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RESPONSE OF CAULIFLOWER GROWTH AND DEVELOPMENT UNDER WATER SCARCITY CONDITIONS IN TEMPERATE ZONE

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ABSTRACT : The study was carried out at the College of Forestry & Hill Agriculture, Hill Campus, Ranichauri, Uttarakhand. Soil moisture content was measured using gravimetric method periodically in 0-15, 15-30, 30-45 and 45-60 cm soil profiles. Field experiments were conducted on cauliflower (*Brassica oleracea*) crop during 2007-08 and 2008-09. The crop was transplanted in October and harvested in February spanning 100 and 99 days, respectively. Four irrigation treatments were maintained based on the maximum allowable depletion (MAD) of available soil water. The treatments were 15% (T_1), 30% (T_2), 45% (T_3) and 60% (T_4) maximum allowable depletion of available soil water. No water stress was maintained at the initial stages of the crop development in order to allow the plants attain a healthy growth. Results revealed that irrigation schedule with 45% maximum allowable depletion of available soil water gave the maximum water use efficiency for cauliflower crop. It was found that for scheduling of irrigation for cauliflower crop 0-30 cm soil profile should be considered as most of the water was found to be extracted from this layer by the plant.

Keywords : *Cauliflower, growth, allowable depletion of mosture, water use efficiency, soil profile.*

Cauliflower is one of several vegetables in the species *Brassica oleracea*, in the family Brassicaceae. It is an annual plant that is reproduced by seed. Typically, only the head (the *white curd*) is eaten. The cauliflower head is composed of a white inflorescence meristem. Cauliflower heads resemble those in broccoli, which differs in having flower buds. Its name comes from Latin word *caulis* (cabbage) and flower, *Brassica oleracea* also includes cabbage, brussels sprouts, kale, broccoli, and collard greens, though they are of different generic cultivar groups.

Cauliflower is one of the most popular crop throughout the world. It thrives well in all soil textures that have good internal drainage. It is relatively sensitive to soil water deficits. Cauliflower needs frequent irrigations for its good growth and yield (Rangarajan, 8).

The water requirement varies widely from crop to crop and also during the period of growth of individual crop (Doorenboss and Pruitt, 2). In case of situations where water supply is limited, the irrigation demand of the entire cropping pattern can not be met fully. In these conditions, deliberate under irrigation, also known as deficit irrigation can play a major role (Iqbal *et al.,* 5). By deficit irrigation, crops are purposefully under irrigated during plant growth stages that are relatively insensitive to water stress as regards to the quality and quantity of the harvestable yield (Musick, 7). Identifying growth stages of a particular cultivar under local conditions of climate and soil fertility allows irrigation scheduling for both maximum crop yield and most efficient use of scarce water resources (Doorenbos and Kassam, 3).

With these background considerations a comprehensive field investigation was undertaken on a silty clay loam soil at the experimental fields of Agricultural Engineering Section, Hill Campus, Ranichauri, Tehri-Garhwal, Uttarakhand. The experimental crop cv. Pusa Snowball of cauliflower was selected, which is a popular variety of the region. The effects of various scheduling of irrigation on the profile soil water status, crop yield, biomass and water use efficiency were studied. Irrigation schedules were based on 15, 30, 45 and

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60 % maximum allowable depletion (MAD) of available soil water (ASW).

MATERIALS AND METHODS

The present study was carried out at the experimental terraces of the Agricultural Engineering Section, College of Forestry & Hill Agriculture, Hill Campus, Ranichauri, Uttarakhand, India. The field is located on a sloping terraced land situated at an altitude of 1850 m above mean sea level. Ranichauri is intersected by 30° 18' N latitude and 78° 24' E longitude. The local climate is sub-humid in temperate zone with an average rainfall of 1240 mm concentrated over the months of June to September. During both years experiments, the temperatures were generally moderate and suitable for the growth of cauliflower crop. The physical properties of the soil of experimental field used for cauliflower crop were as given in Table 1.

Field experiments were conducted on cultivar 'Pusa Snowball' of cauliflower, which is a popular 100-120 days vegetable crop of the locality and suits to the prevailing climate of the region. Water deficits during the period of curd formation have the greatest adverse effect on the yield of the crop, whereas early vegetative and maturation periods are less sensitive (Doorenbos and Kassam, 3). The first field experiment was conducted during the period from 20th October 2007 to 27th January 2008. The second experiment was conducted during 26th October 2008 to 1th February 2009.

Field layout and experimental details

Cauliflower was grown in a terraced land of 180 m^2 area. The field was divided into 20 plots of 3 m x 3 m size. Farm Yard Manure (FYM) was mixed manually with top 20 cm of soil layer at the rate of 20 kg/ha 10 days before transplanting. Second dose of FYM was applied at the time of curd formation (30 days after transplanting) at the rate of 10 kg/ha. The transplanting was done at a spacing of 60 cm (row to row) and 60 cm (plant to plant) during both years' experiments.

Irrigation treatments and scheduling

The irrigation treatments during experiments consisted of irrigation scheduling based on maximum allowable depletion (MAD) of available soil water (ASW) criteria, which was as : T_1 = 15% maximum allowable depletion (MAD) of available soil water (ASW), T_2 = 30% MAD of ASW, T_3 = 45% MAD of ASW and T_4 = 60% MAD of ASW.

Irrigation scheduling was based on the percentage depletion of available soil water in the root zone. The available soil water was taken as the difference between root zone water storage at field capacity and permanent wilting point. For estimating water storage the effective root zone of cauliflower crop was considered as 45 cm (Allen *et al.,* 1), irrespective of growth stage. Using the data of soil moisture measured gravimetrically, the percentage depletion of available soil water in the effective root zone was estimated. The plots were irrigated using a hosepipe and a water meter to give the exact volume of water.

Table 1.Physical properties of soil profiles of the experimental field.

Soil depth (cm)	Particle size distribution (%)			Bulk density (g/cc)	Saturated hydraulic conductivity (cm/day)
	Clay	Silt	Sand		
0-15	30.0	29.5	40.5	1.60	15.2
15-30	32.2	33.3	34.5	1.55	10.3
30-45	34.8	35.8	29.4	1.57	3.3
45-60	34.9	32.1	33.0	1.62	2.5
60-90	35.7	34.0	30.3	1.65	1.6

Data collection

For the study of water balance, crop and biomass response to deficit irrigation and water use efficiency, the data on profile soil moisture content and the growth attributes of the crop under consideration was collected. In order to assess the change in soil water balance, soil moisture was measured in 0-15, 15-30, 30-45 and 45-60 cm soil profiles. The moisture content of soil layers were measured gravimetrically. Moisture measurements were taken on every alternate day.

RESULTS AND DISCUSSION

In order to assess the depth and time variation of soil moisture under different scheduling of irrigation, soil moisture was measured periodically in 0-15, 15-30, 30-45, 45-60 and 60-90 cm soil profiles during both the experiments.

Depth and time variation of soil moisture

The temporal variations of soil moisture in the root zone and below the root zone of the experimental crop are presented in Fig. 1. The figures reveal that the soil moisture experienced a cyclic temporal variation at all soil depths. This trend was observed irrespective of the level of irrigation (MAD level). The amplitude of this cyclic variation (Fig. 1) was higher in upper layers than in lower layers. In experiment 1, there was a rapid decline of soil moisture in 0-15 cm soil profile at 82 days after transplanting (DAS) to the end of growth period. The lower layers of 15-30, 30-45, 45-60 and 60-90 cm soil profiles also exhibited a gradual decline in that order upto the end of the growth period. The decline was quite slow in 60-90 cm soil profile. The amplitude of cyclic variation was more in 0-15 cm soil profile because most of the applied irrigation water was lost through evaporation from the soil surface beside the transpiration. In addition to this, a portion of the applied irrigation water percolated to the lower layers also. Since the frequency of irrigation was high under T_1, plants extracted more water from the upper layers. Therefore, 15-30, 30-45 and 45-60 cm soil profiles did not exhibit much cyclic variation. This trend was observed in both the experiments.

In resemblance to the temporal variation of soil moisture under T_1, soil moisture in 0-15, 15-30, 30-45 and 45-60 cm soil profiles under 30% MAD (T_2) also exhibited cyclic pattern (Fig. 1). Continuous sharp declines of soil moisture in all soil profiles were observed on 82 DAS. The magnitude of cyclic variation was higher in 30-45 and 45-60 cm soil profiles as compared to similar layers of T_1 during both the crop seasons (Fig. 1).

High amplitude of cyclic variation was noted in all soil profiles of the root zone under 45% MAD (T_3). Since the irrigations were scheduled at 45% MAD, the plant roots penetrated deeper in search of water as it was not adequate in the upper soil layers. The temporal variation of soil water was observed to be similar during both the experiments. The temporal variation under T_3 exhibited cyclic pattern upto 84 DAS in 0-15 and 15-30 cm soil profiles during experiment 1, while 30-45, 45-60 and 60-90 cm soil profiles showed a gradual decline on 68 DAS. A similar trend was observed during other experiment also.

Considerable soil moisture fluctuation was observed under 60% MAD (T_4) schedule. All soil profiles exhibited discernible cyclic variation, with considerably low amplitudes in the lower depths as compared to those observed at upper depths. This was ascribed to the large volume of water applied at a time during irrigation.

The 60-90 cm soil profile tended to remain steady upto the last irrigation applied, after which it decreased only marginally during the remaining growth period. Soil moisture below the root zone (60-90 cm soil profile) of the experimental plots experienced minimum cyclic variation with time. A slight continuous decline was observed when irrigations were discontinued. This trend was observed during both experiments, confirming to results of Kashyap and Panda (6).

Table 2. Water use efficiency (WUE) of Cauliflower crop under different scheduling of irrigation during experiments 1 and 2.

Expt. No.	Treatments	Fresh yield kg/ha	ET mm	Irrigation mm	Crop-WUE kg/ha/mm	Field-WUE kg/ha/mm
1 (2007-08)	T_1	12320	218	210	76.45	79.37
	T_2	12300	200	182	75.00	82.42
	T_3	13220	180	159	78.70	89.10
	T_4	11980	181	142	69.06	88.03
2 (2008-09)	T_1	14800	200	202	75.00	74.26
	T_2	14600	198	175	68.18	77.14
	T_3	14760	165	156	77.27	81.73
	T_4	14320	160	121	70.31	92.98

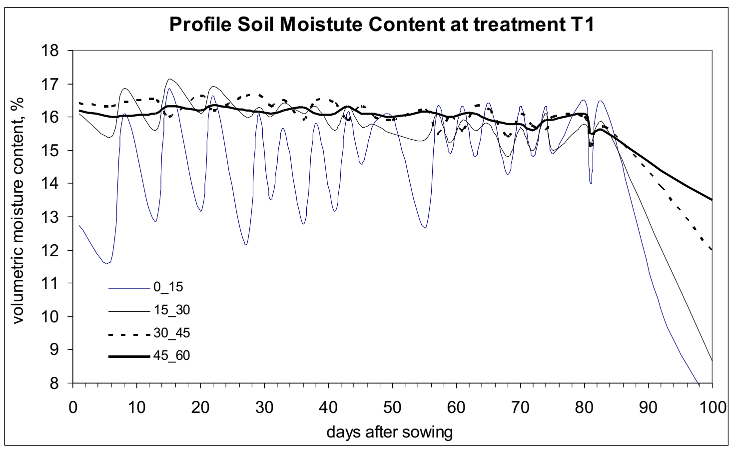

Figure 1: Profile soil moisture content at different soil profiles at 15% MAD (T_1)

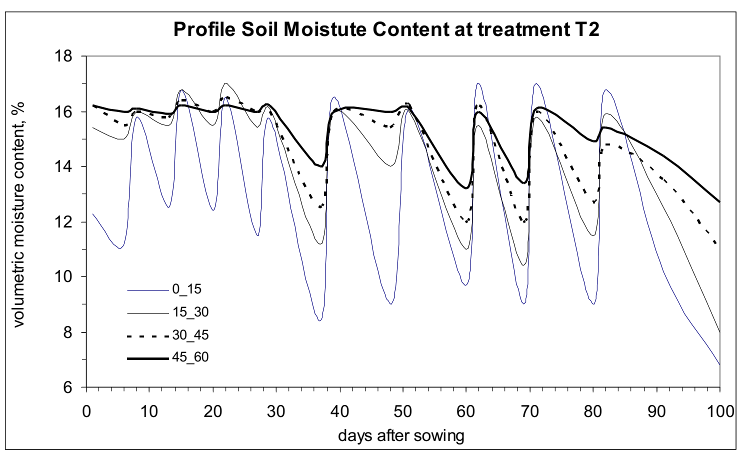

Figure 1: Profile soil moisture content at different soil profiles at 30% MAD (T_2)

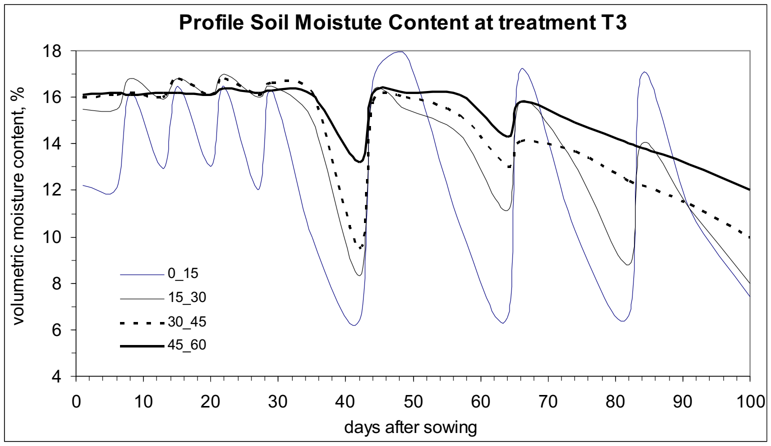

Figure 3: Profile soil moisture content at different soil profiles at 45% MAD (T_3)

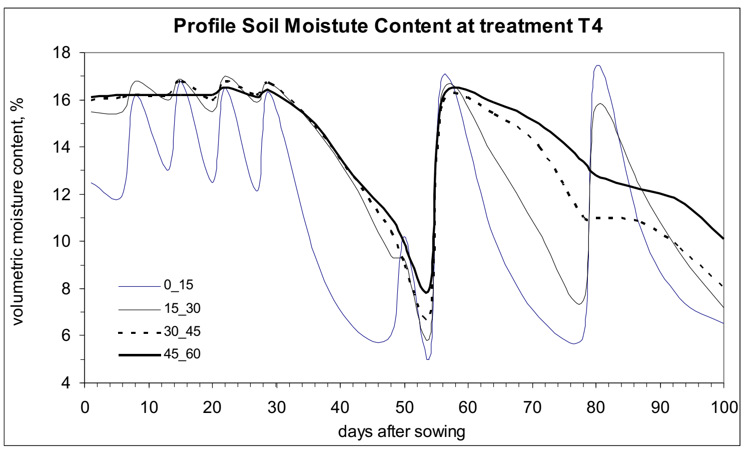

Figure 4: Profile soil moisture content at different soil profiles at 60% MAD (T_4)

Crop water use efficiency

The crop water use efficiency was taken as the ratio of the fresh yield and the crop evapotranspiration. The results pertaining to water use efficiency of the cauliflower crop under different scheduling of irrigation during crop experiments 1 and 2 (Table 2) revealed that the highest crop water use efficiency was attained when the irrigation was scheduled at 45% depletion of ASW (T_3). A rising trend of crop water use efficiency was noticed from T_1 to T_3 and after that it decreased for T_4 and T_5 as the irrigations were delayed. A similar trend was observed during both crop seasons.

Field water use efficiency

The field water use efficiency was estimated in terms of fresh yield obtained per unit of land used and per unit of water available to the field. The results (Table 2) revealed that the highest field water use efficiency was attained when the irrigation was scheduled at 45% depletion of ASW (T_3). Similar to crop water use efficiency, a rising trend of field water use efficiency was noticed from T_1 to T_3 after that it decreased for T_4 and T_5 as the irrigations were delayed. This trend was same during both crop seasons. Field experiments conducted during both crop seasons revealed that irrigation schedule with 45% maximum allowable depletion of available soil water could safely be maintained during the non-critical stages to save water without sacrificing the yield.

CONCLUSIONS

The results of the study revealed that under water scarcity conditions, when soil water stress is imposed during non-critical stages of growth, irrigation is to be scheduled at 45% maximum allowable depletion of available soil water for cauliflower crop grown in silty clay loam soils in a sub-humid and temperate region. A soil water stress of 45% MAD gives the highest crop water use efficiency as well as field water use efficiency. Only 0-30 cm of soil profile is to be considered for scheduling of irrigation for cauliflower crop grown in a silty clay loam soils, since most of the water used by the crop is extracted from this layer.

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