (P=0.05)	0.15	0.16	0.28	0.35
C) Interaction (I X F)				
S.E. ±	0.12	0.125	0.21	0.27
C.D. at (P=0.05)	NS	NS	NS	NS
General Mean	5.22	6.90	8.86	10.71

Plant spread (cm)

The data in respect to plant spread (cm) as influenced by Irrigation levels and fertigation levels and their interactions on plant spread recorded in different interval *i.e.* 30, 60, 90 and 120 DAT was presented in Table 4.

Data indicates that during the year 2018, the irrigation levels were significantly influenced the plant spread at 30, 60, 90 and 120 days after transplanting (DAT) of chilli. Significantly higher plant spread was recorded under the treatment I4 (14.18cm, 24.18cm, 34.82cm and 46.14cm respectively) followed by I3 (14.04cm, 23.84cm, 34.30cm and 45.45cm respectively) and I2 (13.91cm, 23.61cm, 33.97cm and 45.01cm respectively) and these treatments were found at par with one another. However, except for 30 and 60 DAT treatment I_5 (13.74cm and 23.03cm) was found to be at par with I_4. The plant spread was lower under the treatment I1 (11.33cm, 19.94cm, 29.18cm and 38.66cm respectively) at different DAT.

It clearly indicates that as the excess water supplied above its evapotranspiration needs does not found beneficial to increase the plant spread of chilli. Earlier Klickvenga and Siddiq (1985) [8] opined that chilli was sensitive to both water deficit and surplus, providing too much water results in anaerobic condition within root zone. While insufficient water inhibits leaf expansion and photosynthetic capacity. Similar results are reported by Ughade and Mahadkar (2015) [18] for brinjal.

Whereas, application of different levels of fertigation had non-significant effect on plant spread of chilli at 30 and 60 DAT and found significant at 90 and 120 DAT. Due to the effect of fertigation levels, significantly maximum plant spread was observed in treatment F3 (34.17cm and 46.22cm) followed by the treatment F2 (33.25 and 43.86cm) at different dates *i.e.*, 90 and 120 DAT respectively and both the treatments were found at par with each other. The plant spread was minimum in F1 (31.10cm and 40.38cm respectively).

It might be due to greater Co_2 concentration and improved soil temperature enhancing the vegetative growth of plants. Findings of present study are in conformity with (Takele *et al*., 2009 for green paper, Nadiya *et al.*, 2013 and Maind *et al.*, 2018 for chilli) [17, 11, 9].

The interaction effect of irrigation and fertigation levels was noticed non-significant on the plant spread of chilli at 30, 60, 90 and 120 DAT.

Table 4: Influence of different irrigation and fertigation levels on plant spread of chilli

Treatments	plant spread of chilli			
	At 30 DAT	At 60 DAT	At 90 DAT	At 120 DAT
A) Main Plot (Irrigation levels)				
I_1= Drip irrigation at 0.7 ETc	11.33	19.94	29.18	38.66
I_2= Drip irrigation at 0.8 ETc	13.91	23.61	33.97	45.01
I_3= Drip irrigation at 0.9 ETc	14.04	23.84	34.30	45.45
I_4= Drip irrigation at 1.0 ETc	14.18	24.18	34.82	46.14
I_5= Drip irrigation at 1.1 ETc	13.74	23.03	31.84	42.19
S.E. ±	0.21	0.45	0.97	0.82
C.D. at (P=0.05)	0.63	1.33	2.88	2.43
B) Sub Plot (Fertigation levels)				
F_1= 60% of RDF	12.83	22.32	31.1	40.38
F_2= 80% of RDF	13.31	22.92	33.25	43.86
F_3= 100% of RDF	14.19	23.53	34.17	46.22
S.E. ±	0.58	0.74	0.62	1.29
C.D. at (P=0.05)	NS	NS	1.84	3.81
C) Interaction (I X F)				
S.E. ±	1.31	1.65	1.40	2.89
C.D. at (P=0.05)	NS	NS	NS	NS
General Mean	13.44	22.92	32.82	43.49

Yield of chilli per ha (tonnes per ha)

The data pertaining to yield of chilli (tonnes per ha) as influenced by Irrigation and fertigation levels and their interactions recorded and presented in Table 4.17 and graphically depicted in Fig. 5.

The data indicates that during the year 2018, the irrigation and fertigation levels were significantly influenced the yield of chilli per ha In the main plot treatment with different irrigation levels, significantly highest yield of chilli per ha was recorded under the treatment I_4 (17.02tonnes per ha) followed by the treatment I_3 (16.46tonnes per ha) and treatment I_2 (16.21tonnes per ha) and these treatments were found at par with one another. The next followed treatment was I_5 (15.84tonnes per ha). The yield of chilli per ha was lowest under the treatment I_1 (13.61tonnes per ha).

These results are also well supported earlier by Abou-Hussein *et al.*, 1984 [1] and Nesthad *et al*., 2013 [11].

In the sub plot treatment, the fertigation with different levels of fertigation had showed significant effect on yield of chilli per ha Due to the effect of fertigation levels, significantly maximum yield per ha was observed in treatment F_3 (17.31tonnes per ha) followed by treatment F_2 (16.27tonnes per ha) and both the treatments were found at par with each other. The yield of chilli per ha was found minimum in treatment F_1 (13.91tonnes per ha).

It might be due to optimum replenishment of water and nutrients in the effective root zone during critical periods of nutrient demand, which improve the physiological and photosynthetic activities enhancing the vegetative and productive growth of plants. The increased yield under drip irrigation might have resulted due to better water utilization (Manfrinato, 1974) [10], higher uptake of nutrients (Bafna *et al*., 1993) [3] and excellent soil-water relationship with higher oxygen concentration in the root zone (Gornet *et al*., 1973) [6].

The interaction effect of irrigation and fertigation levels was noticed non-significant on the yield of chilli per ha.

Table 5: Effect of different irrigation and fertigation levels on yield of chilli (tonnes per ha)

Treatments	Yield of chilli (tonnes / ha)
A) Main Plot (Irrigation levels)	
I_1= Drip irrigation at 0.7 ETc	13.61
I_2= Drip irrigation at 0.8 ETc	16.21
I_3= Drip irrigation at 0.9 ETc	16.46
I_4= Drip irrigation at 1.0 ETc	17.02
I_5= Drip irrigation at 1.1 ETc	15.84
S.E. ±	0.37
C.D. at (P=0.05)	1.09
B) Sub Plot (Fertigation levels)	
F_1= 60% of RDF	13.91
F_2= 80% of RDF	16.27
F_3= 100% of RDF	17.31
S.E. ±	0.69
C.D. at (P=0.05)	2.04
C) Interaction (I X F)	
S.E. ±	1.55
C.D. at (P=0.05)	NS
General Mean	15.83

Conclusion

During the assessment of different drip irrigation levels on growth parameters and yield of chilli, drip irrigation levels between 80 to 100 per cent of crop evapotranspiration were found non -significant influence on the growth parameters and yield of chilli. Hence irrigation level of 80 per cent of crop evapotranspiration was found better among the all tested treatments. Whereas, application of different levels of fertigationin eleven had non-significant effect on plant height and plant spread of chilli at 30 and 60 DAT and found significant at 90 and 120 DAT. Yield of chilli was found highest in F_3 (fertigation with 100% of RDF)treatment. Further fertigation levels with100 per cent of RDF and 80 per cent of RDF was found statistically at par with each other for the above growth parameters at various stages of crop growth and yield of chilli. Therefore, fertigation with 80 per cent RDF in eleven splits was found optimum. Interaction effect of different irrigation and fertigation level was found non-significant.

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