Impact of AI based irrigation scheduling approachesand drip irrigation methods on yield of chilli (*Capsicum annum* L.) and chemical properties of soil

ABSTRACT

Aim: To assess the effect of AI based irrigation scheduling approaches and drip irrigation methods on soil chemical properties and yield in chilli.

Study Design: The study employs drip irrigation methods as the main plots and irrigation scheduling approaches as the subplots. A split plot design was chosen as suitable design because the main plots (drip irrigation methods) need a bigger plot sizes and subplots (irrigation scheduling approaches) requires more precise results with smaller plot sizes.

Place and Duration of study: Water Technology Centre field, College Farm, College of Agriculture, Rajendranagar, Hyderabadduring *rabi* 2022-23 (first year) and 2023-24 (second year).

Methodology: The investigation consisted of two drip irrigation methods as main plots and four irrigation scheduling approaches as subplots with total of 8 treatment combinations replicated thrice. Data recorded on various parameters was subjected to scrutiny by ANOVA technique for split plot design concept.

Results: Green (fresh) fruit and stalk yield was found to be significantly higher under subsurface drip (41859 and 5107 kg ha^{-1})among drip irrigation methods; whereas, among irrigation scheduling approaches, ET sensor based irrigation triggering resulted in significantly higher green (fresh) fruit and stalk yield (43139and 5196 kg ha^{-1}) followed by irrigation scheduling at 1.0 Epan by manual (control) (42235 and 5065 kg ha^{-1}). The post-harvest soil chemical properties were found to be non-significantly influenced by drip irrigation methods and irrigation scheduling approaches.

Conclusions: Subsurface drip and ET sensor based irrigation triggering resulted in higher fruit and stalk yield which might be recommended for conserving irrigation water and reducing labour use.Whereas, the drip irrigation methods and irrigation scheduling approaches did not exert any significant influence on chemical properties of post-harvest soil.

***Keywords:** Automation, ET sensor, Fruit yield, Soil chemical properties, Subsurface drip.*

INTRODUCTION

Spices are aromatic vegetable ingredients that are used to season meals. Among them, chilli (*Capsicum annum* L.), a member of the Solanaceae family, is considered one of the most important commercial spice crops. Due to its pungency, flavor, appealing color and aroma, chilli is regarded as an essential spice. According to Khan *et al*. (2014), *Capsicum* spp. contains a variety of essential nutrients and bioactive compounds with anti-inflammatory, antiviral, antibacterial, antioxidant, and anticancer properties. During the period 2022-23, chilli is being cultivated in an area of 4.31 lakh ha with production of 4.77 Mt with an average productivity of 11.07 MT ha^{-1} (India Statistics, 2022-2023).

In the present context of climate change, there is need for increase in the productivity. Irrigation is regarded as the most important management factors in determining yield and quality of chilli crop (Demir *et al*., 2022). Therefore, micro-irrigation system, a modern method of irrigation has been developed rapidly in recent years and adopted for a variety of high-value crops in water scarce arid and semi-arid regions. Drip irrigation, in particular, has the potential to use limited water resources most efficiently to produce vegetables (Locascio, 2005), providing high application efficiency and ultimately achieving higher crop yields. However, applying irrigation at the right time and in the right amount is a challenge for farmers in water-scarce scenarios. Considering the case of developing countries with highly populated areas, the only way is to go smarter with the help of cutting edge technologies like the internet of things (IoT) and allied technologies like Artificial Intelligence (AI) (Subeesh and Mehta, 2021). Fully automated systems, where devices communicate with each other and use AI to determine the timing and amount of water to be applied, significantly reduce the need for human intervention. This approach has proven to be feasible and economical for optimizing irrigation water use in crop production.

MATERIAL AND METHODS

The present study was carried out during two consecutive seasons *rabi* 2022-23 and 2023-24 at Water Technology Centre field, College Farm, College of Agriculture, Rajendranagar, Hyderabad. The experimental site falls under the category of semi-arid climate situated in the Southern Telangana Zone. The soil of the experimental site was sandy loam with neutral in nature (7.48), non-saline (Electrical Conductivity (EC)-0.32dS m^{-1}), low in organic carbon (OC) (0.47%), low in available N and P (245.75kg ha^{-1}) high in available phosphorus (26.98 kg ha^{-1}) and potassium (338.32 kg ha^{-1}). The total rainfall of 75.0 and 16.0 mm was received during crop season 2022-23 and 2023-24 respectively.

The experiment was laid out in split plot design with two main plots as I_1- surface drip(0 cm) and I_2- subsurface drip(15 cm depth) and four subplots as S_1-soil moisture sensor based irrigation triggering, S_2-Plant water stress sensor based irrigation triggering, S_3-Evapotranspiration (ET) sensor based irrigation triggering (1.0 ET_c) and S_4-Irrigation scheduling at 1.0 Epan by manual (control). All the treatments were replicated thrice. Automatic irrigation for soil moisture sensor was set at 16.8% soil moisture content as the lower threshold value and 23.6% as the upper threshold value (S_1). The threshold values set for plant water stress sensor based irrigation were 0.3 and 0 crop water stress index (CWSI) as lower and higher threshold values respectively (S_2). Hargreaves empirical method was used to calculate evapotranspiration (S_3). The irrigation scheduling for control treatment was done manually based on daily weather data collected from the weather station (S_4).The sensors were calibrated before installation in the field with the above threshold values for proper functioning.

The chilli hybrid 'Devsena 88' was transplanted in the field during 25 days after sowing (DAS) at a spacing of 80/40 cm x 60 cm in paired rows. The crop was fertilized with 300:60:120 N:P_2O_5:K_2O ha^{-1} in the form of urea, SSP and SOP respectively. The entire dose of P_2O_5 was applied as basal before transplantation; whereas, urea and SOP were supplied at regular intervals as fertigation. Thesoil samples were collected after harvest of the crop from respective treatments from the depth of 0-20 cm using spade and after proper drying and crushing, a composite sample of half a kg was drawn using quartering method and sieved through 2 and 0.5 mm sieves for analysing the soil chemical properties such as pH was measured using glass electrode pH meter from 1:2.5-soil:water suspension (Jackson, 1973), EC (dS m^{-1}) was measured using solubridge method (Jackson, 1973) from 1:2.5-soil:water suspension at 25^0C, OC (%) was measured using Walkley and Black modified method (Walkley and Black, 1934), Available N (Alkaline potassium permanganate method (Subbaiah and Asija, 1956), P (Olsen's method for extraction and ascorbic method for estimation) (Olsen *et al*., 1954) and K (kg ha^{-1}) (Neutral normal ammonium acetate method) (Jackson, 1973). The total green (fresh) fruit yield harvested at total of six pickings and stalk yield at harvest were recorded from net plot area and furnished as kg ha^{-1}. The data recorded during the crop growth periods were subjected to statistical scrutiny. To test the significance, the critical difference (CD) was worked out with an 'F' test at a 5% level of significance.

RESULTS AND DISCUSSION

1. Green (fresh) fruit and stalk yield (kg ha^{-1})

The yield potential of a crop is influenced by both the selected cultivar and the management practices implemented. The sum of green fruit yield of all the pickings and stalk yield at harvest was computed and furnished in the Table 1. The analysis of variance presented in the Table 1, clearly indicated that drip irrigation methods and irrigation scheduling approaches significantly influenced the fruit and stalk yield. On contrary to this, their interaction effect did not influence the fruit and stalk yield significantly during both the years respectively. Significantly higher green fruit (40872 and 42848 kg ha^{-1}) and stalk yield(4967 and 5107 kg ha^{-1}) were registered with subsurface drip over surface drip among drip irrigation methods during 2022-23 and 2023-24 respectively. The results of higher fruit yield under subsurface drip irrigation method were in agreement with the research findings of Al-Mansor *et al*. (2015) in tomato, Kong *et al*. (2010) in bell pepper. Whereas, among irrigation scheduling approaches, ET sensor based irrigation triggering recorded significantly higher green fruit yield (42125 and 44153 kg ha^{-1}) and stalk yield (5123 and 5270 kg ha^{-1}) which was found to be at par with irrigation scheduling at 1.0 Epan manually (41243 and 43232 kg ha^{-1} fruit yield) and (4999 and 5130 kg ha^{-1} fruit yield) and remained significantly superior over other treatments during both the years of study respectively. These results are in accordance with the findings of Ghobari*et al*. (2014).The reason for increase in stalk yield could be attributed to delivering amount of water uniformly across the field according to the crop water requirements resulted in deeper and healthier root system which promoted the increased access to nutrient absorption and translocation resulting in higher leaf photosynthetic structures and their assimilate translocation ensuring sturdy and stronger stalks ultimately resulting in higher stalk yield. The above research findings were similar with the findings of Neelima*et al*. (2023).

2. Soil chemical properties

The data on soil chemical properties recorded and presented in the Table (2&3) indicated that post-harvest soil characteristics such as pH, EC (dS m^{-1}), OC (%), Available N, P and K (kg ha^{-1}) were not significantly affected by either drip irrigation methods or irrigation scheduling approaches. Additionally, the interaction between these factors also did not exert a statistically significant impact on soil chemical properties during both the years. There was no much difference was observed between initial and final values with respect to drip irrigation methods and irrigation scheduling approaches. With regard to drip irrigation methods, during 2022-23, the pH, EC and OC values were 7.46 and

7.49, 0.31 and 0.33 dS m^{-1} and 0.41 and 0.43%, while in 2023-24, they were 7.46 and 7.48, 0.32 and 0.33 dS m^{-1} and 0.40 and 0.42% respectively with the mean values as 7.46 and 7.49, 0.32 and 0.33 dS m^{-1} and 0.41 and 0.43% for surface and subsurface drip respectively. Similar non-significant pH values under different irrigation methods were previously reported by Liu *et al*. (2021). The available N, P and K (kg ha^{-1}) values recorded were 232.3 and 235.4, 22.8 and 24.9 and 319.4 and 322.5 kg ha^{-1} during 2022-23, while in 2023-24, they were 227.0 and 230.5, 21.0 and 23.2 and 314.6 and 318.1 kg ha^{-1}respectively with the mean values as 229.7 and 232.9, 21.9 and 24.0 and 317.0 and 320.3 kg ha^{-1} for surface and subsurface drip respectively.

Among different irrigation scheduling approaches, the pH, EC and OC values varied from 7.46 to 7.50, 0.31 to 0.33 dS m^{-1} and 0.40 to 0.44% respectively during first year whereas in second year, the values ranged from 7.45 to 7.49, 0.31 to 0.34 dS m^{-1} and 0.39 to 0.44% respectively. The mean values of two years were in the series of 7.45 to 7.49, 0.31 to 0.33 dS m^{-1} and 0.40 and 0.44% respectively. On the other hand, the available N, P and K (kg ha^{-1}) values varied from 231.0 to 236.8, 21.9 to 25.7 and 318.6 to 323.3 kg ha^{-1}respectively during first year whereas in second year, the values ranged from 225.8 to 232.3, 20.1 to 24.0 and 313.7 to 318.8 kg ha^{-1}respectively. The mean values were in the series of 228.4 to 234.6, 21.0 to 24.8 and 316.2 to 321.1 kg ha^{-1} respectively.

Table 1: Green (fresh) fruit and stalk yield (kg ha^{-1}) of chilli as influenced by drip irrigation methods and irrigation scheduling approaches

Treatments	Green (fresh) fruit yield (kg ha^{-1})			Stalk yield (kg ha^{-1})		
	2022-23	**2023-24**	**Mean**	**2022-23**	**2023-24**	**Mean**
Main Plot-Drip irrigation systems (I)						
I_1- Surface drip	38736	40689	39712	4729	4883	4806
I_2-Subsurface drip	40872	42848	41859	4967	5107	5037
S.Em±	244	252	238	35	32	30
CD (p=0.05)	1482	1533	1450	211	193	185
Sub plot-Irrigation scheduling approaches (S)						
S_1- Soil moisture sensor based irrigation triggering	36822	38737	37780	4564	4687	4626
S_2- Plant water stress sensor based irrigation triggering	39026	40952	39988	4705	4894	4800
S_3-ET sensor based irrigation triggering	42125	44153	43139	5123	5270	5196
S_4- Irrigation scheduling at 1.0 Epan by manual (Control)	41243	43232	42235	4999	5130	5065
S.Em±	395	412	404	45	49	51
C.D. (P=0.05)	1217	1271	1246	138	152	158
Interaction (M x S)						
S.Em±	542	564	549	65	68	70
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS
Interaction (S x M)						
S.Em±	559	583	572	63	70	73
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS

Table 2. pH, EC (dS m^{-1}) and OC (%) of post-harvest soil as influenced by drip irrigation methods and irrigation scheduling approaches

Treatments	pH			EC (dS m^{-1})			OC (%)		
	2022-23	2023-24	Mean	2022-23	2023-24	Mean	2022-23	2023-24	Mean
Main Plot-Drip irrigation systems (I)									
I_1- Surface drip	7.46	7.46	7.46	0.31	0.32	0.32	0.41	0.40	0.41
I_2-Subsurface drip	7.49	7.48	7.49	0.33	0.33	0.33	0.43	0.42	0.43
S.Em±	0.08	0.09	0.07	0.01	0.01	0.01	0.01	0.01	0.01
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sub plot-Irrigation scheduling approaches (S)									
S_1- Soil moisture sensor based irrigation triggering	7.46	7.45	7.45	0.31	0.31	0.31	0.40	0.39	0.40
S_2- Plant water stress sensor based irrigation triggering	7.47	7.46	7.46	0.32	0.32	0.32	0.42	0.41	0.41
S_3-ET sensor based irrigation triggering	7.50	7.49	7.49	0.33	0.34	0.33	0.44	0.44	0.44
S_4- Irrigation scheduling at 1.0 Epan by manual (Control)	7.48	7.47	7.48	0.32	0.33	0.33	0.43	0.42	0.43
S.Em±	0.12	0.09	0.13	0.01	0.01	0.01	0.02	0.02	0.02
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (M x S)									
S.Em±	0.16	0.14	0.17	0.02	0.02	0.02	0.02	0.03	0.03
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (S x M)									
S.Em±	0.17	0.13	0.18	0.01	0.02	0.02	0.03	0.03	0.03
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Initial	7.48			0.32			0.47		

Table 3: Available N, P and K (kg ha^{-1}) of post-harvest soil as influenced by drip irrigation methods and irrigation scheduling approaches

Treatments	Available N (kg ha^{-1})			Available P (kg ha^{-1})			Available K (kg ha^{-1})		
	2022-23	2023-24	Mean	2022-23	2023-24	Mean	2022-23	2023-24	Mean
Main Plot-Drip irrigation systems (I)									
I_1- Surface drip	232.3	227.0	229.7	22.8	21.0	21.9	319.4	314.6	317.0
I_2-Subsurface drip	235.4	230.5	232.9	24.9	23.2	24.0	322.5	318.1	320.3
S.Em±	3.13	4.24	3.84	0.44	0.41	0.47	9.93	10.03	9.80
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sub plot-Irrigation scheduling approaches (S)									
S_1- Soil moisture sensor based irrigation triggering	231.0	225.8	228.4	21.9	20.1	21.0	318.6	313.7	316.2
S_2- Plant water stress sensor based irrigation triggering	232.9	227.5	230.2	23.4	21.5	22.4	320.2	315.6	317.9
S_3-ET sensor based irrigation triggering	236.8	232.3	234.6	25.7	24.0	24.8	323.3	318.8	321.1
S_4- Irrigation scheduling at 1.0 Epan by manual (Control)	234.6	229.4	232.0	24.4	22.8	23.6	321.9	317.2	319.5
S.Em±	6.22	5.86	5.66	0.79	0.76	0.76	12.20	11.45	12.32
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (M x S)									
S.Em±	8.24	8.34	7.93	1.07	1.02	1.05	17.94	17.25	17.99
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (S x M)									
S.Em±	8.79	8.29	8.01	1.12	1.07	1.08	17.25	16.20	17.42
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Initial	245.75			26.98			338.32		

CONCLUSIONS

The present study conducted during the *rabi* season of 2022-23 and 2023-24 concluded that subsurface drip and ET sensor-based irrigation triggering significantly increased green (fresh) fruit and stalk yield (kg ha^{-1}) of chilli crop which might be recommended to farmersto conserve water and reduce labour in the current context of climate change and labour shortages and also concluded that drip irrigation methods and irrigation scheduling approaches did not exert any significant influence on soil chemical properties.

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Details of the AI usage are given below:

1.

2.

3.

NOMECLATURE:

kg ha^{-1}: kilograms per hectare

MT ha^{-1}: metric tonnes per hectare

%: percentage

dS m^{-1}: desi siemens per metre

ET_c: Crop evapotranspiration

cm: centimetre

N: nitrogen

P: phosphorus

K: potassium

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