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Scheduling of Irrigation in Cauliflower (*Brassica oleracea* var. *botrytis* L.) under Mid Hill Conditions of Himachal Pradesh

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A B S T R A C T

The present investigation entitled Scheduling of irrigation in cauliflower *(Brassica oleracea* var. *botrytis* L.) under mid hill conditions of Himachal Pradesh was conducted during 2011-12 and 2012-13 at the experimental farm of Department of Soil Science and Water Management, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni- Solan, H.P. The experiment was laid out in Randomized Block Design with eight treatments and three replications i.e. 3 cm irrigation at IW/CPE ratio i.e. 1.0 (T_1), 0.8 (T_2) and 0.6 (T_3); at 0.4 (T_4), 0.5 (T_5) bar tensiometric suction; at 25 (T_6) and 50 (T_7) per cent depletion of available water in 0-30 cm depth; farmer's practice (T_8) i.e. 5 cm irrigation at 12-15 days interval depending upon the rainfall). The irrigation schedules had significant effect on crop growth and productivity of cauliflower under $T_{1,}$ T_4 and T_6 irrigation treatments. The crop yield increased by, 29.5, 30.1 and 32.2 per cent over T_3 and 25.5 and 26.0 and 28.1 per cent over T_8 irrigation schedule. Schedule T_1 required less quantity of irrigation water (18.9 cm and 21.9 cm) compared to T_6 (30.9 cm and 36.9 cm) and T_4 (27.9 cm and 33.9 cm) without any significant reduction in yield and gave higher WUE and B:C ratio. Thus, all these three schedules were equally good. Keeping in view the productivity, WUE and B:C ratio, T_1 irrigation schedule was found efficient and economical.

Introduction

Cauliflower (*Brassica oleracea* var. *botrytis L.)* is an important winter vegetable crops of mid hill region of Himachal Pradesh. Its commercial cultivation as an off season vegetable crop for remunerative returns, more demand in the markets of neighbouring plains and improved nutritional awareness of people have attracted the farmers to bring large area under its cultivation. However, the productivity of crop is low and variable owing to erratic distribution of rain fall, poor irrigation facilities and unscientific use of scarce irrigation water. The farmers are largely dependent upon rains and are unable to achieve higher yield of better quality under rainfed conditions for sustaining the crop productivity. This situation is further deteriorated by erratic distribution and meager winter rains in the state which creates a condition of water scarcity during the active growth period of vegetable crops. This crop is sensitive to moisture stress at different growth stages and stress at any critical stage reduces its quality and productivity. Irrigation scheduling is one of the most important tools for overcoming water stress and developing best water management strategies for water scarce and irrigated areas. It is essential for the judicious use of water and maximizing crop yields. Irrigation scheduling is the use of water management strategies to prevent over application of water while minimizing the yield loss due to water shortages or drought stress.

Characteristics of the crop are taken into account, for achieving higher and stable yields of irrigated crop (Kanton *et al.*, 2003; Pejic *et al.*, 2008). The proper irrigation schedule consists of applying irrigation to the crop at the "right time" and in "right amount". On the other hand improper timing and insufficient water application can result in moisture stress, reduced nutrient uptake and lower water use efficiency (Olczyk *et al.*, 2000).

Materials and Methods

Field study was conducted at the experimental farm of Department of Soil Science and Water Management, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni- Solan, H .P during 2011-12 and 2012-13. Farm yard manures and recommended doses of fertilizers in the form of N, P_2O_5 and K_2O nutrients were added as per the schedule of the experiment in the form of calcium ammonium nitrate (CAN), single superphosphate (SSP) and muriate of potash (MOP).the experiment consisted of eight treatments replicated three times in a randomaized block design viz., T_1: 3 cm irrigation at IW/CPE = 1.0, $T_{2:}$ 3 cm irrigation at IW/CPE = 0.8, T_3: 3 cm irrigation at IW/CPE = 0.6, T_4: 3 cm irrigation at 0.4 bar tensiometric suction, T_5: 3 cm irrigation at 0.5 bar tensiometric suction, T_6 : 3 cm irrigation at 25 percent depletion of available water, T_7: 3 cm irrigation at 50 percent depletion of available water, T_8: Farmer's practice (heavy irrigation i.e. 5 cm at 12-15 days interval depending upon the rainfall). The whole dose of FYM, P and K fertilizers were applied at the time of field preparation. The nitrogen fertilizers was applied in three split doses, first dose at the time of transplanting and second dose one month after transplanting and third dose at the time of flowering. Yield was recorded after harvest of cauliflower. RV and RMD were calculated using the formula:

$$\text{Root volume density} = \frac{\text{Volume of roots by displacement method}}{\text{Volume of core}}$$

After completing above, the roots were then transferred to a filter paper and pressed gently in its folds to remove imbibed water. The roots were then dried in oven at 60 ± 5°C till a constant weight and finally, the dried weight was taken and RMD was calculated as follows:

$$\text{Root mass density} = \frac{\text{Dry weight of roots}}{\text{Volume of core}}$$

Consumptive use of water

Consumptive use of water was computed as per the method given by Dastane (1972):

Consumptive use (cm) = Profile water use (cm) + effective rainfall (cm) + ground water contribution (cm). The depth of water table was more than 25 m below the surface soil throughout the period of experimentation. Hence, the ground water contribution was considered as nil.

Profile water use

The profile water use was worked out by the following formula:

$$d = \sum_{i=0}^{n} \frac{M_1^{\,i} - M_2^{\,i}}{100} \times ASi \times Di + ER$$

Where,

d = Moisture deficit in the root zone

$\sum_{i=0}^{n}$ = *Summation of 'n' number of layers of the root zone*

M_1^i = Soil moisture in i^{th} layer of profile 24 hours after irrigation

M_2^i = Soil moisture in i^{th} layer of profile on the day just before the next irrigation

ASi = bulk density of i^{th} layer (g cm^{-3})

Di = Depth of i^{th} layer (cm) and

ER = Effective rainfall (cm)

Water requirement

Total water requirement was computed as :

Water requirement = Sum total of irrigation water applied + Effective rainfall

Water use efficiency (WUE)

The WUE was calculated for each treatment with the help of following formula:

$$\text{WU E (kg ha}^{-1}\text{ mm}^{-1}) = \frac{\text{Yield (kg/ha)}}{\text{Irrigation water applied (mm)}}$$

Effective rainfall

Effective rainfall was calculated by balance sheet method as suggested by Gupta *et al.*, (1972)

Results and Discussion

The two years Pooled result of the growth and quality parameters of cauliflower at harvest stage are given in Table.1. The results revealed that the irrigation scheduling was formed to affect significantly all the plant parameters of cauliflower. Among irrigation schedules T_6 recorded higher value of curd equatorial diameter (15.0 cm), curd polar diameter (9.3 cm), stalk length (5.1 cm) and vitamin C (52.2 mg $100g^{-1}$) over T_3, but was found to be at par with T_4 and T_6 irrigation schedule. It can be attributed to the better performance of various growth parameters due to optimum soil moisture and nutrient availability which ensured balanced water and nutrient supply throughout the crop season. Similar findings on onion crop have been reported by Qadir *et al.*, (2005) and Bagali *et al.*, (2012). Among these schedules stalk length increases due to due to frequent irrigations and quantum of water applied under T_6 (eight to ten irrigations and 30.9 to 36.9 cm quantity of water applied) during the crop season. Vitamin C could be attributed to optimum moisture and nutrient availability creating favorable soil environment Shivakumar *et al.*, (2011). Irrigation schedules had non-significant effect on Curd shape index.

Growth parameters

The result pertaining to curd wt and curd yield are given in Table 2. The results revealed that the effect of irrigation schedules was significant. Significantly higher curd weight was recorded in T_6 (918.2 g $plant^{-1}$) when 3 cm irrigation was applied at 25 per cent depletion of available water over in T_3 (694.2 g plant^{-1}) irrigation schedule. The irrigation schedules had significant impact both on curd weight and curd yield. Curd yield significantly influenced by irrigation schedules. The treatments T_6 (264.4 q/ha), T_4 (259.0q/ha) and T_1 (260.2 q/ha) which were at par with each other registered significantly higher curd yield over T_3 (199.9 q/ha) and T_8 (206.3 q/ha) irrigation schedules. This may be due to the optimum soil moisture content and nutrient availabilities and better root growth. The favorable effects of irrigation in increasing the yield of crops have also been reported by Kadam *et al.,* (2006) and Imtiyaz *et al.,* (2009).

The highest root mass density (1.26 gm^{-3}x10^{-3}) was observed in T_6 irrigation schedule which was at par with T_4 (1.04 gm^{-3}x10^{-3}) irrigation schedules over T_3 (0.63 gm^{-3}x10^{-3}). It might be due to optimum soil moisture contents in rhizosphere which were highest and near FC (23.05 & 21.85) during the crop growth season encouraging better proliferation and elongation of roots. Several workers have documented the favorable effects of irrigation schedules on root growth especially in vegetable crops. The frequent irrigations to okra, wheat and *Lolium perenne* (L.) crops at (25 per cent depletion of available water) produced comparatively higher root growth due to optimum moisture availability (Mandal *et al.,* 2003). Irrigation schedules had a significant effect on RVD in cauliflower. The schedule T_6 RVD of (5.18 m^{3}m^{-3}x 10^{-3}) which gave significantly higher RVD over T_3 (2.81m^{3}m^{-3}x 10^{-3}) and T_8 (4.29 m^{3}m^{-3}x 10^{-3}) irrigation schedules. Higher RVD in T_6 irrigation schedule could be attributed to the better moisture conditions per cent in the root zone and increased the nutrient availability . These results are also in consonance with those Webber *et al.,* (2006) and Zoolech *et al.,* (2011).

Table.1 Effect of irrigation schedule on Curd equatorial diameter, curd polar diameter, curd shape index, stalk length and vitamin C

Treatments	Curd equatorial diameter (cm)	Curd polar diameter (cm)	Curd shape index	Stalk length (cm)	Vitamin-C (mg 100g^{-1})
	Pooled	**Pooled**	**Pooled**	**Pooled**	**Pooled**
T_1	14.5	9.0	0.5	5.0	52.1
T_2	12.8	8.3	0.5	4.7	46.0
T_3	12.4	7.6	0.6	4.3	45.9
T_4	14.6	9.2	0.5	4.9	52.0
T_5	13.3	7.9	0.6	4.5	47.6
T_6	15.0	9.3	0.5	5.1	52.2
T_7	13.7	8.5	0.6	4.6	50.4
T_8	13.6	8.2	0.6	4.4	50.9
CD $_{(0.05)}$	**0.51**	**0.46**	**NS**	**0.40**	**0.46**

Table.2 Effect of irrigation schedules on curd weight, curd yield root mass density and root volume density of cauliflower

Treatments	Curd weight (g plant^{-1})	Curd yield (q/ha)	Root Mass Density (g m^{-3}x10^{-3})	Root volume Density (m^{3} m^{-3}x10^{-3})
T_1	903.5	260.2	0.76	3.41
T_2	816.5	235.1	0.74	3.32
T_3	694.2	199.9	0.63	2.81
T_4	899.5	259.0	1.09	4.89
T_5	776.7	223.6	0.94	4.20
T_6	918.2	264.4	1.26	5.18
T_7	885.0	246.2	1.04	4.35
T_8	716.5	206.3	0.96	4.29
CD $_{(0.05)}$	**13.71**	**9.31**	**0.13**	**0.61**

Treatments	Curd weight (g plant^{-1})	Curd yield (q/ha)	Root Mass Density (g m^{-3}x10^{-3})	Root volume Density (m^{3} m^{-3}x10^{-3})
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T_3	694.2	199.9	0.63	2.81
T_4	899.5	259.0	1.09	4.89
T_5	776.7	223.6	0.94	4.20
T_6	918.2	264.4	1.26	5.18
T_7	885.0	246.2	1.04	4.35
T_8	716.5	206.3	0.96	4.29
CD $_{(0.05)}$	**13.71**	**9.31**	**0.13**	**0.61**

Table.3 Effect of irrigation schedule on nutrient uptake in cauliflower

Treatments	Pooled (Uptake)			Pooled (Uptake)		
	N	**P**	**K**	**Ca**	**Mg**	**S**
T_1	47.7	6.8	44.6	21.7	9.3	5.5
T_2	42.3	8.4	39.9	21.6	8.5	5.9
T_3	37.9	6.6	35.6	19.6	6.4	4.8
T_4	46.8	10.0	42.7	26.0	8.4	7.1
T_5	42.5	8.4	39.7	22.5	7.2	4.8
T_6	49.3	9.6	45.4	26.6	10.1	5.4
T_7	47.1	9.5	44.3	24.1	9.3	5.9
T_8	35.0	5.5	34.4	17.2	6.9	4.2
CD $_{(0.05)}$	**1.85**	**2.67**	**4.83**	**3.62**	**1.77**	**2.05**

Table.4 Water use components of cauliflower as influenced by irrigation schedules

Treatments	Irrigation water applied (cm)		Effective rainfall (cm)		Total water requirement (IWA+E.R) (cm)		Consumptive use (cm)		Water use efficiency (kg ha^{-1} mm^{-1})	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
T_1	*18.9 (4)	21.9 (5)	4.7	5.0	23.6 **(-31.5)	26.9 (-7.8)	15.3	17.7	110.6 ***(11.0)	96.3 (9.6)
T2	15.9 (3)	18.9 (4)	7.2	7.4	23.1 (-33.0)	26.3 (-9.9)	14.7	18.7	103.4 (10.2)	87.9 (8.7)
T_3	12.9 (2)	15.9 (3)	8.4	10.6	21.3 (-38.2)	26.5 (-9.2)	14.8	20.0	95.1 (9.5)	74.4 (7.4)
T4	27.9 (7)	33.9 (9)	3.5	3.2	31.4 (-8.9)	37.1 (27.0)	16.0	21.2	82.2 (8.1)	74.0 (7.3)
T5	24.9 (6)	27.9 (7)	3.8	4.4	28.7 (-16.8)	32.3 (10.6)	16.6	17.7	80.1 (8.0)	67.0 (6.7)
T_6	30.9 (8)	36.9 (10)	3.1	4.6	34.0 (-1.4)	41.5 (42.1)	17.8	27.3	77.9 (7.7)	63.5 (6.3)
T_7	24.9 (6)	30.9 (8)	6.5	4.2	31.4 (-8.9)	35.1 (20.2)	16.9	19.2	79.8 (7.9)	68.9 (6.8)
T_8	29.9 (5)	24.9 (4)	4.6	4.3	34.5	29.2	15.8	14.7	60.8 (6.0)	69.4 (6.9)

Figures in parenthesis are the number of irrigation applied *
Figures in parenthese are the (%) water saving **
Figures in parenthese are the water use efficiency in (kg m^{-3}) ***

Table.5 Cost economics of different irrigation schedules in cauliflower

Treatments	Total cost of cultivation (Rs/ha)	Gross Income (Rs/ha)	Net Returns (Rs/ha)	B:C Ratio
T_1	58,638.5	260200	201561.5	3.43:1
T_2	58,338.5	235100	176761.5	3.02:1
T_3	58,038.5	199900	141861.5	2.44:1
T_4	60,138.5	259000	198861.5	3.30:1
T_5	58,938.5	223600	164661.5	2.79:1
T_6	60,438.5	264400	203961.5	3.37:1
T_7	59,538.5	246200	186661.5	3.13:1
T_8	59,238.5	206300	147061.5	2.48:1

Nutrient uptake

The T_6 irrigation schedule showed significantly higher uptake of N (43.3 kg ha^{-1}) over T_8 (35.0 kg ha^{-1}) schedule and T_4 showed higher uptake of P (10.0 kg ha^{-1}) over T_8 (5.5 kg ha^{-1}) treatment. The T_6 irrigation schedule showed higher uptake of K (45.4 kg ha^{-1}), Ca (26.6 kg ha^{-1}) and Mg (10.1 kg ha^{-1}) over T_8 33.6 kg ha^{-1}, 16.8 kg ha^{-1} and 6.9 kg ha^{-1} schedule and S uptake was highest under T_4 (7.1 kg ha^{-1}) over T_8 (4.2 kg ha^{-1}) schedule. The higher uptake of nutrients recorded under T_6 and T_4 irrigation schedules might be due to optimum moisture conditions resulting in better growth of roots (Table 3) and there by nutrient uptake similar findings on maize, bean and sunflower have been reported by Murthy and Reddy, 2013.

Irrigation water applied and effective rainfall

The data pertaining to water applied and effective rainfall as influenced by different irrigation schedules are given in table 4. During both years highest quantity of irrigation water was applied in T_6 irrigation schedule and minimum recorded under T_3 irrigation schedule. Whereas data on effective rain fall (ER) calculated during both the seasons under different irrigation schedules have been presented in Table 4. During first year of study, ER ranged from 3.1-8.4 cm under different irrigation schedules. Whereas highest (8.4 cm) ER was recorded under T_3 irrigation schedule in which only two irrigations were applied during the period of crop and lowest (3.1 cm) ER under T_6 irrigation schedule in which eight irrigations were applied. Similarly during second year of study highest (10.6 cm) ER was recorded under T_3 irrigation schedule in which 3 irrigations were applied during the crop growth period and lowest (3.2 cm) ER was recorded under T_4 irrigation schedule in which nine irrigations were applied.

Water requirement, consumptive use and water use efficiency

On an average basis among, $T_{1,}$ T_4 and T_6 , T_6 irrigation schedule recorded highest water requirement during both the years followed by T_4 and T_1 schedule but T_1 irrigation schedule saved maximum amount of water i.e (20.7 %) followed by T_4 (7.5 %) and T_6 (18.5 %) irrigation schedule. Irrigation schedule T_1 found to be superior over other schedule. The value of consumptive use of water were 17.8, 27.3 and 16.6,17.3 in T6 and T7 treatment, respectively. This would imply that the CU of water increase with the increase in level of irrigation as expected. This may also be due to the fact that surface layer of the soil remained wet for the longer duration under higher frequency of irrigation thus creating conditions for evaporation of water and absorption at higher rate as compared to the lower frequency of irrigation (Gulati *et al.*, 2001; Raskar and Bhoi, 2003). The mean WUE recorded under T1 treatment (110.0, 96.3 kg ha^{-1} mm^{-1}) during both the years as it decreased with increasing level of irrigation. This may be due to greater loss of water through evapo-transpiration in frequently irrigated crop and without much reduction in yield with fairly lower water use (Sunder Singh 2001; Mahdi *et al.*, 2003; Shiva Kumar *et al.*, 2011;)

Benefit-cost ratio

Worked out for different irrigation schedules has been presented in table 5. A perusal of data reveals that maximum gross income was recorded in T_6 (Rs 264400) irrigation schedule followed by T_1 (Rs 260200), T_4 (Rs 259000) and minimum (Rs 199900) under T_3 irrigation schedule. Similarly, net returns was maximum (Rs 203961.5) under T_6 followed by T_1 (Rs 201561.5), T_4 (Rs 198861.5) and minimum (Rs 141861.5) under T_3 irrigation schedule. The highest B:C ratio (3.43:1) was worked out in treatment T_1 which was rated as the most profitable and cost effective schedule followed by T_6 (3.37:1) which produced maximum yield. Hence, these three irrigation schedules were equally effective and anyone of these irrigation schedules can be used for maximizing the cauliflower yield.

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