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Assessment of fruit quality, dry matter yield and nutrient uptake of *Summer* chilli (*Capsicum annuum* L.) for different irrigation and fertigation levels

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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 0.7 ETc, 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 for different drip irrigation levels, the ascorbic acid content of chilli was found optimum with drip irrigation at 0.80 of crop evapotranspiration and fertigation with 80 per cent of RDF applied in eleven splits, with 20 per cent saving of irrigation water and fertilizer. Oleoresin content of chilli was not influenced by different drip irrigation levels, however, it was found to be optimum to fertigation with 80 per cent of RDF. The significant differences on dry matter yield and nutrient uptake were observed for different drip irrigation and fertigation levels. As drip irrigation levels between 80 to 100 per cent of crop evapotranspiration were found statistically at par with each other for dry matter yield and nutrient uptake by chilli, irrigation level of 80 per cent of crop evapotranspiration was found optimum among the all tested treatments. Whereas, for different levels of fertigation in eleven splits had significant effect on dry matter yield and nutrient uptake by chilli. Dry matter yield and nutrient uptake were 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 dry matter yield and nutrient uptake. Therefore, fertigation with 80 per cent RDF in eleven splits was found optimum.

Keywords: Drip irrigation, fertigation, fruit quality, dry matter yield, nutrient uptake

Introduction

There is a global crisis about water and its management. The crises are significantly about availability of water for use and its highly uneven spatial distribution. Due to the dynamic nature of the water resource and its varied usage, a tall order challenges are enhancing water availability, making it amenable for use and managing the distribution.

The need of the hour is, therefore, to maximize the agricultural production per unit of water *i.e.* more crop per drop of water. Hence, further expansion of irrigation may depend upon the adoption of new water saving 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. Drip irrigation system has the highest irrigation efficiency of more than 90 per cent due to the reduced water losses and uniform water application in precise quantity.

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) [16].

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. Characterized by its typical flavour and aroma, the species is noted for its richness in oleoresin, pungency and ascorbic acid contents. 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) [8]. 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) [5]. Potassium is well known for its role in improving quality. Potassium improves colour, glossiness and dry matter accumulation in fruits (Subhani *et al.*, 1990) [17]. 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 40 m x 36 m size. The gross length and width of each main plot treatment *i.e.* drip irrigation level was 7 x 36 m, divided into three sub plot treatment *i.e.* fertigation levels with each of size 7 x 12 m. Net plot size for each treatment combination was 6 x 3.6 m. A space of 1.0 m 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)

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

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)

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

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).

Ascorbic acid content

Chilli characterized by its typical flavour and aroma, is noted for its richness in oleoresin, pungency and ascorbic acid contents. The nutritive value of chilli is largely determined by the content of ascorbic acid. Total ascorbic acid content of mature green fruit was estimated with 2, 6-Dichlorophenol – Indephenol visual Titration method by using 2, 6 – dichlorophenol indophenol dye (AOAC, 1975) [1] and computed with the following formula.

$$\text{Ascorbic acid (mg } 100^{-1}\text{g}^{-1}) = \frac{\text{Titre value x Dye factor x Volume made up}}{\text{Aliquot of extract Taken for estimation} \times \text{Wt. of sample taken for estimation}} \times 100 \quad ... (3.3)$$

Oleoresin content

Chilli characterized by its typical flavour and aroma, is noted for its richness in oleoresin, pungency and ascorbic acid contents. Oleoresin, which represents the total flavour extract of the ground spice is now being extensively used in processed foods and pharmaceutical products.

Ten grams of chilli powder sample was taken in chromatographic column, plugged with stop cork, 50 ml of acetone was added and allowed overnight. The slurry was collected in a pre-weighed beaker and solvent was evaporated over a water bath. The collected slurry was cooled and weighed. Difference in weight over sample weight gives per cent oleoresin.

Dry matter yield

Five plants uprooted from the observation unit for recording the dry matter weight. After removing the roots, plant samples were kept in well labelled brown paper bag. First the samples were dried in shade. After that samples were placed in oven at 650C±20C temperature for drying, and then weight of dry matter was taken. The averages were worked out to estimate dry yield in q ha-1.

Nutrient uptake

The uptake of nitrogen, phosphorus and potassium were calculated using the following formula.

$$\text{Nutrient uptake (kg ha-1)} = \frac{\text{Nutrient content (\%) x Dry matter Yield (kg ha-1)}}{100} \quad \text{.... (3.4)}$$

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

Treatment	Number of irrigations	Total depth of irrigation water applied (mm)
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 Fruit quality

Ascorbic acid content of chilli

The data shows that the drip irrigation and fertigation levels significantly influenced the ascorbic acid content of chilli (mg $100g^{-1}$). In main plot treatment with different drip irrigation levels, significantly highest ascorbic acid content of chilli was recorded under the treatment I_4 (119.55 mg $100g^{-1}$), followed by the treatment I_3 (118.35 mg $100g^{-1}$) and treatment I_2 (117.80 mg $100g^{-1}$) and these treatments were found at par with each other. The ascorbic acid content of chilli was lowest under the treatment I_1 (110.10 mg $100g^{-1}$).

In the sub plot treatment, the different levels of fertigation had showed significant effect on ascorbic acid content of chilli. Due to the effect of fertigation levels, significantly maximum ascorbic acid content of chilli was observed in treatment F_3 (119.64 mg $100g^{-1}$), followed by treatment F_2 (116.73 mg $100g^{-1}$) and both the treatments were found at par with each other. The ascorbic acid content of chilli was found minimum in treatment F_1 (112.37 mg $100g^{-1}$). The interaction effect of drip irrigation and fertigation levels was noticed non-significant on the ascorbic acid content of chilli.

Earlier Ahmed *et al*. (2014) [8] documented that Vitamin C content in hot pepper fruit was significantly decreased by deficit irrigation treatments at various ripening stages. Water-holding capacity of 100 per cent and 85 per cent, respectively, resulted in the highest content of vitamin C obtained at the ripening stage. Similarly, Mahendran and Bandara (2000) illustrated that deficit irrigation has been found to cause a significant decrease in vitamin C content. Generally, leaf temperature progressively builds up as a consequence of moisture stress and contributes toward the reduction of vitamin C.

Oleoresin content of chilli

The data indicates that main plot treatment *i.e.* different drip irrigation levels had non-significant effect on the oleoresin content of chilli. In general, non-significant effect of drip irrigation levels on oleoresin content of fruits at harvest indicating that the fruit quality of paprika is more controlled by genetics than soil moisture level.

Whereas, in the sub plot treatment, the different levels of fertigation had significant effect on oleoresin content of chilli. For fertigation levels, significantly highest oleoresin content of chilli was observed in treatment F_3 (15.38%), followed by treatment F_2 (14.47%) and both the treatments were found at par with each other. The oleoresin content of chilli was found lowest in treatment F_1 (13.67%).

Dry matter yield of chilli

The data indicates that during the drip irrigation and fertigation levels significantly influenced the dry matter yield of chilli. In the main plot treatment with different drip irrigation levels, significantly highest dry matter yield of chilli was recorded under the treatment I_4 (19.50 q ha^{-1}), followed by the treatment I_3 (19.14 q ha^{-1}) and treatment I_2 (18.92 q ha^{-1}) and these treatments were found at par with each other. The dry matter yield of chilli was lowest under the treatment I_1 (15.36 q ha^{-1}).

In the sub plot treatment, the different levels of fertigation had showed significant effect on dry matter yield of chilli. Due to the effect of fertigation levels, significantly maximum dry matter yield of chilli was observed in treatment F_3 (19.15 q ha^{-1}), followed by treatment F_2 (18.32 q ha^{-1}) and both the treatments were found at par with each other. The dry matter yield of chilli was found minimum in treatment F_1(16.95 q ha^{-1}). The interaction effect of drip irrigation and fertigation levels was noticed non-significant on the dry matter yield of chilli.

Nutrient Uptake

Nitrogen uptake of chilli

The data indicates that the drip irrigation and fertigation levels significantly influenced the nitrogen uptake of chilli. In the main plot treatment with different drip irrigation levels, significantly highest nitrogen uptake of chilli was recorded under the treatment I_4 (43.10 kg ha^{-1}), followed by the treatment I_3 (41.15 kg ha^{-1}) and treatment I_2 (39.54 kg ha^{-1}) and these treatments were found at par with each other. The nitrogen uptake of chilli was lowest under the treatment I_1 (25.97 kg ha^{-1}).

In the sub plot treatment, the different levels of fertigation had showed significant effect on nitrogen uptake of chilli. Due to the effect of fertigation levels, significantly maximum nitrogen uptake of chilli was observed in treatment F_3 (40.60 kg ha^{-1}), followed by treatment F_2 (37.80 kg ha^{-1}) and both the treatments were found at par with each other. Nitrogen uptake of chilli was found minimum in treatment F_1 (32.60 kg ha^{-1}). The interaction effect of drip irrigation and fertigation levels was noticed non-significant on the nitrogen uptake of chilli.

Phosphorus uptake of chilli

The data indicates that the drip irrigation and fertigation levels significantly influenced the phosphorus uptake of chilli. In the main plot treatment with different drip irrigation levels, significantly highest phosphorus uptake of chilli was recorded under the treatment I_4 (3.90 kg ha^{-1}), followed by the treatment I_3 (3.73 kg ha^{-1}) and treatment I_2 (3.67 kg ha^{-1}) and these treatments were found at par with each other. The phosphorus uptake of chilli was lowest under the treatment I_1 (2.07 kg ha^{-1}).

In the sub plot treatment, the different levels of fertigation had showed significant effect on phosphorus uptake of chilli. Due to the effect of fertigation levels, significantly maximum phosphorus uptake of chilli was observed in treatment F_3 (3.68 kg ha^{-1}), followed by treatment F_2 (3.41 kg ha^{-1}) and both the treatments were found at par with each other. Phosphorus uptake of chilli was found minimum in treatment F_1 (2.75 kg ha^{-1}). The interaction effect of drip irrigation and fertigation levels was noticed non-significant on the phosphorus uptake of chilli.

Potassium uptake of chilli

The data indicates that the drip irrigation and fertigation levels significantly influenced the potassium uptake of chilli. In the main plot treatment with different drip irrigation levels, significantly highest potassium uptake of chilli was recorded under the treatment I_4 (36.08 kg ha^{-1}), followed by the treatment I_3 (34.64 kg ha^{-1}) and treatment I_2 (33.68 kg ha^{-1}) and these treatments were found at par with each other. The potassium uptake of chilli was lowest under the treatment I_1 (24.89 kg ha^{-1}).

In the sub plot treatment, the different levels of fertigation had showed significant effect on potassium uptake of chilli. Due to the effect of fertigation levels, significantly maximum potassium uptake of chilli was observed in treatment F_3 (34.85 kg ha^{-1}), followed by treatment F_2 (31.88 kg ha^{-1}) and both the treatments were found at par with each other. Potassium uptake of chilli was found minimum in treatment F_1 (28.31 kg ha^{-1}). The interaction effect of drip irrigation and fertigation levels was noticed non-significant on the potassium uptake of chilli.

Table 2: Effect of different irrigation and fertigation levels on chilli fruit quality

Treatments	Ascorbic acid of chilli (mg 100g^{-1})	Oleoresin content of chilli (%)
A) Main Plot (Irrigation levels)		
I_1= Drip irrigation at 0.7 ETc	110.10	13.95
I_2= Drip irrigation at 0.8 ETc	117.80	14.35
I_3= Drip irrigation at 0.9 ETc	118.35	14.85
I_4= Drip irrigation at 1.0 ETc	119.55	15.15
I_5= Drip irrigation at 1.1 ETc	115.4	14.25
S.E. ±	0.924	0.363
C.D. at (P=0.05)	2.72	NS
B) Sub Plot (Fertigation levels)		
F_1= 60% of RDF	112.37	13.67
F_2= 80% of RDF	116.73	14.47
F_3= 100% of RDF	119.64	15.38
S.E. ±	1.47	0.391
C.D. at (P=0.05)	4.34	1.15
C) Interaction (I X F)		
S.E. ±	3.29	0.875
C.D. at (P=0.05)	NS	NS
General Mean	116.24	14.51

Table 3: Effect of different irrigation and fertigation levels on Dry matter yield of chilli and Nutrient Uptake

Treatments	Dry matter yield of chilli (q ha^{-1})	Nitrogen uptake (kg ha^{-1})	Phosphorus uptake (kg ha^{-1})	Potassium uptake (kg ha^{-1})
A) Main Plot (Irrigation levels)				
I_1= Drip irrigation at 0.7 ETc	15.36	25.97	2.07	24.89
I_2= Drip irrigation at 0.8 ETc	18.92	39.54	3.67	33.68
I_3= Drip irrigation at 0.9 ETc	19.14	41.15	3.73	34.64
I_4= Drip irrigation at 1.0 ETc	19.50	43.10	3.90	36.08
I_5= Drip irrigation at 1.1 ETc	17.78	35.73	3.27	29.51
S.E. ±	0.221	1.241	0.0941	0.96
C.D. at (P=0.05)	0.651	3.65	0.277	2.81
B) Sub Plot (Fertigation levels)				
F_1= 60% of RDF	16.95	32.60	2.75	28.31
F_2= 80% of RDF	18.32	37.80	3.41	31.88
F_3= 100% of RDF	19.15	40.60	3.68	34.85
S.E. ±	0.456	0.978	0.116	1.03
C.D. at (P=0.05)	1.34	2.88	0.343	3.01
C) Interaction (I X F)				

S.E. ±	1.02	2.18	0.260	1.79
C.D. at (P=0.05)	NS	NS	NS	NS
General Mean	18.14	37.1	3.30	31.71

Conclusion
For different drip irrigation levels, the ascorbic acid content of chilli was found optimum with drip irrigation at 0.80 of crop evapotranspiration and fertigation with 80 per cent of RDF applied in eleven splits, with 20 per cent saving of irrigation water and fertilizer. Oleoresin content of chilli was not influenced by different drip irrigation levels, however, it was found to be optimum to fertigation with 80 per cent of RDF. Impact of different drip irrigation levels on total dry matter production and uptake of nutrients by chilli indicated that drip irrigation at 1.00 ETc were found to be significantly superior among the different drip irrigation levels. However, it were found at par with drip irrigation at 0.90 ETc and at 0.80 ETc. Thus drip irrigation at 0.8 of crop evapotranspiration was found to be better among all the tested treatments. Whereas, among the different levels of fertigation in eleven splits, fertigation with 100 per cent of RDF and 80 per cent of RDF were found statistically at par with each other in case of total dry matter production and nutrient uptake by chilli. Therefore, fertigation with 80 per cent RDF in eleven splits was found optimum. Interaction effect of different drip irrigation and fertigation level was found non-significant. Uptake was found lower in treatment of drip irrigation at 1.1 ETc. It might be due to regulated supply of water and nutrients directly to the root zone at various stages of crop growth, resulted in adequate availability of plant nutrients and with the increased density of functional roots in the root zone.

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