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INFLUENCE OF IRRIGATION REGIMES AND FERTIGATION LEVELS ON YIELD AND PHYSIOLOGICAL PARAMETERS IN CAULIFLOWER

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ABSTRACT

Scheduling of irrigation at 1.2 ETc irrigation regimes recorded significantly maximum curd yield (37.58 t ha^{-1}) than 0.6, 0.8 and 1.0 ETc irrigation regimes. The higher fertigation level i.e., 100 per cent RD of N and K at every week up to 60 DAT and phosphorus as basal dose registered maximum curd yield (38.94 q ha^{-1}). The Maximum photosynthetic rate, stomatal conductance and transpiration rate and minimum leaf temperature and stomatal resistance were observed due to 1.2 ETc irrigation regimes and 100 % RDF at all crop growth stages of cauliflower. The positive and highly significant correlation was observed between growth and yield attributes and physiological parameters (photosynthetic rate, stomatal conductance and transpiration rate) whereas negative correlation was observed with leaf temperature and stomatal resistance at all the growth period.

INTRODUCTION

Cauliflower (*Brassica oleracea var. botrytis L.)* being a cole crop belonging to the family Brassicaceae (Syn. *Cruciferae*) is grown extensively in India for its high nutritional value. Agronomic traits such as curd yield and its components are major selection criteria for increasing its productivity. Water scarcity is one of the major problems for cauliflower production mainly in western part of India.

Cauliflower growth and development majorly depends on physiological parameters like photosynthesis, stomatal conductance and transpiration rate. To carry out photosynthesis, a plant needs water, light (as its source of energy), carbon dioxide, various essential nutrients and sufficient warm air temperatures. Decreased photosynthetic rate, stomatal conductance and transpiration rates with increasing water stress duration has been reported by various researchers (Hnilickova and Duffek, 2004). Stomatal conductance being sensitive and regulated process is lowest in the treatment with less number of irrigations (Ajithkumar, 2008). Temperature and available carbohydrates control the rate of increase in curd diameter in cauliflower (Olesen and Grevsen, 2000). Light saturated photosynthetic rate (Pmax) showed an optimum response to temperature and an increase with increasing nitrogen content of leaves (Kage *et al.,* 2001a.).

There is urgent need to reduce the consumption of water in irrigation by developing new technologies and methods that could help to utilize precious input in an effective way. Fertigation is such innovative technology of applying water soluble fertilizers through drip irrigation. Drip irrigation is one of the latest and efficient methods of irrigation having about 90 per cent irrigation efficiency. This method increases the crop yield in general to the tune of 25-30 per cent with saving of irrigation water to the extent of 50 to 60 per cent, when compared to conventional irrigation method (Yadav *et al.,* 1993). Fertigation saves fertilizers up to 25 per cent (Vaishnava *et al.* 1995), thus fertigation results in appropriate and efficient use of precious commodities such as water and fertilizer. As the water soluble fertilizers are very costly inputs, therefore the efforts are made by various researchers to reduce the quantity of water soluble fertilizers (Nitrogen and Potassium) in conjunction with straight fertilizer (Single super phosphate) to enhance the yield potential of cauliflower and fertilizer use efficiency. In the view of above mentioned considerations, this study was carried out to investigate the response of cauliflower for varying irrigation regimes and fertigation levels with modification in physiological parameters and curd yield in Rahuri, Maharashtra (India) which is categorised as dry and warm climate.

MATERIALS AND METHODS

The field experiment was conducted at Post Graduate Instructional Farm, Mahatma Phule Krshi Vidyapeeth, Rahuri, Dist. Ahmednagar (Maharashtra) during *rabi* season of 2011-12. The soil of the experiment field was silty clay in texture having sand, silt and clay percentage as 15.81, 37.45 and 46.27, respectively. The soil physical properties were assessed by adopting the standard procedure of Piper (1966). The moisture content (Richard, 1947) at field capacity and permanent wilting point was 36.84 and 18.17 per cent, respectively. The bulk density (Dastane, 1972) of experimental site was 1.37 g cm^{-3}. The soil was moderately alkaline in reaction

Table 1: Yield attributes and yields of cauliflower as influenced by different treatment at harvest

Treatments		Curd length(cm)	Curd width (cm)	Curd weight (g)	Curd yield(t ha^{-1})
A.	Irrigation regimes				
I_1 :	0.6 ETc	10.33	14.47	752.17	28.04
I_2 :	0.8 ETc	10.68	15.34	849.17	31.54
I_3 :	1.0 ETc	10.82	15.77	918.92	33.72
I_4 :	1.2 ETc	12.82	17.07	1047.42	37.58
	S.E.(m)+	0.17	0.22	9.53	1.29
	C.D. (P = 0.05)	0.59	0.75	33.00	3.88
B.	Fertigation levels				
F_1:	Fertigation of 100 % RD of N and K at every week up to 60 DAT (8 splits) + P as basal	12.53	16.90	1100.75	38.94
F_2:	Fertigation of 75 % RD of N and K at every week up to 60 DAT (8 splits) + P as basal	11.22	15.88	929.50	34.34
F_3:	Fertigation of 50 % RD of N and K at every week up to 60 DAT (8 splits) + P as basal	10.25	14.80	758.00	28.15
F_4:	100 % RD of NPK through soil application + drip irrigation.	10.68	15.06	778.42	29.45
	S.E.(m)+	0.28	0.17	13.30	1.54
	C.D. (P = 0.05)	0.82	0.50	38.84	4.66
C.	Interaction (A × B)	N.S.	N.S.	Sig.	Sig.
D.	General mean	11.17	15.66	891.67	32.72

(pH 7.80). The electrical conductivity (Piper, 1966) and organic carbon (Nelson and Sommer, 1982) content of soil was 0.23 dSm^{-1} and 0.49 per cent, respectively.

The field experiment was laid out in a split plot design and replicated three times as suggested by Panse and Sukhatme (1967). The treatment consist of four irrigation regimes *viz.*, I_1 : 0.6 ETc, I_2 : 0.8 ETc, I_3 : 1.0 ETc and I_4 : 1.2 ETc and four treatment of fertigation levels *viz.*, F_1 : Fertigation of 100 per cent recommended dose of N and K at every week up to 60 DAT and phosphorus as basal application, F_2 : Fertigation of 75 per cent recommended dose of N and K at every week up to 60 DAT and phosphorus as basal application, F_3 : Fertigation of 50 per cent recommended dose of N and K at every week up to 60 DAT and phosphorus as basal application and F_4 : 100 per cent recommended dose of NPK through soil application + drip irrigation. The transplanting of cauliflower (var. Indam-9803) was done on 25th Nov, 2011 at a spacing of 60 cm × 45 cm on the broad bed furrows.

Fertigation of nitrogen and potassium was as per the treatments through potassium nitrate (13:0:45 NPK grade) and urea at every week up to 60 DAT. In conventional fertilizer method, fertilizers were applied in the form of urea and muriate of potassium. Phosphorus fertilizer was applied in the form of SSP in all the treatments.

Irrigation water was applied at every alternate day based on pan evaporation data. The quantity of irrigation water was calculated by using following formula (Vermerien and Jobling, 1980).

$$ETc = Epan \times Kpan \times Kc$$

Where,

ETc = Evapotranspiration of crop (mm)

Epan = Pan evaporation (mm)

Kpan = Pan Coefficient (0.7)

Kc = Crop coefficient (as per growth stages)

$$\text{Volume of water (Lit day}^{-1}\text{ plant}^{-1}) = \frac{Ep \times Kp \times Kc \times S_1 \times S_2 \times Wa}{E}$$

Where,

S_1 = Spacing between laterals (m)

S_2 = Spacing between emitters (m)

Wa = Wetted area (%)

E = Efficiency of system (%)

The operation time of the system (T) was calculated by using the following formula

$$T = \frac{V}{q \times Ne}$$

Where,

T = Operating time of system (hrs.)

V = Total volume of water (lit.)

q = Emitter discharge (Lph)

Ne = Number of emitters $plot^{-1}$

Scheduling of irrigation was done by using crop coefficient in drip irrigation (Doorenbos and Pruitt, 1977).

Plant growth and yield attributing characters were recorded periodically at an interval of 15 days. Physiological observations *viz.*, photosynthetic rate, stomatal conductance, stomatal resistance, canopy temperature and transpiration rate were recorded periodically at an interval of 15 days starting from 30 days after transplanting by using IRGA (Infra Red Gas Analyser) model LICOR-6400XT for each treatment. Correlations between the growth parameters and weather parameters in all the growing structure were also worked out

RESULTS AND DISCUSSION

Effect of irrigation regimes

Application of irrigation at 1.2 ETc irrigation regime proved its

Table 2: Physiological parameters as influenced periodically by different treatments in cauliflower.

Treatments	Photosynthetic rate (μ mol m^{-2} s^{-1}) 30 DAT	45 DAT	60 DAT	At harvest	Stomatal conductance (m mol m^{-2} s^{-1}) 30 DAT	45 DAT	60 DAT	At harvest	Stomatal resistance (m mole m^{-2} s^{-1}) 30 DAT	45 DAT	60 DAT	At harvest
A. Irrigation regimes												
I_1 : 0.6 ETc	22.84	41.38	29.57	6.13	0.63	0.83	0.70	0.31	1.60	1.32	1.46	3.46
I_2 : 0.8 ETc	23.06	42.54	30.93	7.26	0.65	0.84	0.72	0.44	1.58	1.28	1.31	2.32
I_3 : 1.0 ETc	23.77	42.62	31.81	9.00	0.77	0.87	0.77	0.49	1.32	1.16	1.30	2.25
I_4 : 1.2 ETc	25.20	43.03	32.40	10.07	0.78	0.89	0.79	0.53	1.31	1.14	1.28	1.96
SE(m)+	0.46	0.21	0.40	0.64	0.02	0.03	0.02	0.02	0.05	0.02	0.02	0.10
CD (P=0.05)	1.59	0.75	1.40	2.30	0.07	0.05	0.06	0.08	0.17	0.05	0.06	0.35
B. Fertigation levels												
F_1 : Fertigation of 100 % RD of N and K at every week up to 60 DAT (8 splits) + P as basal	24.72	43.29	32.87	9.42	0.74	0.88	0.81	0.52	1.36	1.15	1.30	2.18
F_2 : Fertigation of 75 % RD of N and K at every week up to 60 DAT (8 splits) + P as basal	24.03	42.65	31.62	8.52	0.71	0.87	0.75	0.45	1.44	1.16	1.332.55	
F_3 : Fertigation of 50 % RD of N and K at every week up to 60 DAT (8 splits) + P as basal	22.77	41.51	29.46	7.03	0.68	0.83	0.73	0.42	1.51	1.27	1.40	2.65
F_4 : 100 % RD of NPK through soil application + drip irrigation.	23.36	42.39	30.76	7.50	0.70	0.85	0.74	0.43	1.46	1.18	1.38	2.62
S.E. (m)+	0.51	0.37	0.70	0.59	0.02	0.01	0.02	0.02	0.05	0.03	0.03	0.09
C.D. (P=0.05)	N.S.	1.08	2.18	1.74	0.05	0.03	0.06	0.05	0.14	0.08	0.09	0.26
C. Interaction (A × B)	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
D. General mean	23.72	42.39	31.18	8.12	0.71	0.86	0.75	0.45	1.45	1.22	1.34	2.50

superiority by recording maximum and significant higher yield attributes *viz.,* curd length (12.82 cm), curd width (17.07 cm), curd weight (1047.42 g) and curd yield (37.58 t ha^{-1}) and it was at par with 1.0 ETc irrigation regime in case of curd yield. This might be due that, the optimum moisture in the vicinity of root zone throughout the crop growth period which enhance the vegetative growth of the crop thereby increase the photosynthesis and efficient translocation of photosynthates towards the reproductive organ i.e., curd, which increases the length, width and weight of curd finally resulted in increased curd yield of cauliflower (Table 1). Dry matter per plant, head girth, average weight of head and its yield were significantly higher in 100 % ET levels (43.40 t ha^{-1}) over 75 % ET (38.46 t ha^{-1}) and 50 % ET (30.91 t ha^{-1}) levels (Pawar and Firake, 2003). Lingaiah *et al.* (2005) revealed that plants subjected to drip irrigation at 1.0 and 0.8 Epan were superior in their head diameter, head weight, yield and water use efficiency compare to 0.6 Epan and surface irrigation. These results are also in accordance with those reported by Tiwari *et al.* (2003), Deolankar *et al.* (2004) and Kadam *et al.* (2006).

The mean photosynthetic rate, stomatal conductance and transpiration rate which were influenced significantly by different irrigation regimes and presented in Table 2. Application of irrigation at 1.2 Etc regime registered maximum and significantly higher photosynthetic rate, stomatal conductance and transpiration rate than rest of the irrigation regimes and it was at par with 1.0 ETc irrigation regimes at all the growth stages of cauliflower. The photosynthetic rate was increased up to 45 DAT and thereafter decreases towards curd maturity stage may be because, at higher moisture regime crop increased the uptake of water which enhanced the turgidity of cells and make stomata remains open which increase the entry of CO_2 for enhancing photosynthesis, whereas under the moisture stress condition viz, 0.6 or 0.8 ETc irrigation regimes, because of inadequate water uptake, partially closure of stomata inhibit the entry of CO_2 which reflected in stomatal conductance, less transpiration rate which lead to reduced photosynthetic rate. These results are in accordance with the finding of Hnilickova and Duffek (2004), Kochler *et al.,* (2007) and Ajithkumar *et al.,* (2008).

Significantly lower stomatal resistance was observed with higher irrigation regimes (1.2 and 1.0 ETc) at all the crop growth stages compared to 0.6 and 0.8 ETc irrigation regimes, whereas increased stomatal resistance and leaf temperature were noticed under lower irrigation regimes *i.e.,* 0.6 and 0.8 ETc at all the crop growth stages (Table 2). This might be because of under moisture stress condition (0.6 and 0.8 ETc regimes) stomata remains partially closed which leads to reduced entry of CO_2 and exit of O_2. Similar results were also reported by Pearson *et al.* (2003) and Kochler *et al.* (2007) in cauliflower.

Effect of fertigation regimes

Table 2: Continue....

Treatments		Leaf temperature (°C) 30 DAT	45 DAT	60 DAT	At harvest	Transpiration rate (mol H_2O m^{-2} s^{-1}) 30 DAT	45 DAT	60 DAT	At harvest
A.	Irrigation regimes								
I_1 :	0.6 ETc	32.56	29.62	31.86	30.46	8.65	12.99	11.25	7.42
I_2 :	0.8 ETc	31.97	28.64	31.66	30.40	8.95	13.59	12.99	9.39
I_3 :	1.0 ETc	31.62	26.42	30.19	29.95	10.31	14.17	13.14	9.43
I_4 :	1.2 ETc	31.55	26.11	29.55	29.64	10.90	14.81	13.85	9.80
	SE(m)+	0.11	0.26	0.43	0.17	0.17	0.28	0.47	0.25
	CD (P=0.05)	0.31	0.89	1.50	0.60	0.60	0.97	1.62	0.88
B.	Fertigation levels								
F_1:	Fertigation of 100 % RD of N and K at every week up to 60 DAT (8 splits) + P as basal	31.80	27.45	30.44	29.93	10.00	14.65	13.48	9.67
F_2:	Fertigation of 75 % RD of N and K at every week up to 60 DAT (8 splits) + P as basal	31.95	27.59	30.53	30.06	9.90	14.11	12.65	8.81
F_3:	Fertigation of 50 % RD of N and K at every week up to 60 DAT (8 splits) + P as basal	31.99	27.92	31.20	30.26	9.27	13.09	12.48	8.77
F_4:	100 % RD of NPK through soil application + drip irrigation.	31.96	27.83	31.09	30.20	9.65	13.71	12.62	8.79
	S.E. (m)+	0.134	0.148	0.16	0.113	0.27	0.33	0.17	0.14
	C.D. (P=0.05)	N.S.	N.S.	0.47	N.S.	N.S.	0.97	0.53	0.41
C.	Interaction (A × B)	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
D.	General mean	31.93	27.70	30.81	30.11	9.70	13.89	12.81	9.01

Table 3: Correlation coefficient between growth parameters and physiological parameters of cauliflower

Parameters	30 DAT Stalk length	No. of functional leaves	Plant spread	45 DAT Stalk length	No. of functional leaves	Plant spread
Photosynthetic rate	0.799**	0.804**	0.825**	0.799**	0.804**	0.825**
Stomatal conductance	0.519*	0.544*	0.506*	0.519*	0.544*	0.506*
Stomatal resistance	-0.574*	-0.666**	-0.663**	-0.574*	-0.666**	-0.663**
Transpiration rate	0.736**	0.714**	0.753**	0.736**	0.714**	0.753**
Leaf temperature	-0.357^{NS}	-0.249^{NS}	-0.401^{NS}	-0.357^{NS}	-0.249^{NS}	-0.401^{NS}

** 1 % Significance level = 0.623; * 5 % Significance level = 0.497

Table 3: Continue...

Parameters	60 DAT Stalk length	No. of functional leaves	Plant spread	At harvest Stalk length	No. of functional leaves	Plant spread	Total dry matter	Yield
Photosynthetic rate	0.520*	0.514*	0.651**	0.945**	0.936**	1.000**	0.855**	0.876**
Stomatal conductance	0.729**	0.580*	0.731**	0.538*	0.645**	0.627**	0.784**	0.679**
Stomatal resistance	-0.874**	-0.600*	-0.845**	-0.626**	-0.609*	-0.656**	-0.806**	-0.638**
Transpiration rate	0.640**	0.621*	0.596*	0.621*	0.610*	0.654**	0.808**	0.710**
Leaf temperature	-0.816**	-0.652**	-0.852**	-0.678**	-0.735**	-0.750**	-0.905**	-0.718**

** 1 % Significance level = 0.623; * 5 % Significance level = 0.497

Fertigation of cauliflower with 100 per cent RD of N and K at every week up to 60 DAT and phosphorus as basal application registered significantly increased yield attributing characters than rest of the treatments. However, this treatment effect is at par with fertigation at 75 per cent of RD of N and K at every week up to 60 DAT and phosphorus as basal application in case of curd yield. At higher fertigation level, crop meet out its nutritional requirement at respective growth stage which lead to luxurious growth and thereby enhancement of yield (Table 1). Similar results were reported by Bansod (2007), Tanpure *et al.* (2007), Chetan and Singh (2009), Imtiyaz *et al.* (2009) and Bozkurk *et al.* (2011). Shinde *et al.* (2006) shows that fertigation with 125 per cent of the recommended rates of NPK fertilizer resulted in the highest weight of head of cabbage than 150 and 100 per cent recommended dose. The yields of early cauliflower were maximum at 100 per cent of recommended nitrogen dose (Chetan and Singh, 2011).

Fertigation @ 100 per cent RD of N and K at every week up to 60 DAT and phosphorus as basal application registered significantly higher rate of photosynthesis and at par with fertigation @ 75 per cent RD of N and K at every week up to 60 DAT and phosphorus as basal at all the crop growth stages except 30 DAT in case of photosynthetic rate and transpiration rate (Table 2). The maximum photosynthesis at 100 per cent level of fertigation might be due to crop meet out the nutritional requirement reflected on more vegetative growth in respect of number of leaves and leaf area per plant which increases leaf area to increase the interception of light thereby increase the photosynthetic rate, stomatal conductance and transpiration rate. Similar results were also reported by Olsen and Grevsen (2000) and Kage *et al.* (2001a.).

Fertigation at 100 per cent and 75 per cent RD of N and K at every week up to 60 DAT and phosphorus as basal application registered significantly lower and at par value of stomatal resistance at all the crop growth stages whereas, fertigation at 50 per cent of RD of N and K at every week up to 60 DAT and phosphorus as basal application registered significantly increased stomatal resistance and leaf temperature at all crop growth stages. These results are in accordance with those reported by Olesen and Grevsen (2000) and Kage *et al.* (2001b.).

Correlation studies

The correlation was determined between physiological parameters and yield parameters of cauliflower at 30, 45, 60 DAT and at harvest and presented in Table 3. The positive and highly significant correlation was observed between growth parameters *viz.,* stalk length, number of functional leaves and plant spread with photosynthetic rate, stomatal conductance and transpiration rate, whereas negative correlation was observed with stomatal resistance and leaf temperature. However, non significant correlation was observed with leaf temperature at 30 and 45 DAT. At harvest of crop the positive and highly significant correlation was observed between growth parameters *viz.,* stalk length, number of functional leaves, plant spread and dry matter and curd yield with photosynthetic rate, stomatal conductance and transpiration rate while negative correlation was observed with stomatal resistance and leaf temperature.

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